INDUSTRIAL RESEARCH

SESAR Solution PJ02-01 SPR-INTEROP/OSED for V3 - Part II - Safety Assessment Report

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PJ02 EARTH

INCREASED RUNWAY AND AIRPORT THROUGHPUT

This SESAR Solution PJ02-01 SPR-INTEROP/OSED Part II Safety Assessment Report (SAR) is part of project PJ02.01 EARTH and has received funding from the SESAR Joint Undertaking under grant agreement No 731781 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 PJ02-01 (Wake Turbulence Separation Optimisation) by EUROCONTROL, NATS, ENAIRE and DLR.

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, ENAIRE and DLR. No contribution to this report is expected from Airbus (Wake Monitoring).

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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, Large and Medium 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 PJ02-01 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 document specifies the SESAR Solution PJ02-01 safety assessment results in the scope of the operational scenarios designed and validated by EUROCONTROL, NATS, ENAIRE and DLR. The current version includes contributions from EUROCONTROL (arrivals), NATS (departures) and DLR (Wake Decay Enhancing). No contribution to this report is expected from Airbus (Wake Monitoring).

The Arrivals Concepts Solutions safety analysis in this SAR is based on the safety work done by Project P06.08.01 in SESAR 1, contained in the corresponding SAR [6]. This version of the SAR contains updates of what has been done for both the Arrivals and Departures Concepts Solutions in SESAR 2020.

The safety assessment is carried out by the Project partners (work sharing detailed in Section 2) in five main threads: EUROCONTROL, NATS, ENAIRE and DLR. EUROCONTROL (leading the Validation Plan) is responsible for consolidating the Safety Assessment Plan and NATS (leading the SPR-INTEROP/OSED) is responsible for consolidating the Safety Assessment Report (this document).

This safety assessment report aggregates the five main working threads of the safety assessment back to the four concepts areas of the SESAR Solution PJ02-01:

- Arrivals Concepts Solutions
    - Pairwise Separations for Arrivals (PWS-A) with Optimised Runway Delivery (ORD) tool support
    - Weather Dependent Separations for Arrivals (WDS-A) with WDS-A tool support and Enhanced ORD tool support
- Departures Concepts Solutions
    - Pairwise Separations for Departures (PWS-D) with Optimised Separation Delivery (OSD) tool support
    - Weather Dependent Separations for Departures (WDS-D) with WDS-D tool support and Enhanced OSD tool support
- Wake Risk Monitoring Concept Solution
- Wake Decay Enhancing Concept Solution

2 Introduction

This Safety Assessment Report (SAR) [1]is addressing Project 02 Solution 01 (PJ02-01) Wake Turbulence Separation Optimisation in the frame of SESAR 2020.

PJ02-01 encompasses the following operational improvements:

Arrivals Concepts Solutions

- AO-0306: Wake Turbulence Separations (for arrivals) based on Static Aircraft Characteristics (PWS-A)
- AO-0310: Weather-dependent reductions of Wake Turbulence Separations for final approach (WDS-A)
- AO-0328: Optimised Runway Delivery on Final Approach (ORD)

Departures Concepts Solutions

- AO-0323: Wake Turbulence Separations (for departures) based on Static Aircraft Characteristics (PWS-D)
- AO-0304: Weather-dependent reductions of Wake Turbulence Separations for Departure (WDS-D)
- AO-0329: Optimised Separation Delivery for Departure (OSD)

Wake Risk Monitoring Concept Solution

- AO-0327 - Reduction of Wake Turbulence Risk through Wake Risk Monitoring

Wake Decay Enhancing Concept Solution

- AO-0325 - Reduction of Wake Turbulence Risk considering Acceleration of Wake Vortex Decay in Ground Proximity

The SESAR Solution PJ02-01 design and validation work is organized according to five main threads, defined via the following operational scenarios:

EUROCONTROL Thread

- RTS1: WDS-A with ORD for Arrivals, on single Runway (RWY) operating in segregated mode, for Paris CDG airport (encompassing transition from/to Distance or Time-based (DBS or TBS) standard separations)

[1] The opinions expressed herein reflect the authors view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

- RTS2: WDS-A with ORD for Arrivals, and WDS-D with OSD for Departures, on single RWY operating in mixed mode, for Paris CDG airport
- RTS3a: PWS-A with ORD for Arrivals, and PWS-D with OSD for Departures, on a single RWY operating in mixed mode, for Vienna airport
- RTS3b: PWS-A with ORD for Arrivals, on a single RWY operating in segregated mode, for Copenhagen airport
- RTS4a: PWS-A with ORD for Arrivals, and PWS-D with OSD for Departures, on a single RWY operating in mixed mode, for Vienna airport
- RTS4b: PWS-A and WDS-A with ORD for Arrivals, and PWS-D and WDS-D with OSD for Departures, on CSPR RWYs operating in segregated and mixed mode, for Paris CDG airport

NATS Thread

- RTS5: PWS-D and WDS-D with OSD for Departures, on dependent parallel RWYs operating in segregated mode, with a small number of arrivals landing on the departure runway under tactically enhanced arrival management, and encompassing transition in case of degraded mode, for London Heathrow airport

ENAIRE Thread

- RTS6: Real Time simulation conducted by ENAIRE to evaluate the feasibility of WDS-A for Arrivals, and PWS-D with OSD for Departures on parallel RWYs operating in segregated mode for Barcelona airport

AIRBUS Thread

- The Wake Risk Monitoring concept solution will be applied to a dataset of flight test data containing a series of known wake turbulence encounters, as well as a larger dataset not including known wake turbulence encounters to assess the performance of the solution.

DLR Thread

- LT10: A live trial conducted by DLR in Vienna airport to assess the application of a wake decay enhancing device in the Vienna airport environment.

The above work share threads integrate back into the concepts threads as described below. For more information about the concepts, please see Section 3 in the SPR-INTEROP/OSED Part[22].

2.1 Arrivals Concepts Solutions

All WT separation modes are supported by a separation delivery tool providing Target Distance Indicators (TDI) to Approach and Tower runway controllers.

In the current report the ICAO, RECAT-EU and PWS-A modes where distance-based separation is applied will be referred to as “Distance-Based” (DB) modes whilst the modes where time-based separation is applied will be referred to as “Time-based” (TB) modes.

This Safety Assessment started by the identification of Safety Criteria (SAC) describing what is acceptably safe for the new WT separation modes. Then Safety Objectives were derived at operational level (OSED) to satisfy the Safety Criteria in normal, abnormal and failure conditions. Finally, when the high-level design architecture supporting the operational level was defined, Safety Requirements in normal/abnormal conditions and considering failure aspects were derived to satisfy the Safety Objectives. Safety Requirements were determined though the success and the failure approaches, as described by the SESAR Safety Reference Material (SRM) [1].

This Safety Assessment presents the assurance that the identified Safety Requirements for the V1-V3 phases are complete, correct and realistic.

This Safety Assessment builds on the P06.08.01 Safety Assessment Report (SAR) from SESAR 1 [6].

During this iterative process, Safety Validation Objectives have been identified and have been addressed during Validation Exercises.

This Safety Assessment was conducted jointly with the Human Performance assessment, in particular during the different meetings/workshops, validation exercise and analysis. This led to the identification of common and consistent Safety and Human Performance requirements and recommendations.

The following provides the key principles of each concept:

- **PWS-A** involves arrival wake turbulence separation according to a wake turbulence scheme which is based upon aircraft type pairs rather than grouping aircraft types into wake categories. This is to provide a better distribution of wake risk between aircraft type pairs as well as to better optimise separations between aircraft type pairs compared with using 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.
- **WDS-A** is the conditional reduction or suspension of wake separation minima on final approach, applicable under pre-defined wind conditions, on the basis that under those wind conditions the wake turbulence generated by the lead aircraft is either transported by the wind out of the path of the follower aircraft on final approach or has decayed sufficiently to be acceptable to be encountered by the follower aircraft.
- Although there are some exceptions, the application of the arrival wake turbulence separation rules of the PWS-A and WDS-A concepts requires an Air Traffic Control (ATC) support tool to visualise the required minimum separation on the Controller Working Position (CWP). This is done through the **ORD** concept, which provides additional support to assist Controllers in delivering the required minimum separation to the runway threshold by considering the effect of compression.

The current distance-based separation based on WT categories might benefit from the support of the separation indicators (indicators reflecting the distance-based WT categories), hence the DBS concept can also be operated with indicators (identified as DBS in this report).

The changes introduced by these concepts are directly influencing the spacing on final approach, and therefore there is a need to assess their impact on the wake turbulence encounter risk and to some extent on the mid-air collision and runway collision risk. Safety Criteria (SAC) have been formulated on the accident precursors which are influenced by the new WT separation modes, with the aim to contribute to the satisfaction of the SESAR safety strategic target of maintaining pre-SESAR ATM safety levels, despite possible traffic increase in the future.

Safety Objectives have been set at ATM service level to ensure satisfaction of the SAC by the new WT separation modes, in all operating conditions (normal, abnormal and failure). Functional hazard assessments have been conducted to identify the relevant hazards and corresponding operational risks.

Safety validation activities have been performed to assess satisfaction of the safety objectives by the new WT separation modes in normal operating conditions.

Specific WVE risk assessments have been conducted to allow definition of acceptably safe separation minima for each WT separation mode. For the Time-Based modes those risk assessments are based on the comparison of the WVE risk for the new modes in different wind speed range against the Distance-based Separation (DBS) in low wind (as reasonable worst case and maximum acceptable risk) and in order to confirm the expected positive effect of wind on wake decay and transport, hence on WVE risk.

A design analysis of the high-level architecture supporting operations in new WT separation modes has been conducted. This design analysis led to the identification of a complete and consistent set of high-level and detailed safety requirements associated to the different sub-systems (e.g. Separation Delivery Tool, Arrival Sequencer tool, Wind sensor) and people (e.g. Controllers, Supervisors and Flight Crew). In addition, Recommendations and Safety Issues to be considered in future steps up to implementation have been identified.

These safety requirements are either functionality & performance or mitigations to system generated hazards. All Safety Requirements are listed in Appendix B and have been fed into the Part I of this SPR-INTEROP/OSED. The Appendix C of this Safety Assessment Report lists the Assumptions, Limitations, Issues and Recommendations.

2.2 Departures Concepts Solutions

This Safety Assessment presents the assurance that the identified Safety Requirements for the V1-V3 phases are complete, correct and realistic and builds on the work completed for the CREDOS Preliminary Safety Case [19].

During this iterative process, Safety Validation Objectives have been identified and were addressed during Validation Exercises.

The assessment was conducted jointly with Human Performance experts and identified common Safety and Human Performance requirements and recommendations.

The following provides the key principles of each 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) ATC support 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 1 Section 3.2.4.2.

The changes will directly influence the spacing on the initial departure path, and, therefore, there is a need to assess their impact on the wake turbulence encounter risk, and to some extent[2] on the mid-air collision risk. Safety Criteria (SAC) have been formulated on the accident precursors which are influenced by the new WT separation modes, with the aim to contribute to the satisfaction of the SESAR safety strategic target of maintaining pre-SESAR ATM safety levels, despite possible traffic increase in the future.

Safety Objectives have been set to ensure satisfaction of the SAC in all operating conditions (normal, abnormal and failure) and a Functional hazard assessment has been conducted to identify the relevant hazards and corresponding operational risks.

Safety validation activities have been performed to assess satisfaction of the safety objectives by the new WT separation modes in normal operating conditions.

Specific WVE risk assessments are still to be conducted to allow definition of acceptably safe separation minima for each WT separation mode. This will need input from aircrew and may involve additional modelling to determine how wake behaves on departure at specific locations.

The safety requirements have been produced as a result of the hazard analysis and are listed as mentioned above for the Arrival's Concepts.

2.3 Reduction of Wake Turbulence Risk through Wake Risk Monitoring Concept Solutions

Ground-based identification of wake turbulence encounters using recorded on-board data and traffic positions broadcast by surrounding aircraft via ADS-B Out helps to ensure safety by allowing to objectively characterise wake turbulence risk as a function of e.g. location, traffic mix or separation rules. This will provide additional objective information for the monitoring of suitability of the optimised wake turbulence separations and support the deployment of updated wake turbulence separation rules. It also positively impacts the Human Performance KPA by complementing identification and reporting of wake turbulence encounters by Flight Crews and ATCOs.

Rationale: Long-term wake turbulence risk monitoring can be part of the deployment phase of new wake turbulence separation concepts, providing the regulation authority with a direct means to

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[2] [2] At the time of writing the Departures AIM has not been finalised

verify that all identified safety objectives and safety requirements have been met during its operational life.

2.4 Wake Decay Enhancing Concept Solution

The following provides the key principles of the concept:

- **Wake Decay Enhancing Concept** - The highest risk of encountering wake vortices prevails during final approach in ground proximity, where the vortices cannot descend below the glide path but tend to rebound because of the interaction with the ground surface. In SESAR a method is developed and demonstrated at an international airport that accelerates wake vortex decay in that critical height range. The installation of so-called plate lines beyond the runway tails (aligned parallel to the runway direction) may improve safety by reducing the number of wake vortex encounters and increase the efficiency of wake vortex advisory systems.

2.5 Previous Work Relevant for SESAR Solution 02-01

2.5.1 Arrivals Concepts Solutions

For the arrivals concept and the development of ATC support tool prototypes, previous work from Project P06.08.01 and OFA 01.03.01 in SESAR 1 is relevant. SESAR 1 Project P06.08.01 Flexible and Dynamic Use of Wake Turbulence Separations focused on separation delivery of arriving aircraft, which led to the operational deployment of a Time-based Separation(s) (TBS) tool at London Heathrow. Other relevant research is RECAT-EU and RECAT-EU-PWS. RECAT-EU and RECAT-EU-PWS are optimisations of ICAO wake turbulence categories scheme, developed by EUROCONTROL in consultation with European stakeholders.

2.5.2 Departures Concepts Solutions

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 (PJ02-01 – in this SAR). 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.

2.5.3 Wake Risk Monitoring Concept Solution

Previous work in Project P09.11 from SESAR 1 is relevant. The project focused on on-board prediction of wake turbulence encounters, and also performed some preliminary work on detection of wake turbulence encounters based on air-to-air data exchange.

2.5.4 Wake Decay Enhancing Concept Solution

The plate line principle has been investigated within DLR internal projects employing different devices [15] to [16]. First, fundamental research was conducted employing a towing tank through which a simplified aircraft model was towed and the flow was visualized with dye. Quantitative measurements were conducted with particle image velocimetry. For this initial work a massive obstacle was installed on the ground. Large eddy simulations were used to better understand the underlying vortex dynamics, to optimize the obstacle shape and to investigate the impact of crosswind and headwind. As a result, a plate line with optimized plate shape, plate number and plate separation was designed. Finally, flight experiments were conducted with the DLR research aircraft HALO (Gulfstream G550) at special airport Oberpfaffenhofen where the vortex plate interaction was studied employing LiDAR measurements. The LiDAR measurement results indicate that the lifetime of the longest lived and thus potentially most hazardous vortex could be reduced by one third.

2.6 General Approach to Safety Assessment

The safety assessment has been conducted in accordance with the SESAR Safety Reference Material (SRM) [1] and associated Guidance [2]. The SRM is based on a twofold approach:

- a new *success approach* which is concerned with the safety of operations supported by the new WT separation modes and ATC tools in the absence of failure; and
- a conventional *failure approach* which is concerned with the safety of operations supported by the new WT separation modes and ATC tools in the event of failure within the end-to-end System

These two approaches are applied to the derivation of safety properties at each of two successive stages of the development of the new WT separation modes, as follows:

Safety Specification at the OSED Level

This is defined as what the new WT separation modes and ATC tools have to achieve at the Air Traffic Management (ATM) operational 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 the SPR 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 SPR-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 safety requirements) and V3 (detailed safety requirements) phases of the development lifecycle. The purpose here is to feed the SESAR Solution PJ02-01 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.

2.7 Scope of the Safety Assessment

This Safety Assessment Report (SAR) is limited to the scope of SESAR Solution PJ02-01 in the frame of SESAR 2020. SESAR Solution PJ02-01 is addressing the Static Pair Wise Separation (PWS), Optimised Runway/Separation Delivery (ORD/OSD) and Weather Dependent Separation (WDS) concepts for Arrivals and Departures and is looking at ways to improve Wake Risk Monitoring and Awareness and a way to facilitate Enhancing Wake Decay in ground proximity on final approach.

This safety assessment defines the set of Safety Criteria (SAC), Safety Objectives (SOs) and Safety Requirements (SRs) for all the SESAR Solution PJ02-01 concepts solutions.

Meanwhile, whilst outlining the strategy employed by SESAR Solution PJ02-01 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 arrivals concepts solutions and 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 final approach segment for the arrivals concepts solutions and 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 OSED Level and Safe Design at the SPR Level.

2.8 Layout of the Document

Section 1 presents the executive summary of the document.

Section 2 provides background information regarding the definition, design and validation of the PWS with ORD/OSD and WDS for Arrivals and Departures, the Wake Risk Monitoring and Awareness and the Wake Decay Enhancing Concepts Solutions, the principles for safety assessment in SESAR Programme and the scope of this safety assessment.

Section 3 addresses the safety specification at OSED level, through the definition of Safety Criteria (SAC), the determination of Safety Objectives (SO) and link to validation objectives.

Section 4 addresses the safe design at SPR level, through the derivation of high level and detailed Safety Requirements (SR) 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 PJ02.01 arrivals and departures SAF & HP workshop which took place on the 30th of October 2018 in the frame of SESAR 2020

Appendix J presents the results of the workshop with pilots from Air France and CDG ATCOs which took place on the 28th of January 2019 in the frame of SESAR 2020

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

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

Appendix J presents the A-WDS-Xw methodology

Appendix K presents the D-WDS-Xw methodology

3 Safety Specifications at the OSED Level

This Section covers the following Concepts Solutions:

- Arrivals Concepts Solution in Section 3.1
- Departures Concepts Solutions in Section 3.2
- Wake Decay Enhancing in Section 3.3

Each group of Concepts Solutions have independent Operational Improvements that should be selectable with respect to deployment at capacity constrained Very Large, Large and Medium sized airports.

It should be noted that no input into this SAR is expected from the Wake Risk Monitoring concept so no specific sections have been created for these two OI steps.

3.1 Arrivals Concepts Solutions

3.1.1 Scope for the Arrivals Concepts Solutions

This section addresses the following activities:

- Concept overview, describing the baseline and solutions scenarios - Section 3.1.2
- Description of the key properties of the Operational Environment which are relevant to the safety assessment – Section 3.1.3
- Identification of the airspace users requirements – Section 3.1.4
- Identification of the pre-existing hazards that affect traffic in the relevant operational environment (airspace, airport) and the risks which are reasonably expected to be mitigated to some degree and extent by the operational services provided by the Arrivals Concepts Solutions – Section 3.1.5
- Setting of the SAfety Criteria for the Arrivals Concepts Solutions (from the Safety Plan[27]) – Section 3.1.6
- Comprehensive determination of the operational services that are provided by the Arrivals Concepts Solutions to address the relevant pre-existing hazards and derivation of Safety Objectives (success approach) in order to mitigate the pre-existing risks under normal operational conditions – Section 3.1.7
- Assessment of the adequacy of the operational services provided by the Arrivals Concepts Solutions under abnormal conditions of the Operational Environment – Section 3.1.8
- Assessment of the adequacy of the operational services provided by the Arrivals Concepts Solutions in the case of internal failures and mitigation of the System-generated hazards (derivation of Safety Objectives (failure approach)) – Section 3.1.9
- Achievability of the SAfety Criteria for the Arrivals Concepts Solutions – Section 3.1.10
- Validation & verification of the safety specification for the Arrivals Concepts Solutions – Section 3.1.11

3.1.2 Concept Overview

3.1.2.1 Baseline Scenario

3.1.2.1.1 Current separation schemes

Separation schemes applied in the reference scenarios:

- The distance-based WT separation regulations for arrivals based on WT categories as per e.g. ICAO, RECAT-EU 6 category or UK6 CAT.

Please see PJ.02-01 SPR-INTEROP/OSED [22] section 3 for more information about the ICAO and RECAT-EU distance based schemes.

3.1.2.1.2 Current operating method for the arrivals concepts solutions

The standard procedures currently used to transfer an arriving aircraft from En-route airspace through TMA and approach to touchdown are summarized in this sub-section.

Merge for Final Approach interception

Typically, an aircraft will transition from En-route airspace into the TMA and approach to join the flow for the active landing runway via a Standard Arrival Route (STAR). Within the TMA, the aircraft is first controlled by one or more – dependent on the traffic density and the number of directions aircraft can come from – Approach (radar) controllers. The role of these positions is to merge and descend traffic into a single flow. The names of these controllers and their distribution of tasks may vary from unit to unit. E.g., there may be an initial controller (INI), an intermediate controller (INT) or feeder, and final controller (FIN) or director (see Figure 1). The majority of alterations to the landing sequence of aircraft occur in the INI and INT controller positions. Unless an emergency or missed approach, event occurs it is rare for the FIN controller to make a change to the sequence flow of arrivals from the INT controller.

The FIN controller vectors the aircraft to the final approach fix on the localizer before transferring to the tower (TWR) or runway controller.

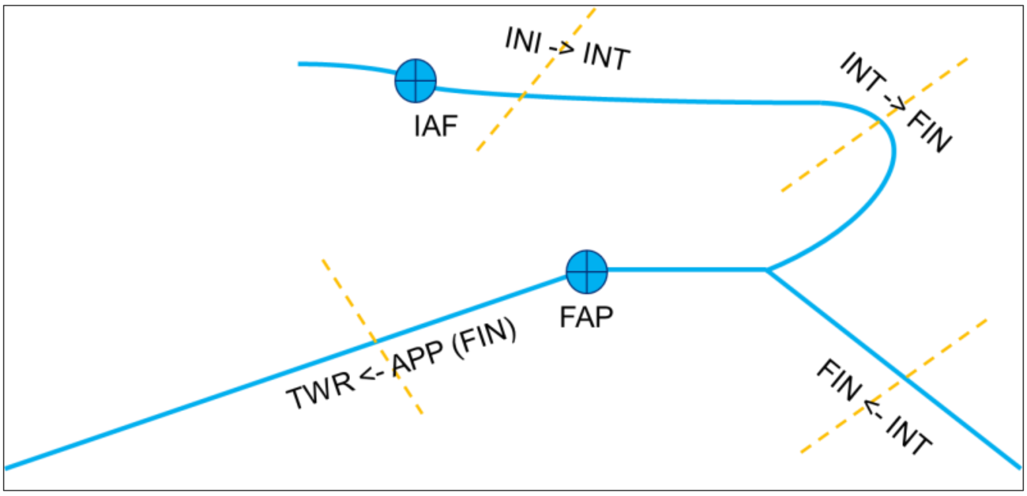

Figure 1: Example approach segments between controller positions

Speed control is defined in many airports' AIP, though the tactical application of this will be subject to variables such as wind and traffic density.

The speed control profile generally outlined is 220 KIAS on base leg until localizer interception, then reduce to 180 KIAS until on glide slope, then reduce to 160 KIAS until the Deceleration Fix at 4 NM from the runway landing threshold. Afterwards, the aircraft adopts its Final Approach Speed (FAS); see Figure 2. Because of differences in Final Approach Points (FAP), varying between approximately 5.5 NM and 13 NM from the runway landing threshold, the length of the segments where a certain speed is controlled may vary.

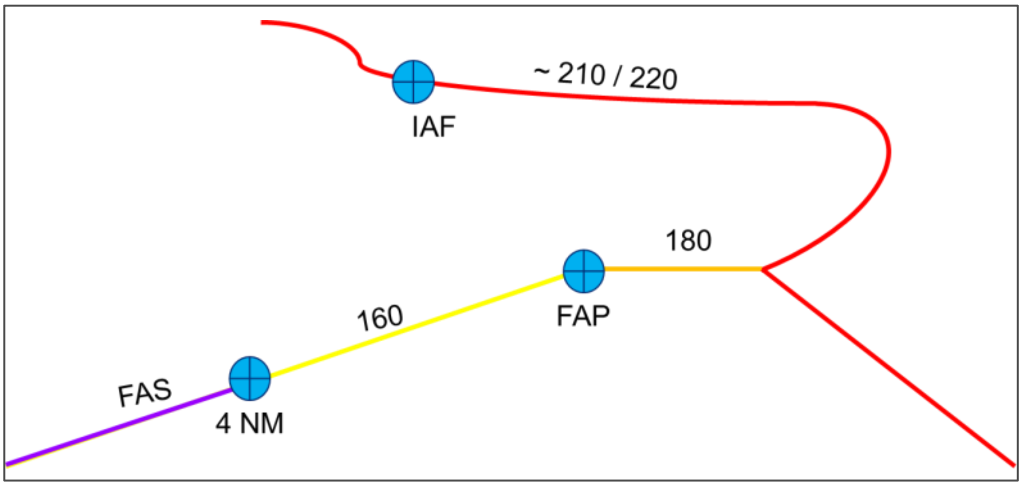

Figure 2: Generic speed control procedure on approach

Variation in ground speed can be about +/- 30 knots, decreasing to +/- 10 knots on the segment after the Deceleration Fix at 4 NM from the runway landing threshold until touchdown. It has furthermore been observed in radar data that the statistical distribution of speed can vary considerably over airports.

The speed profile from the last instructed speed to the Final Approach Speed (FAS), starting from around 6 NM to 4 NM from the runway threshold until touchdown, varies considerably depending on aircraft type, landing weight, stabilization altitude, stabilization mode, weather conditions, and the associated airline operator cockpit procedures (from under 100 KIAS for some Light wake category aircraft types to over 160 KIAS for some Heavy wake category aircraft types). Aircraft starts decelerating at Deceleration Fix (DF) and FAS is reached at Stabilization Fix (SF).

SEPARATION ASSURANCE

Considering the approach path, the location of the FAP, the speed control applied and the wind conditions, the resulting ground speed profile of two succeeding aircraft determines how the **separation** develops on the final approach.

Based on experience, the approach controller(s) will set up the initial separation, taking into account the above-mentioned factors. In addition, the applicable separation minimum (WT or MRS) is considered.

The point until where the defined minimum should be assured is split into two main practices: delivery to threshold (most common) and delivery to the Deceleration Fix at 4 NM from the runway landing threshold. Note that in both cases, ATC is responsible for separation to threshold. In the latter case, WT separation minima are ensured to the Deceleration Fix at 4 NM from the runway landing threshold, taking into account compression after the Deceleration Fix to touchdown.

The separation targeted for, usually includes a certain buffer to account for compression of the distance separation on the last segment of the approach (beyond the Deceleration Fix). The separation buffer applied is primarily based on the experience of the controller, taking into account the actual traffic and wind situation.

Monitoring separation is primarily done using the distance markers on the radar screen as a reference. Next to that, most units have some kind of 'feeder cursor' to measure distance between two selected aircraft. At some airports, there is predictive information on how the distance develops, but this seems to be used rarely.

Generally speaking, the TWR controller has few options to directly manage separation. However, in some ATC units the TWR controller has responsibility already from 6 NM or 8 NM before the runway landing threshold and has a radar rating. Otherwise, to resolve a loss of separation, the controller can apply or offer the aircraft visual separation (provided VMC applies), give a go-around instruction, or – and in exceptional cases and when the runway configuration allows – let the aircraft divert to the parallel runway. It is also possible to ask the approach controller to let the following aircraft reduce speed.

The next sub-sections provide a brief description of the TBS, ORD, S-PWS and WDS concepts.

The concepts described here are for segregated mode use only: arrivals on singular runway different from the runway used for departures.

3.1.2.2 Solution Scenario

3.1.2.2.1 Static Pair Wise Separation (PWS-A) concept for the Arrivals Concepts Solutions

The PWS-A concept is a wake turbulence scheme which is based upon individual aircraft types rather than grouping aircraft types into wake categories. In a wake category scheme the separations need to be designed to protect the lightest follower aircraft type in a category from the heaviest leader aircraft type in a category. This leads to inefficient separations between other aircraft type pairs which do not need the same amount of protection. The PWS-A WT scheme provides more efficient separations (at a resolution of 0.5 NM) as they can be optimised for each aircraft type pair based upon the static characteristics of each aircraft type.

The PWS-A WT schemes include RECAT-2 (a 96 x 96 aircraft type matrix) together with a 20-CAT matrix (RECAT-EU 6-CAT with 14 sub-categories) which have been developed by EUROCONTROL.

The PWS-A concept could be operated in distance-based mode (DB-PWS-A) or in time-based mode (TB-PWS-A). Both modes of operation involve reduced separations (compared with current day operations) as the WT separations have been optimised at the level of aircraft type pairs. The time-based mode will have further reductions of separation as a function of the headwind conditions.

The concept aims to improve overall runway throughput through using the more efficient WT separations. However, it could also be used to improve runway throughput resilience to delay (assuming no change in declared capacity). In TB-PWS-A mode the concept can be used to improve predictability through improved resilience to headwind conditions.

In either mode a Separation Delivery tool will be required as the controllers will not know the required separation (even in a distance-based operation). The same Separation Delivery tool as is used in the TBS concept can be used to operate the TB-PWS-A concept. This includes the Final Target Distance Indicator (FTD) for providing an indication of the required separation to apply at threshold (or 1 NM) and the Initial Target Distance Indicator (ITD) to provide an indication of the predicted compression. When using TB PWS-A, the FTD will use the same method used in the TBS concept. When using DB-PWS-A the FTD will be defined based on the DB-PWS-A WT scheme. The methods for calculating the ITD remain the same.

A PWS-A concept could be operated only in DB-PWS-A mode in which case there will be no need for mode transition. However if the concept is extended to include the TB-PWS-A mode then there will be a need to support mode transitions, which in case the required wind conditions service (e.g. runway surface and glide path) becomes unavailable, will support the mode switch from TB-PWS-A to DB-PWS-A mode.

Operational constraints which affect TBS which include ROT and MRS will remain applicable in the PWS-A concept.

3.1.2.2.2 Weather Dependant Separation (WDS-A) concept for the Arrivals Concepts Solutions

WT separation could be reduced as a function of weather. In conditions of sufficient total wind or crosswind, the time separation equivalent to the applicable DBS separation could be reduced by taking advantage of the positive effect of wind on wake decay and transportation.

The key principle of WDS-A is to define the minimum distance in trail separation to apply as a function of weather. This can either be a function of total wind or cross wind.

If it is based on a total wind, then as the magnitude of the total wind increases, the decay rate of wake turbulence increases allowing a reduction of wake turbulence separations. That would allow for a reduction of the time separations compared to the ones observed in low wind conditions between aircraft landing pairs using distance-based separation based on WT categories or PWS-A such that the wake encounter risk is equivalent or lower. There is a need to consider the impact on both IGE and OGE decay rates, particularly as OGE decay rates may not be impacted as much as IGE decay rates.

If it is based on a crosswind, then as the magnitude of the crosswind increases, the probability of the WT to be transported out of the follower aircraft path increases allowing a reduction of wake turbulence separations. When the cross wind exceeds a certain value, the WT can be assured of being crosswind transported out of the path of the follower aircraft within a defined time separation, allowing for the reduction of the WT separation to the defined time separation. Moreover, as for the total wind concept, the crosswind also increases the decay rate of wake turbulence and hence decreases the severity in case of wake turbulence encounter.

The concept achieves the same predictability improvement through improved resilience as is achieved with the TBS concept but can give additional gains due to reduced separations based on the total wind or cross wind.

The WDS-A concept can use as reference for the time separation computation the distance-based separation based on WT categories, in which case the WT separation modes within this safety assessment are abbreviated A-TB-WDS-Tw for total wind and A-TB-WDS-Xw for cross wind.

The WDS-A concept can also be combined with the PWS-A concept, using as reference for the time separation computation the TB-PWS-A, in which case the WT separation modes within this safety assessment are abbreviated A-TB-WD-PWS-Tw for total wind and A-TB-WD-PWS-Xw for cross wind.

The WDS-A time separation minima defined as a function of the respectively total and cross wind shall account for the local wind measurement uncertainty and evolution between computation time and actual separation delivery time.

For that purpose, either a buffer might be added in the design of the time separation or a buffer might be added in the wind threshold definition.

Similarly, to the TBS concept, in case of conditional application of the TB-WDS-A mode, there is a need for mode transitions driven by criteria (wind activation threshold):

- A-TB-WDS-Tw and A-TB-WD-PWS-Tw modes shall be activated only when the reference total wind (as used in the separation minima design) is equal or greater than the A-WDS-Tw threshold (to be determined as function of local conditions).
- A-TB-WDS-Xw and A-TB-WD-PWS-Xw modes shall be activated only when the cross wind (as used in the separation minima design) is equal or greater than the A-WDS-Xw wind threshold.

Either form of the WDS-A concept will use the same HMI that is proposed for the TBS and PWS-A concepts. This includes the FTD for providing the required separation to apply at the separation delivery point and the ITD to provide an indication of the predicted compression (ORD concept). When using the A-WDS-Tw (resp. A-WDS-Xw) modes, the FTD will be computed applying the same method as that used in the TBS concept but using a reduced time separation depending on the total wind (resp. crosswind). The definition of the total wind and crosswind used to define allowed time separation reduction is to be defined locally. It can range from anemometer wind up to full glide path profile.

In either form of WDS-A mode, and as for the TBS mode, the FTD will be based on the largest amongst all operational constraints (i.e. WDS-A WT separation, MRS, ROT or other runway spacing). The methods for calculating the ITD remain the same as for TBS.

The WDS-A concept will need the same headwind forecasting and measuring services as used in TBS for the FTD and ITD computation. However, there will also be other total- or cross- wind forecasting considerations depending on the nature of the WDS-A concept.

For the ECTL TBS concept, the activation threshold only applies at the surface (below 300ft) which means the longer-term forecast (1-2 hours) is only needed for the surface. With regards to the needs for FTD and ITD computation, the GWCS only needs to forecast several minutes ahead.

In addition, if the WDS-A concept is intended to be used strategically to improve airport capacity, then the wind forecasting horizon for the wind thresholds increases to several hours in order to provide the Network Manager sufficient time to plan ahead.

Another consideration is the different components of a wind forecast. You can forecast the wind magnitude and / or the wind direction

As the WDS-A concept is developed the wind forecasting / measuring requirements will be refined and updated accordingly.

3.1.2.2.3 Optimised Runway Delivery on Final Approach

This section is a summary of section 3.3.2.1.1 from the SPR-INTEROP/OSED[22]. For more details, please see the corresponding section in the OSED.

This section describes the ORD concept and in particular the Separation Delivery tool that supports and is used by the Controllers in delivering the required separation or spacing on approach to the runway landing threshold. The Separation Delivery tool calculates and displays Target Distance Indicators (TDIs) on the Approach and Tower CWPs. The TDIs include an FTD indicator which displays the required separation / spacing to be delivered to the required delivery point and an Initial Target Distance (ITD) indicator which displays the required spacing to deliver at the DF to support the Controller in delivering the required separation / spacing. The ITD is the FTD plus the predicted compression distance plus any additional buffer (if needed, as safety mitigation to uncertainty in the aircraft speed or wind forecast). The compression distance is the difference between the distance the leader travels from the DF to the point of delivery and the distance the follower travels in the same period of time.

The key steps regarding the calculation and display of these TDIs are as follows:

- Determine the Approach Arrival Sequence;
- Identify all applicable separations / spacing's per arrival pair (includes in-trail and not-in-trail pairs);
- Compute the equivalent distance for any time separations or spacing's;
- Select the maximum applicable separation or spacing which is known as the FTD;
- Compute the ITD by taking into account the effect of compression;
- Determine if the TDI should be displayed;
- Display the TDI on all applicable CWPs.

Target Distance Indications (TDIs) are displayed on the extended runway centreline of the Final Approach controller radar display and the Tower controller Air Traffic Monitor (ATM) display.

The initial arrival sequence could be taken from an AMAN server and input into the separation tool. Alternatively, it can be generated by a dedicated functionality based on actual aircraft position and the expected distance to fly to threshold or it can be taken from the Electronic Flight Progress Strip (EFPS). The controllers shall have the ability to manually alter this sequence using a sequence switching HMI.

TDIs are to be displayed on the extended runway centreline for all leader aircraft that are established on the localiser. The computation and display of ITD and FTD shall start at a moment defined according to a combination of factors relating to an aircraft's position and vector within a defined volume of airspace.

Figure 3 below shows an example of implementation design for the TDIs: in this example, shapes are constraints specific and colours are CWP specific.

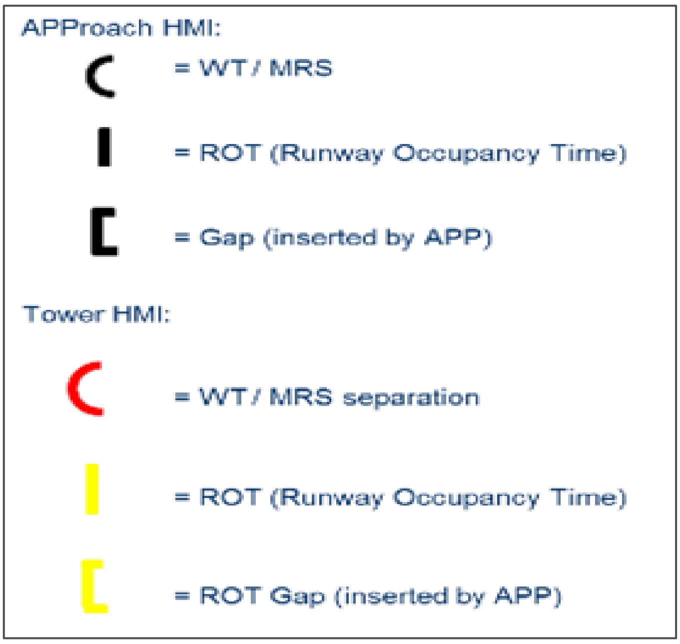

Figure 3: Example of HMI Design for TDIs

Modes of Operation

In case of conditional application of the time-based mode, the concept utilises a wind threshold to provide a safety buffer depending upon the local airport wind variability and the wind forecasting reliability to ensure that the concept allows for a maximum x seconds of errors in the FTD computation. This means the system requires two modes of operation:

- Distance Based (DBS);
- Time Based (TBS).

In both modes (under normal operating conditions) the same HMI will be used. In DBS mode the FTD will be defined by the distance separations of the selected WT scheme, whilst in TBS mode the FTD will be computed as a function of leader and follower category pair, the time separation from the Pairwise time separation table, the glideslope headwind profile and the follower final approach TAS profile or time-to-fly profile. In both modes the ITD will be computed as a distance added to the FTD, function of leader and follower final approach TAS profile or time-to-fly profile and headwind profile on the glideslope. The controllers and supervisors are shown the current mode of operation through an indication on the HMI.

The decision to switch between DBS mode and TBS mode shall be taken by the Approach and Tower Supervisor on the basis of the information provided by the MET services.

The separations are applied on the basis of wind conditions that may change from the time the separation is computed (at the latest before interception) and the time the aircraft reach the safety critical region of the glide below 300ft, meaning these separations have to be robust to wind conditions variation.

If the glideslope headwind profile is, for example, overestimated by the forecast, the result will be to observe a higher average groundspeed compared to the Separation Delivery Tool expectations and, as a consequence, a lower time separation applied than initially expected by the tool which could increase the risk of WVE.

The decision to activate the TBS mode shall be based on a criterion (total wind threshold) ensuring that whatever the reduction allowed in distance separation, the WVE risk will remain acceptable. As an example, because wake decay is strongly correlated to wind the threshold could be based on the total wind (not only headwind) in the critical region (below 300ft: reasonable worst location on the glide path where separations are designed).

The transition from one mode (TBS or DBS) to the other shall not jeopardize the capability of the ATCO to perform his separation duties. The two different modes share the same HMI and they both have TDIs (unless in case of system failure). The main significant difference with TBS mode active with respect to DBS mode is that the FTD is reduced compared to the DB separations.

A decision on the transition from DBS mode to TBS mode or vice versa shall have been made through a coordination process between the Approach and Tower Supervisor and the MET services. The decision shall be based on information about stable wind conditions and above a pre-defined wind threshold.

Once the decision is taken, both the Approach and Tower controllers are informed, and the requested operations are done in due time in order to have the same mode of operation on all the working positions.

In case of an unexpected drop in the total wind below the minimum threshold a tactical decision to go back to DB mode shall be taken. Once again, the decision is coordinated amongst the Approach and Tower Supervisors and the MET service. This is however considered as an abnormal mode and should remain a rare event. For avoiding it, a tactical decision (coordinated with MET services) to switch mode can be anticipated or postponed if the weather evolution turns out to deviate from the initial prediction.

Harmonisation with Other Separation and Spacing Constraints on Final Approach

The separation delivery tool can use different Wake Turbulence scheme to maintain the separations between aircraft pair. The schemes can be the standard reference used nowadays at European airport like ICAO or RECAT-EU or more advanced schemes. Two of these new advanced schemes are part of the PJ02.01 work: Static Pairwise Separation and Weather Dependent Separations for Arrivals (see sections 3.1.2.2.1 and 3.1.2.2.2).

The Separation Delivery Tool factors in the Minimum Radar Separation (3NM or 2.5NM), the runway occupancy time (ROT) or other additional in-trail/not-in-trail separation/spacing constraints (e.g. scenario specific spacing, spacing minimum which may be different from the MRS, specific airborne constraint, etc.).

The Final Target Distance indicator is required to reflect the maximum separation or spacing constraint to be applied between the arrival pair.

3.1.2.3 Summary of WT separation modes covered by this safety assessment for the arrivals concepts solutions

The following **WT separation modes** of operation based on combinations of the new WT separation concepts outlined in the previous sub-sections are covered in this safety assessment:

Id.	WT separation scheme& associated operation	Concepts involved
DB-PWS-A	Distance Based PWS-A (RECAT-EU-PWS)	PWS-A, ORD
TB-PWS-A	Time Based PWS-A (TB RECAT-EU-PWS)	TB, PWS-A, ORD
A-TB-WDS-Tw	WDS-A Total wind based on conditional reduction of TBS minima	A-WDS-Tw, TB, ORD
A-TB-WDS-Xw	WDS-A Crosswind based on conditional reduction of TBS minima	A-WDS-Xw, TB, ORD
A-TB-WD-PWS-Tw	WDS-A Total wind based on conditional reduction of TB-PWS-A minima	A-WDS-Tw, TB, PWS-A, ORD
TB-WD-PWS-Xw	WDS Cross wind based on conditional reduction of TB-S-PWS minima	A-WDS-Xw, TB, PWS-A, ORD

All WT separation modes are based on the use of Target Distance Indicators (TDI) and as such are supported by the ORD separation delivery tool.

In the current report the DBS and DB-PWS-A modes will be referred to as “Distance Based” (DB) modes whilst the TB-PWS-A, A-TB-WDS-Tw, A-TB-WDS-Xw, A-TB-WD-PWS-Tw and A-TB-WD-PWS-Xw modes will be referred to as “Time Based” (TB) modes. The WDS-A modes represent a sub-category of the Time-Based modes. The headwind TBS concept applied currently at Heathrow (with no conditional application) is referred to as “TBS”.

Note that the safety assessment for the TB and DB modes with indicators has been done in SESAR 1.

3.1.3 Arrivals Concepts Solutions Operations Environment and Key Properties

This section describes the key properties of the Operational Environment that are relevant to the SESAR Solution PJ02-01 safety assessment (information summarized from SPR-INTEROP/OSED Part I Section 3.2[22]) relevant for the Arrivals Concepts Solutions.

3.1.3.1 Airspace and Airport characteristics for the Arrivals Concepts Solutions

The Arrivals Concepts Solutions are applicable to capacity constrained Very Large Airports (more than 250k movements per year), Large Airports (between 150k and 250k movements per year) and Medium Airports (between 40k and 150k movements per year). These airports typically operate in Very High, High or Medium Complexity TMA sub-operating environments.

The runway configurations and modes of runway operations employed at European Very Large, Large and Medium Airports include:

- Single runway operating in mixed mode operations
- Independent parallel runways operating in segregated mode operations
- Dependent parallel runways operating in segregated mode operations with the option of some arrival aircraft landing on the designated departure runway
- Closely spaced parallel runways operating in segregated mode operations
- Closely spaced parallel runways operating in mixed mode operations

3.1.3.2 Types of Airspace – ICAO Classification for the Arrivals Concepts Solutions

Control areas around aerodromes are usually ICAO Class C or D:

- **ICAO Class C:** IFR and VFR flights are permitted, all flights are provided with air traffic control service and IFR flights are separated from other IFR flights and from VFR flights. VFR flights are separated from IFR flights and receive traffic information in respect of other VFR flights
- **ICAO Class D:** IFR and VFR flights are permitted, and all flights are provided with air traffic control service, IFR flights are separated from other IFR flights and receive traffic information in respect to VFR flights, VFR flights receive traffic information in respect of all other flights.

An ATC clearance is needed and compliance with ATC instructions is mandatory. A speed limit of 250 KIAS applies if the aircraft is below FL 100 (10,000ft) in the UK.

3.1.3.3 Airspace Users – Flight Rules for the Arrivals Concepts Solutions

The type of traffic permitted at an aerodrome and the associated restrictions is specified in the Aeronautical Information Publication (AIP) for the aerodrome. For example, Heathrow permits IFR traffic and also VFR and SVFR traffic under associated restrictions.

3.1.3.4 Traffic Levels and complexity for the Arrivals Concepts Solutions

In the Reference Scenarios the level of arrivals traffic in peak hours is as per the current RWY throughput at the respectively Very Large, Large and Medium airports.

In the Solutions Scenarios the level of arrivals traffic in peak hours is as per the increased RWY throughput enabled by the Solutions.

3.1.3.5 Separation Minima

In Baseline:

- The ICAO radar separation standards for arrivals and departures including MRS, which prevents aircraft collision, and WT separation which is intended to protect aircraft from adverse Wake Turbulence Encounters (WTEs).

- For Arrivals, that involves distance-based WT separations based on WT categories as per e.g. ICAO, RECAT-EU 6 category or UK 6 category schemes.

- For arriving aircraft category pairs with no defined WT separation then the MRS is to be applied. This is typically 3 Nautical Miles (NM) although can be 2.5NM under certain conditions prescribed in ICAO Doc 4444 or as prescribed by the appropriate Air Traffic Services (ATS) authority.

With the Solution Scenarios:

- With PWS-A the ATCOs will apply a separation scheme where separations are based on each aircraft type pair instead of the standard separations scheme where aircraft types are grouped on 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.
- With WDS-A the WT separations will be reduced thanks to weather conditions (total wind or 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 taking into account the relative lateral navigation performance of the lead and follower aircraft along the extended runway centre-line of the straight-in approach path. For the total wind concept there is still a need to take into account the time separation required for the wake turbulence generated by the lead aircraft to decay so that it is safe to be encountered by the follower aircraft.
- When the runway occupancy time spacing for providing for clearance of the runway by the lead aircraft in time for the follower aircraft to be able to be given clearance to land (ROT Spacing) is the largest separation or spacing constraint then this is required to be applied between the arrival pair. This may be applied as a pre-defined ROT Spacing between wake category pairs where the lead aircraft type has a mean arrival runway occupancy time (aROT) significantly greater than 50s (such as RECAT-EU CAT-A aircraft types of up to around 90s, RECAT-EU CAT-B aircraft types of up to around 75s and RECAT-EU CAT-C aircraft types of up to around 65s), or as Spacing Minimum adjusted dependent on the headwind conditions on final approach for non-wake pairs where the lead aircraft has a mean aROT of less than 50s (e.g. RECAT-EU CAT-D, CAT-E and CAT-F aircraft types).

3.1.3.6 Aircraft ATM capabilities for the Arrivals Concepts Solutions

The Aircraft ATM capabilities are as per the Reference Scenario IFR/VFR/SVFR operations at the respectively Very Large, Large and Medium airports. No additional ATM capabilities are envisaged.

The Aircraft ATM Capabilities include the following:

- Transponder (Elementary Mode-S Surveillance (ELS) or Mode A/C)
- Transponder (Enhanced Mode S Surveillance (EHS) (for UK Airports)
- Air-Ground Voice Communication System (VCS)
- Flight Management System (FMS) Capability

3.1.3.7 Ground ATM capabilities

In the Reference Scenarios:

- Flight Data Processing System
- Arrival Manager
- Departure Manager (for mixed mode)
- Airport Collaborative Decision Making (A-CDM) (for mixed mode)
- Advanced Meteorological Information
- Surveillance System for Surface Movement (e.g. Advanced Surface Movement Guidance and Control System (A-SMGCS))
- Tower CWPs (Airport Tower Supervisor, Tower Runway Controller, Tower Ground Controller, Tower Clearance Delivery Controller or Apron Manager)
    - Electronic Flight Progress Strips
    - Traffic Situation View Display
    - Meteorological Information Display
    - ATC Voice Communications
- TMA CWPs (TMA Supervisor, TMA Planning Controller, TMA Executive Departure Controller, Final Approach Controller)
    - Flight Progress Strips (Either electronic or paper)
    - Radar Situation View Display
    - ATC Voice Communications

With the Solution Scenarios:

Besides the ATCO delivery Tool support for Arrivals which are part of the Change (see details at §2.3.2 in the SAP) the following ground ATM capabilities are considered in the operational environment:

- Local environment weather information and wind forecasting and monitoring capabilities (TBS, ORD, PWS-A and WDS-A concepts rely on wind forecasting and monitoring at the surface and along the final approach path).
- Aircraft performance information in support of ORD concept
- Trajectories information in support of ORD concept.

3.1.3.8 Terrain Features – Obstacles for the Arrivals Concepts Solutions

There is a requirement to take into account terrain features and obstacles that may impact the wind field when developing and validating the WDS-A concepts. The local topography such as hangar buildings, terminal buildings and high ground in the vicinity of the aerodrome may impact both surface winds and winds aloft on the straight-in approach path.

3.1.3.9 CNS Aids for the Arrivals Concepts Solutions

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

- Air-Ground Voice Communication System
- Ground-Ground Voice Communications System
- Instrument Landing System (ILS) and possibly Microwave Landing System (MLS) for some airports
- RNAV / GNSS Navigation Services
- Possibly Ground Based Augmentation System (GBAS) for some airports
- Primary & Secondary Radar Surveillance System for the TMA and Initial, Intermediate and Final Approach
    - 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 landing stabilisation phase of Final Approach.

3.1.4 Airspace Users Requirements for the Arrivals Concepts Solutions

According to the OSED, the following airspace user requirements are relevant for PJ02 01:

- Flight Crews shall be briefed on the applicable concept (e.g. PWS-A or WDS-A) to ensure sufficient understanding. Also, they shall be aware of the current mode of operation at the airport which can be achieved through the Digital Automatic Terminal Information Service (D-ATIS).
- Flight Crew shall notify the Approach Controller of an inability to fly the standard procedure or of any non-conformant final approach speeds.
- The aircraft type is an important input into the Separation Delivery tool due to the possible implications of an error. The Flight Crew could be required to confirm aircraft type on first call to allow the Controllers to cross check it. If this is not feasible then an alternative method to reduce the chance of aircraft type errors will need to be found (i.e. via Datalink).
- The cautionary wake vortex advisory phraseology may require to be modified for the applicable concept.
- Additional spacing can be requested by Flight Crew but it is expected to be rare as Flight Crew will be briefed on the applicable concept.

3.1.5 Relevant Pre-existing Hazards for the Arrivals Concepts Solutions

A pre-condition for performing the safety assessment for the introduction of a new concept is to understand the impact it would have in the overall ATM risk picture. The SRM Guidance D and E [2] provide a set of Accident Incident Models (AIM - one per each type of accident) which represent an integrated risk picture with respect to ATM contribution to aviation accidents.

In order to determine which AIMs are relevant for each of the PJ02.01 Arrivals Concepts Solutions, this sub-section presents the relevant aviation hazards (that pre-exist in the operational environment before any form of de-confliction has taken place) that have been identified within the HP & SAF scoping & change assessment session (using Guidance F.2.2 of [2]).

It has been concluded that the safety-relevant impact of the change brought in by the Arrivals Concepts Solutions is limited to the Interception and Final Approach Path (including initiation of a Missed Approach (Go-Around)). The relevant pre-existing hazards, together with the corresponding ATM-related accident types and AIMs are presented in Table 1 for the Arrivals Concepts Solutions.

Pre-existing Hazards [Hp]	ATM-related accident type & AIM model
Hp#1a "Adverse Wake Encounter on Final Approach"	Wake Turbulence-induced Accident (WTA) on Final Approach Path & associated AIM in Appendix D
Hp#2a "Situation in which the intended 4D trajectories of two or more airborne aircraft are in conflict- Final Approach"	Mid-Air Collision (MAC) on the Final Approach Path & associated AIM in Appendix D
Hp#3 "The preceding landing aircraft are not clear of the runway-in-use"	Runway Collision (RC) & associated AIM in Appendix D

Table 1: Pre-existing hazards relevant for the PJ02-01 Arrivals Concepts Solutions

3.1.6 SAfety Criteria for the Arrivals Concepts Solutions

This section defines the set of SAfety Criteria applicable to the operational scenarios for the arrivals concepts solutions.

SAfety Criteria (SAC) define the acceptable level of safety (i.e. accident and incident risk level) to be achieved by the Solution under assessment, considering its impact on the ATM/ANS functional system and its operation.

The SAC setting is driven by the analysis of the impact of the Change on the relevant AIM models (models identified at §3.1.5) and it needs to be consistent with the SESAR safety performance targets defined by PJ 19.04 (as per [21]).

For PJ02-01 the Safety Validation Target is:

"The reduction in the total number of WAKE Final Approach accidents per year of -0.33% and in the total number of RWY Collision accidents per year of -0.53%, due to SESAR 2020 improvements with respect to a hypothetical "do nothing" scenario, in which no changes are made to ATM safety of the Baseline (2005) while traffic is allowed to increase until it reaches the capacity level targeted for SESAR in 2035."

(note that the safety benefit is the outcome of maintaining the Baseline safety levels whilst accepting the Capacity benefit i.e. traffic increase brought in by the Concept)

Two sets of safety criteria are formulated:

- A first one aimed at ensuring an appropriate Separation design i.e. definition of WT separation minima which, if correctly applied in operation, guarantee safe operations on final approach segment and initial common approach path respectively;

- A second one aimed at ensuring correct Separation delivery i.e. that the defined WT separation minima are correctly applied by ATC.

SEPARATION DESIGN

The following definition will be employed to designate a **pair of aircraft**:

Two consecutive arrivals on the same runway, or on Closely Spaced Parallel RWYs (CSPR), or an arrival following a departure in mixed mode on the same runway or on CSPR.

A SAC is defined for each Arrival WT separation mode within the scope (PWS-A, WDS-A) driven by the applicable WT Accident AIM model (Final Approach – see Appendix D).

- on risk of WT Encounter on Final Approach related to correct application of the WT scheme under consideration (see in AIM WT on Final Approach model Appendix D Figure 27 the outcome of precursor Wake Encounter (WE) 6S "Imminent wake encounter under fault-free conditions" not mitigated by barrier B2 "Wake encounter avoidance")

A-TB-WDS-Tw-SAC#1: The probability per approach of wake turbulence encounter of a given severity for a given traffic pair spaced at WDS Total wind minima on Final Approach segment for any applicable total wind conditions shall not increase compared to the same traffic pair spaced at reference distance WTC-based minima in reasonable worst-case conditions*.

* Reasonable worst-case conditions recognized for WT separation design (as detailed at [7] §4.2.1)

A-TB-WDS-Xw-SAC#1: The probability per approach of wake turbulence encounter of a given severity for a given traffic pair spaced at WDS Cross wind minima on Final Approach segment for any applicable cross wind conditions shall not increase compared to the same traffic pair spaced at reference distance WTC-based minima in reasonable worst-case conditions*.

RECAT-EU-PWS-SAC#1: For an aircraft type pair at RECAT-EU-PWS minima on Final Approach segment, the pair-wise wake turbulence encounter severity shall not be higher than the severity of reference aircraft type pair (selected as acceptable baseline with proven extensive operations) at ICAO minima and in reasonable worst-case conditions*

The strategy intended for meeting the above SACs will rely upon the analysis of experimental data (traffic, meteo, wake) possibly combined with modelling.

Once the Design has met the SAC above, the following safety issue still remains to be addressed:

Safety issue: The frequency of wake turbulence encounters at lower severity levels might increase due to the reduced separation minima. As the frequency of wake turbulence encounters at each level of severity depends on local traffic mix, local wind conditions and proportion of time of application of the concept, there is a need to find a suitable way for controlling the associated potential for WT-related risk increase.

An additional SAC, to be derived on each WT separation mode, is defined in order to cap the safety risk from the case where the correctly defined WT separation minima are not correctly applied, with potential for severe wake encounter higher than if those minima were correctly applied.

- on risk of Imminent wake encounter under unmanaged under-separation (see WE 6F in AIM WTA Final Approach model Appendix D Figure 27):

> **A-SAC#F1:** The probability per approach of imminent wake encounter under unmanaged under-separation on Final Approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

The strategy intended for meeting the A-SAC#F1 relies upon qualitatively showing that the use of the tool will involve a significant reduction of the frequency of unmanaged under-separations which will compensate for the risk increase brought in by the higher probability of imminent wake encounter associated to those unmanaged under-separations.

SEPARATION DELIVERY

A set of SACs, to be derived on each WT separation mode, are defined in order to ensure that the defined WT separation minima are correctly applied for separation delivery, i.e. that the right Functional System in terms of People, Procedures, Equipment (e.g. separation delivery tool) is designed such as to enable safe operation in each separation mode. The correct application of WT separation minima needs to account for the additional separation constraints imposed by the Surveillance separation (during interception and along the final approach path) and the need of preventing RWY collision[3]. For achieving that, the safety risk related to under-separation and its precursors needs to be controlled, driven by the AIM WT on Final Approach models and accounting for constraints imposed by the MRS minima and by the AIM RWY collision model.

- on risk of Unmanaged under-separation (WT) in adequate separation mode during interception and final approach (see WE 7F.1 in AIM WT on Final Approach model Appendix D Figure 27):

> **A-SAC#F2:** The probability per approach of Unmanaged under-separation (WT) in adequate separation mode during interception & final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

- on risk of Unmanaged under-separation induced by inadequate selection & management of separation mode i.e. selection of and transition between any adequate modes of operation i.e. A-WDS-Tw, A-WDS-Xw, DBS (see WE 7F.2 in AIM WT accident on Final Approach model):

[3] In case of aircraft inability to recover from a severe wake encounter a wake accident will occur (encompassing loss of control or uncontrolled flight into terrain; that is not related to the Controlled Flight into Terrain accident and associated AIM model)

A-SAC#F3: The probability per approach of unmanaged under-separation (WT) during interception & final approach shall not increase due to inadequate selection of or transition between any adequate modes of operation

- on risk of Imminent infringement (WT) during interception and final approach (see WE 8 in AIM WT accident on Final Approach model):

A-SAC#F4: The probability per approach of Imminent infringement (WT) during Interception & final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

- on risk of Imminent collision during interception and final approach path (see in AIM MAC FAP model MF4):

A-SAC#F6: The probability per approach of Imminent collision during interception and final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline).

- on risk of Imminent infringement (radar separation) during interception and final approach path (see in AIM MAC FAP model MF5.1 and MF7.1):

A-SAC#F7: The probability per approach of Imminent infringement (radar separation) during interception and final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline).

- on risk of Crew/Aircraft induced spacing conflicts (spacing conflicts induced by Crew/Aircraft and not related to ATC instructions for speed adjustment) during interception and final approach (see WE 10/11 in AIM WT accident on Final Approach model):

A-SAC#F5: The probability per approach of Crew/Aircraft induced spacing conflicts during interception & final approach shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

- on risk of runway conflict due to conflicting ATC clearances (see in AIM RWY collision model D.2, the precursor RP2.4 which might be caused by e.g. spacing management by APP ATCO without considering ROT constraint or APP ATCO clearing a/c to land while another a/c has been cleared for line-up (applicable only in mixed mode) and which outcome is mitigated by B2: ATC Collision Avoidance involving e.g. last moment detection by TWR ATCO with or without Runway Incursion Monitoring and Conflict Alert System RIMCAS):

A-SAC#R1: The probability per approach of Runway Conflict resulting from Conflicting ATC clearances shall be no greater in operations based on WT scheme under consideration than in current operations applying reference minima (e.g. ICAO or an established operational baseline)

It should be noted that no SAC was derived for the risk of Runway conflict due to premature landing (not cleared by ATCO) or unauthorised RWY entry of ac/vehicle as no change is introduced by the arrivals concepts compared to today's operations.

3.1.7 Mitigation of the Pre-existing Risks – Normal Operations for the Arrivals Concepts Solutions

3.1.7.1 Operational Services to Address the Pre-existing Hazards for the Arrivals Concepts Solutions

The arrival concepts under assessment are applicable to the final approach operations from merging for interception until the aircraft has landed. Therefore, both Approach Control Service and Aerodrome Control Service are impacted by these concepts. The operational services (i.e. delivered to the Airspace Users) listed in Table 2 have been seen as relevant to these concepts.

ID[4]	Air Navigation Service Objective	Pre-existing Hazard
Airport Operational Scenario Planning Phase		
ACT	Determination and activation of the separation mode (in case of conditional application of the Time-Based modes) Note: only automatic de-activation is possible (TB to DB mode), the activation (DB to TB mode) has to always be done manually by the controllers/supervisors	**Hp#1a** (Wake risk)
GPM	Coordination of pre-planned or tactical GAP management	**Hp#3** (Runway collision risk)
Approach and Landing		
FCF	Facilitate capture of the Final approach	**Hp#1a** (Final Approach wake risk) **Hp#2a** (Final Approach MAC risk)
SP2	Maintain separation between aircraft intercepting different final approach paths (closely spaced parallel runways)	**Hp#1a** (Final Approach wake risk) **Hp#2a** (Final Approach MAC risk)
SP3	Maintain spacing/separation between aircraft on the same final approach path	**Hp#1a** (Final Approach wake risk) **Hp#2a** (Final Approach MAC risk) **Hp#3** (Runway collision risk)
SP4	Maintain aircraft separation between successive arrivals on the Runway Protected Area (RPA)	**Hp#3** (Runway collision risk)
SP5	Maintain aircraft separation between arrivals and	**Hp#3** (Runway collision risk)

[4]SP= SeParate aircraft with other aircraft; FCF= Facilitate Capture of the Final approach; ACT = Activation/Transition phase.

	departures in mixed mode (departure behind an arrival vacating or departure in front of arrival) on the Runway Protected Area (RPA)	

Table 2: Relevant ATM/ANS services and Pre-existing Hazards for the PJ02-01 Arrivals Concepts Solutions

3.1.7.2 Derivation of Safety Objectives (Functionality & Performance – success approach) for Normal Operations for the Arrivals Concepts Solutions

The purpose of this section is to derive functionality & performance Safety Objectives (as part of the success approach) in order to mitigate the pre-existing aviation risks under normal operational conditions (i.e. those conditions that are expected to occur on a day-to-day basis) such as to meet the defined Safety Criteria.

To derive the Safety Objectives one needs to interpret, from a safety perspective, the OSED Operational Concept specification (i.e. how the PJ02-01 concept contributes to the aviation safety) by making use of the European Air Traffic Management Architecture (EATMA) representation as per the Operational layer. More specifically, this means using the OSED Use Cases and their representation through the EATMA Process Models as defined by the PJ02-01 OSED. The purpose is to derive a complete list of Safety Objectives, allowing to specify the Change involved by the Concept at the operational service level, by considering the PJ02.01 concepts as a series of continuous processes described through the Use Cases. This allows showing how the Safety Objectives participate in the achievement of the relevant operational services and contribute to safety barriers (in the relevant AIM models) i.e. how they contribute to meeting the Safety Criteria.

The OSED presents the consolidated list of functionality & performance Safety Objectives (SO) under normal operational conditions. The link to the Safety Criteria is shown in the last column for each SO, via the relevant Use Case and operational service that are concerned with the change and allowed the SO derivation.

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
	ATC shall be able to apply consistent and accurate DBS, TBS, PWS-A or WDS-A wake turbulence separation rules on final approach (encompassing interception) and landing, through operating under Distance Based modes (DBS, DB-PWS-A) and Time Based modes (TBS, T-PWS-A, A-WDS-Tw and A-WDS-Xw), with the possibility to safely switch between a TB-mode and the corresponding DB-mode. **LIM#005:** Regarding the conditional application of Time-Based modes, in line with the OSED, only the activation and deactivation conditions of each WT separation mode and the switching between each TB-mode and the corresponding DB-mode are covered within this specification and related safety assessment, but not other transitions between modes.	Airport Operational Scenario Planning Phase for PWS, WDS and ORD for Arrivals	ACT: Determination and activation of the separation mode (in case of conditional application of the Time-Based modes)	**SAC#F2** **SAC#F3**
SO 002	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).	As above	As above	**SAC#F3**
SO 003	In case of conditional application of TB-modes the wind threshold(s) for the activation criteria specific to each TB-	As above	As above	**Any mode-A-SAC#F1**

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
	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			**SAC#F3**
SO 004	In case of conditional application of 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-A modes or respectively TB-PWS-A and A-TB-WD-PWS modes are not met anymore	As above	As above	**SAC#F3**
SO 005	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		FCF: Facilitate capture of the Final approach path SP3: Maintain spacing/separation between aircraft on the same final approach path	**A-SAC#F2** **A-SAC#F4**
SO 006	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		FCF: Facilitate capture of the Final approach path SP3: Maintain spacing/separation between aircraft on the same final	**A-SAC#F2** **A-SAC#F4** **A-SAC#F6** **A-SAC#F7** **A-SAC#R1**

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
	spacing constraint (e.g. departure gaps)		approach path GPM: Coordination of pre-planned or tactical GAP management	**A-SAC#R2**
SO 007	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		FCF: Facilitate capture of the Final approach path	**A-SAC#F5**
SO 008	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.		SP3: Maintain spacing/separation between aircraft on the same final approach path	**A-SAC#F2** **A-SAC#F4** **A-SAC#F6** **A-SAC#F7** **A-SAC#R1** **A-SAC#R2**
SO 009	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		SP2: Maintain separation between aircraft intercepting different final approach path (closely spaced parallel runways) SP3: Maintain spacing/separation between aircraft on the same final	**A-SAC#F5**

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
			approach	
SO 010	ATC (and potentially Flight Crew/Aircraft) shall consider the potential for WDS separation infringement due to lateral deviation from final approach path (e.g. dog leg when WDS crosswind is operated)		As above	**A-SAC#F2** **A-SAC#F4** **A-SAC#F5**
SO 011	The runway spacing or other spacing constraint (e.g. departure gaps) shall be input to and accounted for the Separation Delivery Tool (in support of SO 006) It is assumed that landing clearances will be provided in the same manner as per current operations based on WTC scheme		SP4: Maintain aircraft separation between successive arrivals on the Runway Protected Area (RPA) Maintain aircraft separation between arrivals and departures in mixed mode (departure behind an arrival vacating or departure in front of arrival) on the Runway Protected Area (RPA) GPM: Coordination of pre-planned or tactical GAP management	**A-SAC#R1**
SO 012	TWR ATC shall request the insertion of departure gaps from APP ATC, and shall coordinate with APP the modification and cancellation of these gaps as operationally needed		GPM: Coordination of pre-planned or tactical GAP management Maintain aircraft separation between arrivals and departures in mixed mode	**A-SAC#R1** **A-SAC#R2**

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
			(departure behind an arrival vacating or departure in front of arrival) on the Runway Protected Area (RPA)	

Table 3 PJ02.01 Safety Objectives (success approach)

The next table shows the success case safety objectives for arrivals per execution phase and their associated SAC:

ID	Description	Ref. SAC
WT Separation Mode Activation/Transition Phase		
SO 001	ATC shall be able to apply consistent and accurate DBS, TBS, PWS-A or WDS-A wake turbulence separation rules on final approach (encompassing interception) and landing, through operating under Distance Based modes (DBS, DB-PWS-A) and Time Based modes (TBS, T-PWS-A, A-WDS-Tw and A-WDS-Xw), with the possibility to safely switch between a TB-mode and the corresponding DB-mode.	**SAC#F2** **SAC#F3**
SO 002	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).	**SAC#F3**
SO 003	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	**Any mode-SAC#1** **SAC#F3**
SO 004	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-A modes or respectively TB-PWS-A, A-TB-WD-PWS modes are not met anymore	**SAC#F3**
Execution Phase – Interception		
SO 005	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	**A-SAC#F2** **A-SAC#F4**
SO 006	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 (e.g. departure gaps)	**A-SAC#F2** **A-SAC#F4** **A-SAC#F6** **A-SAC#F7** **A-SAC#R1** **A-SAC#R2**
SO 007	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	**A-SAC#F5**
Execution Phase – Final Approach		
SO 008	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.	**A-SAC#F2** **A-SAC#F4** **A-SAC#F6** **A-SAC#F7**

		A-SAC#R1 **A-SAC#R2**
SO 006	See above	
SO 009	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	**A-SAC#F5**
SO 010	ATC (and potentially Flight Crew/Aircraft) shall consider the potential for WDS-A separation infringement due to lateral deviation from final approach path (e.g. dog leg when WDS crosswind is operated)	**A-SAC#F2** **A-SAC#F4** **A-SAC#F5**
SO 011	The runway spacing, or other spacing constraint shall be input to and accounted for the Separation Delivery Tool (in support of SO 006)	**A-SAC#R1**
SO 012	TWR ATC shall request the insertion of departure gaps from APP ATC, and shall coordinate with APP the modification and cancellation of these gaps as operationally needed	**A-SAC#R1** **A-SAC#R2**

Table 4: List of Safety Objectives (success approach) for Normal Operations for the PJ02-01 Arrivals Concepts Solutions

3.1.8 Safety Objectives for Arrivals Concepts Solutions under Abnormal Conditions

The purpose of this section is to assess the ability of operations based on the new WT separation modes and ATC tools to work through (robustness), or at least recover from (resilience) any abnormal conditions that might be encountered relatively infrequently (these might be either operational situations/use cases that have not been covered in 3.1.7.2 or conditions external to the scope of the new System which are not under our control).

3.1.8.1 Identification of Abnormal Conditions for the Arrivals Concepts Solutions

The following abnormal conditions have been identified in Project 06.08.01 in SESAR 1, also relevant for this iteration.

ID	Abnormal Scenario
1	Change of Aircraft landing runway intent
2	Abnormal procedural aircraft airspeed and/or abnormal stabilized approach speed
3	Lead aircraft go-around
4	Delegation of separation to Flight Crew
5	Actual Wind on final approach different from the wind used for FTD/ITD computation
6	Flight Crew Notification of Aircraft Speed non-conformance
7	Unexpected drop of ground wind below safe threshold
8	Late change of landing runway (not planned)
9	Scenario specific spacing requests (e.g. unforeseen need for RWY inspection)

1/ Change of Aircraft landing runway intent

This situation represents the case of an aircraft changing its runway intent late and requiring to be inserted in the sequence of the "new" runway with a sequence already established.

Two distinct cases need to be addressed:

- Change of aircraft intent before merging towards Final Approach
- Change of aircraft intent after merging towards Final Approach or already established

The second case differs from the first one, as the Approach controllers have less time to handle a late change. The risk is for the aircraft to be inserted in the sequence without updating the arrival sequence, which, if not detected involves the use of incorrect TDIs (corresponding to a different aircraft) with potential for imminent infringement and ultimately large under-separation – mitigation is derived as per SO 103.

2/ Abnormal procedural aircraft airspeed and/or abnormal stabilized approach speed

This situation represents the case of an aircraft not respecting the procedural airspeed before the Deceleration Fix (e.g. respecting 160 KIAS) or the stabilized approach speed specific to the aircraft type (e.g. VAPP) after the Deceleration Fix.

For TB-modes, the risk is that both FTD and ITD are erroneous, as their computation is based on the pre-defined TAS profile for that aircraft type, with potential for imminent infringement and ultimately large under-separation – mitigation is derived as per SO 102, i.e. aircraft speed conformance alert.

For DB-modes, only the precision of ITD is affected, with risk of imminent infringement and need to instruct a missed approach due to compression after the deceleration fix – mitigation as per SO 102

For the affected aircraft pair, ATC either needs to apply speed corrections or to manage compression manually and, if in TB-modes, to apply distance-based WTC separation minima if speed corrections can't be applied.

3/ Lead aircraft go-around

This situation represents the case where the lead Aircraft is executing a missed approach at any point during the final approach (either instructed by ATC or decided by Flight Crew).

The risk is for ATCO to not update the arrival sequence which might involve the use of incorrect TDIs (corresponding to a different aircraft) with potential for imminent infringement and ultimately large under-separation – mitigation is derived as per SO 103.

4/ Delegation of separation to Flight Crew

This situation occurs in good visibility conditions, in case the Final APP or TWR ATCO needs to delegate the WT separation to Flight Crew (e.g. in case the FTD is going to be infringed, in order to avoid initiating a go around).

If the Flight Crew accepts the request, the Final Approach ATCO or Tower Runway ATCO shall instruct the Flight Crew to maintain visual separation with the aircraft ahead. In this case the responsibility to maintain separation will be passed to the Flight Crew.

No change compared to current operations based on DBS without indicators.

5/ Actual Wind on final approach different from the wind used for FTD/ITD computation

Impact on the computed/displayed FTD

For the **Time-Based modes,** if the actual wind conditions on final approach are different from the wind conditions provided by the short term MET prediction and used for FTD computation, the displayed FTD will not provide the right separation minima to be applied and in the worst case the shown distance will be lower than the correct one, with risk of under-separation. More specifically the wind conditions used for the FTD computation are:

- In TB-PWS-A modes: glideslope wind profile,
- In A-TB-WDS-Tw and A-TB-WD-PWS-Tw modes: reference Total wind,
- In A-TB-WDS-Xw and A-TB-WD-PWS-Xw modes: reference Cross wind.

In the current safety assessment, the risk of under-separation induced by the uncertainty in glideslope wind prediction (together with the one induced by uncertainty in the actual final approach speed profile) is mitigated as follows:

- Define time separation buffers for the applicable time separation minima and for various wind conditions; these buffers decrease as the wind increases;
- Select, amongst the considered wind conditions, the one which displays the maximum time separation buffer;
- In case of conditional application, reduce the time separation buffer. The conditional application is expected to be used in many implementations, in order to maintain acceptable performance in terms of resilience and/or throughput (note that at airports where wind conditions are stable adding a separation buffer in the design of separation minima to be used by the FTD will be sufficient to mitigate that risk; however, at airports with changing wind conditions a conjunction of an added separation buffer and the conditional application of the time based modes will be necessary).

However, the above mitigations are not sufficient in the longer term, because if the difference in wind conditions persists the operation will be performed with reduced safety margins and higher exposure to risk of imminent infringement and under-separation. An additional mitigation is derived as per SO 101 i.e. wind conditions monitoring and alerting, whilst specifically considering the **type/component of wind relevant** for each time-based separation concept. If in WDS-Tw/Xw, upon being alerted, the ATCOs shall revert to the correspondent distance-based separation mode (DBS or DB-PWS-A). If in TBS or TB-PWS-A, the tool shall re-compute the TDIs based on the correct wind value.

Note: No impact on FTD in DBS and DB-PWS-A modes.

Impact on the computed/displayed ITD

For **all WT separation modes,** the difference between the actual head wind on the glideslope and the glideslope headwind profile used by the separation delivery tool will impact the accuracy of the ITD and in the worst case the spacing shown will be lower than the correct one with risk for needing to instruct a missed approach due to the non-anticipated compression after the deceleration fix. The mitigation derived above can be re used here – SO 101 (with monitoring of the glideslope wind conditions). Upon being alerted the ATCOs shall manage compression without indicators as per today operations.

Note: The case of wind conditions resulting in a significant difference in the ground speed of aircraft being merged from opposite sides of the extended runway centre-line and a significant change in ground speed as the aircraft turn on to final approach does not involve any change in the way APP ATCO is managing the turn for interception in the current DBS operations without indicators. The Target Distance Indicators are correctly displayed, and ATCO will target them when instructing aircraft to turn for interception whilst accounting for the challenging wind conditions in the same way they do it in current operations.

6/ Flight Crew Notification of Aircraft Speed non-conformance

Flight crew provides notification of approach procedural airspeed non-conformance issues and/or unusually slow or fast landing stabilisation speed for the aircraft type.

In order to mitigate the subsequent risk of not providing adequate spacing to cope with the compression effect, APP ATCO shall take into account, for the merging on to final approach, the notified speed-related aspects to determine the additional spacing that is required to be set up behind the ITD indication – mitigation is derived as per SO 104.

7/ Unexpected drop of reference wind below safe threshold

In case of conditional application of the Time Based modes, when the TB-mode activation criteria is not met anymore (i.e. an unexpected drop of the reference wind below the safe threshold), the TB-mode shall be deactivated (revert to correspondent DB- mode) – see SO 004 (derived at §3.1.7.2)

8/ Late change of landing runway (not planned)

This situation represents the case of a change of the assigned landing runway which was not planned, requiring an establishment of a new arrival sequence for this switched runway.

The risk is for using a not correctly updated arrival sequence which, if not detected involves the use of incorrect TDIs (corresponding to a different aircraft) with potential for imminent infringement and ultimately large under-separation – mitigation is derived as per SO 105.

9/ Scenario specific spacing requests

ATCO shall be able to handle requests for spacing which are specific to scenarios like e.g. unforeseen RWY inspection or temporary blockage or aircraft difficulty for braking. The separation delivery tool shall be able to display TDIs behind the adequate aircraft, based on Controller input, as per SO 106.

The following OSED Use case/Non-nominal flows will be addressed when failure conditions are analysed at §4.1.5:

- Insufficient spacing on Final approach
- ITD catch-up alert on Final approach.

3.1.8.2 Safety Objectives for Abnormal Conditions for the Arrivals Concepts Solutions

The following Safety Objectives considering the abnormal conditions identified above have been derived for arrivals:

ID	Description	Abnormal Scenario	Ref. SAC
SO 101	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 wind in TB-modes only; for the ITD – glideslope wind in all modes (TB and DB).	5	**A-SAC#F2** **A-SAC#F3**
SO 102	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	2	**A-SAC#F5**
SO 103	ATC shall maintain an updated arrival sequence order following a late change of aircraft runway intent or a go-around	1 and 3	**A-SAC#F2** **A-SAC#F4** **A-SAC#F5** **A-SAC#F6** **A-SAC#R1**
SO 104	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	6	**A-SAC#F5**
SO 105	The Target Distance Indicators shall be correctly updated in case of late (not planned) change of landing runway Issue 02: In case of a late landing runway change, it should be verified if the arrival sequencing tool can be timely reconfigured in order to display the Approach Arrival Sequence for the switched runway and update the TDIs accordingly.	8	**A-SAC#F2** **A-SAC#F4** **A-SAC#F5** **A-SAC#F6** **A-SAC#R1**
SO 106	ATC shall be able to handle scenario specific spacing requests while using the separation delivery tool	9	**A-SAC#R1** **A-SAC#R2**

Table 5: List of Safety Objectives (success approach) for Abnormal Operations for the PJ02-01 Arrivals Concepts Solutions

3.1.9 Mitigation of System-generated Risks (failure approach) for the Arrivals Concepts Solutions

This section concerns operations in the case of internal failures. Before any conclusion can be reached concerning the adequacy of the safety specification at the OSED level, it is necessary to assess the possible adverse effects that failures internal to the end-to-end Functional System supporting the new WT separation modes and ATC tools might have upon the provision of the relevant operations and to derive safety objectives (failure approach) to mitigate against these effects.

This section provides the list of the identified Operational Hazards, their operational effects, with the mitigation of those effects and the associated severity. The severity classification scheme is based on the Wake Turbulence Accident Model (see Appendix D).

3.1.9.1 Identification and Analysis of System-generated Hazards for the Arrivals Concepts Solutions

The list of hazards for arrivals is based on the analysis which was previously done in Project P06.08.01 in SESAR 1. These hazards have been refined further for this iteration.

In SESAR 1, a number of safety workshops for TBS phase 1 took place at NATS premises and were facilitated by NATS safety representatives and involving Approach and Tower Controllers. Hazards, their causes and consequences were identified and assessed during these workshops.

Further on, in TBS phase 2, the Operational Hazards relevant for TB-PWS-A with indicators (corresponding to the TBS separation mode) and DB-PWS-A with indicators (corresponding to DBS separation mode) have been identified and analysed within the TB-PWS-A SAF/HF workshop (Dec 2014) [8], complemented by further safety expert analysis supported by project and operational expertise, and the outcomes have been documented in the TB-PWS-A Safety Assessment Report [8]. Appendix E presents the OHA/HAZID table which led to the identification of the Operational Hazards for TBS and DBS modes, including failure mode, possible causes, preventive mitigations; operational effects and protective mitigations based on workshop and brainstorming activities.

In the frame of P06.08.01, the TB-PWS-A hazard identification and analysis has been further extended by the safety, project and operational experts in order to encompass the newly introduced WT separation modes and ATC tools (based on the use of Target Distance Indicators).

The hazards and mitigations were further refined to reflect the developments of PJ02.01 during a workshop which took place at EUROCONTROL Bretigny on October 30th, 2018. The workshop was facilitated by SAF and HP experts from EUROCONTROL and it included APP, TWR ATCOs and Supervisors, together with safety, human performance and concept experts. For the full list of participants please see Appendix F. Further, a workshop with pilots from Air France and CDG ATCOs took 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 PJ02.01, PJ02.02 and PJ02.03. However, only results from PJ02.01 and PJ02.03 were kept in this SAR. For the detailed results of this workshop please see Appendix G.

The Operational Hazards have been identified at operational service level, i.e. aligned to the Safety Objectives in normal conditions and such as to allow their anchoring into the AIM Wake Turbulence Accident model.

It should be noted that hazards Hz#01a, 01b, 02a, 02b, 03a, 03b, 04a, 04b apply in the Reference operations as well (i.e. current operations using DBS minima without indicators), with the same operational effects. Meanwhile most of the means for mitigating the hazard effects are modified by the introduction of the new WT separation modes, as Target Distance Indicators are provided to ATCOs for the application of the separation minima applicable in each mode, whilst ensuring that the severity of the hazard effects is not degraded. Obviously, certain hazard causes and associated preventive mitigations are also changed, but that aspect will be tackled within the failure analysis of the SPR-level design in 4.1.5.

The following table provide the consolidated list of the Operational Hazards, with their operational effects, the mitigations protecting against effect propagation and the allocated severity. The severity allocation was based on the severity classification schemes of the relevant Accident Incident Models (AIM) as per the guidance to SRM [2] (Guidance E) and which are included in Appendix D.

ID	Hazard Description	High Level Causes (derived from Success SO)	Operational Effects	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
		Inadequate ATCO instruction Inadequate ATCO-pilot communication	When applying WDS for example, ATCO may be drawn into reducing to the new separation minima before the current transition procedures (e.g. from 3 to 2.5NM or 1000ft) allow, especially when the Separation Delivery Tool is used, due to the ATCO being drawn in delivering to the TDI. This means an imminent infringement, i.e. spacing is eroded with risk for temporary and limited under-separation (e.g. less than 0.5 NM) during separation establishment	**Protective Mitigations** Resolve situation by vectoring, level instructions or go-around WAKE FAP B3 Management of Imminent Infringement MAC FAP B3 ATC Collision Avoidance	WK-FA-SC3b MAC-FA-SC3

[5] Example: LOC overshoot resulting in the follower catching-up the leader that performed the overshot; one cause might be the wrong or untimely ATCO heading instruction; a second cause might be the late Pilot response.

			on Final App or later during Final App can happen.		
	Separation not being recovered following imminent infringement of A/C pair instructed by ATC to merge on the Final Approach interception	(e.g. Go around, break off etc- depends on the triggering event) ATCO failure to instruct timely the separation recovery action before the imminent infringement is evolving to a large under-separation Pilot failure to timely execute the separation recovery instruction	Large under-separation (of more than e.g. 0.5 NM) occurs during separation establishment on Final App or later during Final App.	**<u>Protective Mitigations</u>** With respect to WTE risk: Follower within WV influence area, WV survival in the flight path (F6) <u>– this is degraded with MRS 2NM (compared to MRS 2.5NM)</u> The **use of tool is expected to mitigate** that risk increase by contributing to the reduction of separation infringements thanks to the increased separation delivery accuracy. WAKE FAP F6 Wake Decay & Transport MAC FAP B2 ACAS Warning	WK-FA-SC3a MAC-FA-SC2b
	Inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach	Unanticipated pilot/aircraft behaviour during interception (overshoot; a/c lateral, vertical or speed deviation;	Spacing is eroded with risk for temporary and limited under-separation (e.g. less than 0.5 NM) during separation establishment on Final App or later during	**<u>Protective Mitigations</u>** ATC recovery from imminent infringement by adequate action (vectoring, level instructions or go-around) WAKE FAP B3 Management of	WK-FA-SC3b MAC-FA-SC3

	interception profile without ATC instruction given	wrong a/c turns on the indicator)	Final App	Imminent Infringement MAC FAP B3 ATC Collision Avoidance	
	Separation not being recovered following imminent infringement due to aircraft deviation from Final Approach interception profile without ATC instruction given				
	Inadequate separation management of an aircraft pair naturally catching-up as instructed by ATC on the Final Approach	Inadequate use of separation indicators by the APP ATCO when a/c is established on final Lack/loss of indicator for one aircraft on Final App	Imminent infringement, i.e. spacing is eroded with risk for temporary and limited under-separation (e.g. less than 0.5 NM) the Final App	**Protective Mitigations** ATCO detects the missing indicator and: Aircraft established on Final approach stabilized with 160kts IAS and behind ITD is allowed to continue the approach,	WK-FA-SC3b MAC-FA-SC3

				otherwise initiate Go around WAKE FAP B3 Management of Imminent Infringement MAC FAP B3 ATC Collision Avoidance	
	Separation not being recovered following imminent infringement by an aircraft pair instructed by ATC on the Final Approach				
	Inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach profile without ATC instruction given		Spacing is eroded with risk for temporary and limited under-separation (e.g. less than 0.5 NM) on the Final App	**Protective Mitigations** Supported by catch-up warning; Re-clear a/c to fly a different speed if possible OR Go-around; WAKE FAP B3 Management of Imminent Infringement MAC FAP B3 ATC Collision Avoidance	WK-FA-SC3b MAC-FA-SC3

	Separation not being recovered following imminent infringement due to aircraft deviation from Final Approach profile without ATC instruction given				
	One or multiple separation minima infringements due to undetected corruption of separation indicator	Corruption of one or multiple separation indicators	Large under-separation (of more than e.g. 0.5 NM) occurs for one or multiple aircraft pairs on the Final App	**Protective Mitigations** Partial mitigation: Buffer for ITD and FTD take margins on the wind computation. In DB-mode: ATCO will realise that the tool is using incorrect wind reference because successive aircraft separated correctly using the indicators will have the tendency to infringe the correct FTD as the leader decelerates, triggering a go-around by the TWR controller.	WK-FA-SC3a MAC-FA-SC2b *However, because multiple aircraft might be affected before failure is detected, a Safety Objective more demanding than the corresponding hazard severity will be allocated via an impact modification factor IM=20*

				In TB-modes: It is difficult for the ATCO to realise that the tool is using incorrect wind reference. The a/c will be separated according to a wrong FTD, i.e. wake separation infringement. *For the incorrect separation indicator in relation to speed non-conformance:* go-around of the follower (because TDI might be wrong) WAKE FAP F6 Wake Decay & Transport MAC FAP B2 ACAS Warning	
	One or multiple imminent infringements due to lack/loss of separation indicator for multiple or all aircraft		One or multiple imminent infringements, i.e. spacing is eroded with risk for temporary and limited under-separation (e.g. less than 0.5 NM) on the Final App	**Protective Mitigations** ATCO detects the missing indicators and reverts to Baseline DBS (a supporting DBS table is required, especially in TB PWS with multiple categories) Aircraft established on Final approach stabilized with 160kts IAS and behind ITD are allowed to	WK-FA-SC3b MAC-FA-SC3 *However, because multiple aircraft might be affected before failure is detected, a Safety Objective more demanding than the corresponding hazard severity will be allocated via an impact*

				continue the approach All other aircraft – either not established on Final or not at stabilized IAS 160kts or not behind ITD: - Initiate Go-around or break off - Establish ICAO DBS asap WAKE FAP B3 Management of Imminent Infringement MAC FAP B3 ATC Collision Avoidance	*modification factor IM=10*
	One or multiple separation minima infringements induced by ATC through inadequate selection & management of the separation mode		Large under-separation (of more than e.g. 0.5 NM) occurs for one or multiple aircraft pairs during separation establishment on Final App or later during the Final App	WAKE FAP F6 Wake Decay & Transport MAC FAP B2 ACAS Warning	WK-FA-SC3a MAC-FA-SC2b *However, because multiple aircraft might be affected before failure is detected, a Safety Objective more demanding than the corresponding hazard severity will be allocated via an impact modification factor*

					IM=20
	Runway conflict due to landing clearance in conflict with another landing (ROT not respected) or with cleared line-up/take-off (GAP not respected)	Inappropriate line-up instruction given by controller (not enough time for take-off without infringing separation with landing aircraft) Lack or wrong coordination with APP ATCO regarding the gap in front of the arrival Pilot slow in executing line-up/take-off results in consuming the arrival gap ATCO delayed instruction for take-off ATCO not compliant with correct ROT Wrong sequence	The situation when an arrival aircraft is landing on a runway which is being used by a departing aircraft, the two aircraft being thus in conflict, but where the situation is solved by the corrective action of the TWR ATCO (e.g. initiate go-around).	**Preventive Mitigations:** A wrong Sequence planning information is systematically detected by ATCO (via his situation awareness & own view of the correct sequence and possible use of a gap) A failure, loss or corruption of the sequence list tool will have an impact on the ATCO performance, but is safely mitigated by ATCO keeping full awareness of the sequence in the short term. ATCO will apply a more conservative strategy (e.g. instruct 2 departures in a gap instead of the 3 initially planned), will estimate the departures fitting in the arrival gaps by himself. **Protective Mitigations** Go around timely instructed & executed (RWY Col AIM Barrier B2)	RWY-C SC3

		planning information Loss or corruption of the sequence list tool			
	Runway Conflict not prevented by ATCO involving unauthorised AC/vehicle		The situation when an arrival aircraft is landing on a runway which is being used by a departing aircraft, the two aircraft being thus in conflict, but where the situation is solved by the corrective action of the TWR ATCO (e.g. initiate go-around).		

Table 6: System-Generated Hazards and Analysis for the PJ02-01 Arrivals Concepts Solutions

During the 06.08.01 TB-PWS HP/SAF workshop [9], the separation minima infringement (Wake turbulence separation or MRS) was discussed and the outcome of the discussion was the following:

- Approaching the separation indicator ("FTD") with potential for over-passing it, is seen as an imminent infringement (considered a hazard) that requires a separation recovery action (e.g. speed adjustment, Go around as appropriate). In case, whilst waiting for the separation recovery action to become effective, the aircraft temporarily over-passes the FTD with no more than 0.5 NM, that occurrence remains at the same severity level as an imminent infringement.
- If the separation recovery is not timely or not effective, that is an even higher severity hazard (corresponding to a Large under-separation in the Wake Turbulence Accident AIM).
    - Passing more than 0.5 NM in front of the separation indicator ("FTD") is a significant safety occurrence that is required to be recorded & analysed.

Based on this discussion:

- A spacing conflict induced by Crew/Aircraft (i.e. due to aircraft deviation from interception or Final Approach profile) and adequately managed by ATC (no imminent infringement) is classified with a severity SC3b (WAKE FAP) and SC3 (MAC FAP).
- An imminent infringement (encompassing situations where separation minima is temporarily infringed of no more than 0.5 NM, waiting for the separation recovery action to become effective) is classified with a severity SC3b (WAKE FAP) and SC3 (MAC FAP).
- A separation minima infringement of more than 0.5 NM (Large under-separation) is classified with a severity SC3a (WAKE FAP) and SC2b (MAC FAP).

It should be noted that, in the Wake Turbulence Accident AIM, an imminent infringement which is correctly recovered (which might involve a temporary separation infringement of no more than 0.5 NM) is considered to have the same potential for wake encounter as any traffic correctly separated according to the rule.

3.1.9.2 Derivation of Safety Objectives (integrity/reliability) for the Arrivals Concepts Solutions

Safety Objectives (addressing integrity/reliability) are formulated to limit the frequency at which the operational hazards identified in the previous section could be allowed to occur using the Risk Classification Scheme defined in Appendix H.

Table 7 lists the failure Safety Objectives (integrity/reliability) to be considered during the design phase for arrivals.

Even though all the hazards identified previously have been allocated two severities since they impact both WAKE FAP and MAC FAP, quantitative figures have been assigned only for the WAKE FAP severities. This is because there were no figures for the severity classification scheme of the MAC FAP model at the creation of this safety assessment report. When the figures for the MAC FAP model will be available, the two severities (MAC and WAKE) will have to be compared and the most stringent should be applied for the Safety Objectives in Table 7.

SO ref (hazard	Safety Objectives (integrity/reliability)

severity)	
Safety Objectives relative to the Final Approach interception phase	
SO 201 Hz#01a (WK-FA SC-3b MAC-FA-SC3)	The frequency of occurrence of the inadequate separation management of a pair of aircraft instructed by ATC to merge on the Final Approach interception (which is nevertheless recovered by ATC i.e. SMI[6]≤0.5NM), shall not be greater than 2x10-3 /approach *(2x10-3/approach means 2 occurrences every 3 days for an airport with 135,000 landings per year)* ***Explanation:*** *Computation of the Safety Objective:* $SO = \frac{MTFoO}{N*IM} = \frac{1E-02}{5*1}$ = *2E-03 occurrences per approach* *Computation of the no of occurrences per day: 2E-03*135000/365 = 0.74* *Which comes to 2 occurrences every 3 days*
SO 202 Hz#01b (WK-FA-SC3a MAC-FA-SC2b)	The frequency of occurrence of separation not being recovered following imminent infringement of A/C pair instructed by ATC to merge on the Final Approach interception (SMI>0.5NM) shall not be greater than 4x10-5/ approach *(4x10-5/approach means 6 occurrence per year for an airport with 135,000 landings per year)*
SO 203 Hz#02a (WK-FA SC-3b MAC-FA-SC3)	The frequency of occurrence of the inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach interception profile without ATC instruction given (which is nevertheless recovered by ATC i.e. SMI≤0.5NM), shall not be greater than 2x10-3 /approach *(2x10-3/approach means 2 occurrences every 3 days for an airport with 135,000 landings per year)*
SO 204 Hz#02b (WK-FA-SC3a MAC-FA-SC2b)	The frequency of occurrence of separation not being recovered following imminent infringement due to aircraft deviation from Final Approach interception profile without ATC instruction given (SMI>0.5NM) shall not be greater than 4x10-5/approach *(4x10-5/approach means 6 occurrence per year for an airport with 135,000 landings per year)*
Safety Objectives relative to the Final Approach phase	
SO 205 Hz#03a (WK-FA SC-3b	The frequency of occurrence of the inadequate separation management of an aircraft pair naturally catching-up as instructed by ATC on the Final Approach (which is nevertheless recovered by ATC i.e. SMI≤0.5NM) shall not be greater than 2x10-3 /approach *(2x10-3/approach means 2 occurrences every 3 days for an airport with 135,000*

[6] SMI stands for Separation Minima Infringement (WT or MRS)

MAC-FA-SC3)	*landings per year)*
SO 206 Hz#03b (WK-FA-SC3a MAC-FA-SC2b)	The frequency of occurrence of separation not being recovered following imminent infringement by an aircraft pair instructed by ATC on the Final Approach (SMI>0.5NM) shall not be greater than 4x10-5/approach *(4x10-5/approach means 6 occurrences per year for an airport with 135,000 landings per year)*
SO 207 Hz#04a (WK-FA SC-3b MAC-FA-SC3)	The frequency of occurrence of the inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach profile without ATC instruction given (which is nevertheless recovered by ATC i.e. SMI≤0.5NM) shall not be greater than 2x10-3 /approach *(2x10-3/approach means 2 occurrences every 3 days for an airport with 135,000 landings per year)*
SO 208 Hz#04b (WK-FA-SC3a MAC-FA-SC2b)	The frequency of occurrence of separation not being recovered following imminent infringement due to aircraft deviation from Final Approach profile without ATC instruction given (SMI>0.5NM) shall not be greater than 4x10-5/approach *(4x10-5/approach means 6 occurrences per year for an airport with 135,000 landings per year)*
Safety Objectives relative to Interception and Final Approach (common mode failures)	
SO 209 Hz#05 (WK-FA-SC3a MAC-FA-SC2b; IM=20)	The frequency of occurrence of one or multiple separation minima infringements due to undetected corruption of separation indicator (SMI>0.5NM) shall not be greater than 2x10-6/approach *(2x10-6/approach means 1 occurrences every 4 years for an airport with 135,000 landings per year)* *Explanation:* *Computation of the no of occurrences per year: 2E-6*135000/365 = 7.4E-04* *Which comes to 1 occurrence every 1350 days which represents 1 occurrence every 3.7 years (rounded to 1 occurrence every 4 years)*
SO 210 Hz#06 (WK-FA-SC3a MAC-FA-SC2b; IM=10)	The frequency of occurrence of one or multiple imminent infringements due to lack/loss of separation indicator for multiple or all aircraft (which are nevertheless recovered by ATC i.e. SMI≤0.5NM) shall not be greater than 2x10-4 /approach *(2x10-4/approach means 1 occurrence every 15 days for an airport with 135,000 landings per year)*
Safety Objectives relative to the management of the separation mode	
SO 211 Hz#07 (WK-FA-SC3a MAC-FA-SC2b; IM=20)	The frequency of occurrence of one or multiple separation minima infringements induced by ATC through inadequate selection or management of a separation mode shall not be greater than 2x10-6/approach *(2x10-6/approach means 1 occurrences every 4 years for an airport with 135,000 landings per year)*
Safety Objectives relative to mixed mode of operations	
SO 212	The frequency of occurrence of a runway conflict due to conflicting ATC clearances

Hz#08 (RWY-C SC3)	shall not be greater than 10-7/movement. (10-7/movement means 2,6x10-4/day) It should be noted that **2,6x10-4/day** is **too stringent** for this type of operational hazard. This value will be updated once the Severity Classification Scheme for the Runway Collision Model is updated.

Table 7: Safety Objectives (integrity/reliability) for the PJ02-01 Arrivals Concepts Solutions

Figure 4 depicts the structure relating the different Safety Objectives as determined by the causal links between the corresponding hazards, respectively for the interception phase (IA) and during the final approach (FA). The safety objectives corresponding to the hazards based on common modes failures (addressing both phases) are stand-alone (no link to other hazards). This structure will be further detailed in 4.1.5.1 within the causal analysis of each hazard, based on Fault Trees.

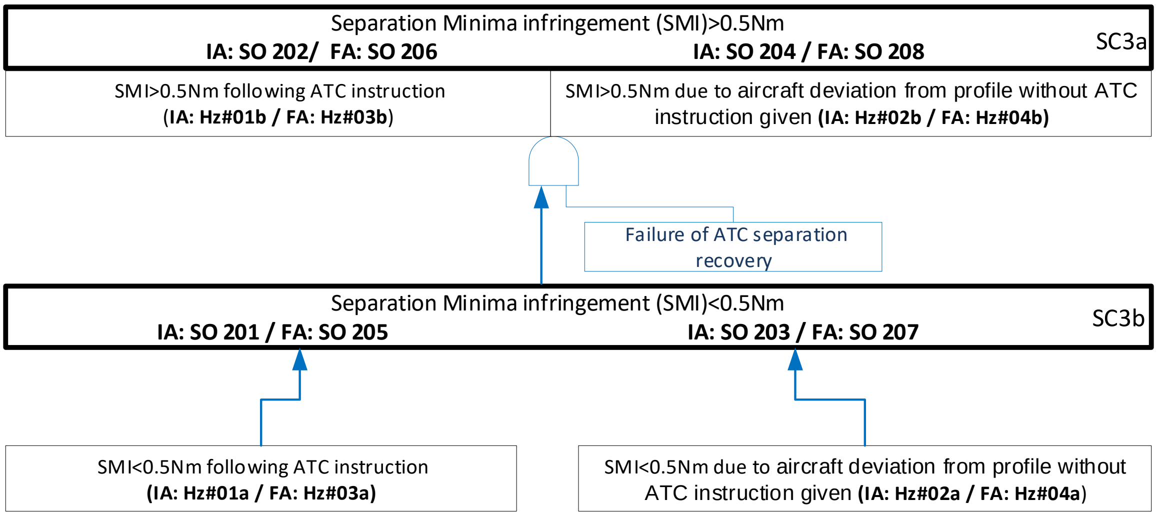

Figure 4: Safety Objectives with Hazards associated to: The Interception of the Final Approach (IA) respectively the Final Approach until delivery at the threshold (FA) for the Arrivals Concepts Solutions

3.1.10 Achievability of the Safety Criteria for the Arrivals Concepts Solutions

As specified in the Safety Plan[27], safety evidence will be collected from the planned validation. Safety Validation Objectives are defined for each exercise and the safety-related outcomes of the validation exercises will feed the Safety Criteria and will be traced back to the safety validation objectives. Decision for deriving (or not) new Safety Requirements or further refining existing ones will be taken from these results.

The exercise safety validation objectives and the related success criteria are summarized in

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
RTS01 - Conducted by EUROCONTROL to assess	**OBJ-PJ02.01-V3-VALP-SA1:** To assess the	**CRT-PJ02.01-V3-VALP-SA1-001:** There is	A-SAC#F2, A-SAC#F3,

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
the application of time based Weather Dependent Separations (WDS -AO-0310) with Optimised Runway Delivery (ORD - AO-0328) for arriving aircraft using the Paris CDG airport and approach environment	impact of weather dependent separations on the final approach on operational safety compared to current wake vortex separation scheme	evidence that the level of operational safety is maintained and not negatively impacted under weather dependent separations on the final approach compared to the current operations applying wake vortex separation scheme without ORD tool.	A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3
		CRT-PJ02.01-V3-VALP-SA1-002: There is evidence that WDS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#R1
		CRT-PJ02.01-V3-VALP-SA1-003: The probability of Go around due to inadequate consideration of ROT constraint is not increased	A-SAC#R1
RTS2 - Conducted by EUROCONTROL to assess the application of wake turbulence separations based on static aircraft characteristics for arriving aircraft (static PairWise Separations - PWS-A -AO-0310) with ORD (AO-0328)	**OBJ-PJ2.02-V3-VALP-SA2:** To assess the impact of static pairwise separations for arrivals with ORD on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of time based Static Pair Wise separations for arrivals PWS-A with ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
		operations under nominal conditions.	
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4
		CRT-PJ2.01-V3-VALP-SA2-003: that time based Static Pair Wise separations for arrivals PWS-A with ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1
RTS03a - Conducted by EUROCONTROL to assess the application of wake turbulence separations based on static aircraft characteristics for arriving aircraft (static PairWise Separations - PWS-A -AO-0310) and wake turbulence separations based on static aircraft characteristics for departures (static PairWise Separations -	**OBJ-PJ2.02-V3-VALP-SA3:** To assess the impact of the ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of time based Static Pair Wise separations for arrivals PWS-A with ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions. **CRT-PJ2.01-V3-VALP-SA3-**	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
PWS-D -AO-0323)		**001 :** To assess the impact of the ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool. **CRT-PJ2.01-V3-VALP-SA3-003 :** To collect partial supporting evidence that the ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4
		CRT-PJ2.01-V3-VALP-SA2-003: that time based Static Pair Wise separations for arrivals PWS-A with ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the	A-SAC#R1

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
		reference scenario	
RTS03b - Conducted by EUROCONTROL to assess the application the operational feasibility of time based separations with the Optimised Runway Delivery (ORD - AO-0328) tool in a Performance Based Navigation environment	**OBJ-PJ2.02-V3-VALP-SA3:** To assess the impact of the ORD tool with separation requirements based on the current wake vortex categories compared to no ORD on operational safety.	**CRT-PJ2.01-V3-VALP-SA3-001:** To assess the impact of TBS with the ORD tool on operational safety compared to distance based separation in segregated runways mode operations under nominal conditions.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3
		CRT-PJ2.01-V3-VALP-SA3-002: To collect partial supporting evidence that TBS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#R1
		CRT-PJ2.01-V3-VALP-SA3-003: To collect partial supporting evidence that TBS with ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1
RTS04a – Please see Departures section			
RTS04b - Conducted by EUROCONTROL The first aim is to assess the operational feasibility of time based static Pair-Wise	**OBJ-PJ2.02-V3-VALP-SA2:** To assess the impact of static pairwise separations for arrivals with ORD on operational safety compared to	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of arrivals PWS-A with the ORD in CSPR environment on operational safety compared to current	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2,

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
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 using g the Paris CDG airport and approach environment.	current wake vortex separation scheme	operations applying wake vortex separation scheme without ORD tool in a non CSPR environment under nominal conditions.	A-SAC#R3
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals in a CSPR environment does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4
		CRT-PJ2.01-V3-VALP-SA2-003: To collect partial supporting evidence that time based Static Pair Wise separations for arrivals PWS-A with ORD under CSPR maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario.	A-SAC#R1
RTS5 – Please see Departures section			
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	**OBJ-PJ2.02-V3-VALP-SA1:** To assess the impact of weather dependent separations on the final approach on operational safety compared to current wake vortex separation	**CRT-PJ2.01-V3-VALP-SA1-001:** There is evidence that the level of operational safety is maintained and not negatively impacted under weather dependent separations on the final	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
for arrivals (WDS-A) and Wake Turbulence Separations (for Departures) based on Static Aircraft Characteristics (S-PWS-D)	scheme	approach compared to the current operations applying wake vortex separation scheme without ORD tool.	
FTS09 – conducted by EUROCONTROL to support the CBA for the wake separation concepts. To assess the performance impact of the different wake separation solutions on arrivals of the different concepts both when solutions are deployed in combination (e.g. PWS-A with ORD tool) and/or when solutions are deployed individually. The FTS takes as input the expected traffic sequence at IAF and different parameters (WV separation, MRS, ROT, etc.) to provide an estimate of the expected throughput and spacing between landing aircraft.	No Safety Validation Objective needed to be set for this FTS		

Table 8 below, for all the safety relevant exercises performed in the frame of PJ02.01. The last column indicates the Safety Criteria that are covered by each validation exercise or other validation method (e.g. safety assessment through analysis and brainstorming with operational experts).

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
RTS01 - Conducted by EUROCONTROL to assess the application of time based Weather Dependent Separations (WDS -AO-0310) with Optimised Runway Delivery (ORD - AO-0328)	**OBJ-PJ02.01-V3-VALP-SA1:** To assess the impact of weather dependent separations on the final approach on operational safety compared to current wake vortex separation	**CRT-PJ02.01-V3-VALP-SA1-001:** There is evidence that the level of operational safety is maintained and not negatively impacted under weather dependent separations on the final	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
for arriving aircraft using the Paris CDG airport and approach environment	scheme	approach compared to the current operations applying wake vortex separation scheme without ORD tool.	
		CRT-PJ02.01-V3-VALP-SA1-002: There is evidence that WDS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#R1
		CRT-PJ02.01-V3-VALP-SA1-003: The probability of Go around due to inadequate consideration of ROT constraint is not increased	A-SAC#R1
RTS2 - Conducted by EUROCONTROL to assess the application of wake turbulence separations based on static aircraft characteristics for arriving aircraft (static PairWise Separations - PWS-A -AO-0310) with ORD (AO-0328)	**OBJ-PJ2.02-V3-VALP-SA2:** To assess the impact of static pairwise separations for arrivals with ORD on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of time based Static Pair Wise separations for arrivals PWS-A with ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4
		CRT-PJ2.01-V3-VALP-SA2-003: that time based Static Pair Wise separations for arrivals PWS-A with ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1
RTS03a - Conducted by EUROCONTROL to assess the application of wake turbulence separations based on static aircraft characteristics for arriving aircraft (static PairWise Separations - PWS-A -AO-0310) and wake turbulence separations based on static aircraft characteristics for departures (static PairWise Separations - PWS-D -AO-0323)	**OBJ-PJ2.02-V3-VALP-SA3:** To assess the impact of the ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of time based Static Pair Wise separations for arrivals PWS-A with ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions. **CRT-PJ2.01-V3-VALP-SA3-001 :** To assess the impact of the ORD on operational safety compared to current operations	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
		applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool. **CRT-PJ2.01-V3-VALP-SA3-003 :** To collect partial supporting evidence that the ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4
		CRT-PJ2.01-V3-VALP-SA2-003: that time based Static Pair Wise separations for arrivals PWS-A with ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1
RTS03b - Conducted by EUROCONTROL to assess the application the	**OBJ-PJ2.02-V3-VALP-SA3:** To assess the impact of the ORD tool	**CRT-PJ2.01-V3-VALP-SA3-001:** To assess the impact of TBS with the ORD tool	A-SAC#F2, A-SAC#F3,

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
operational feasibility of time based separations with the Optimised Runway Delivery (ORD - AO-0328) tool in a Performance Based Navigation environment	with separation requirements based on the current wake vortex categories compared to no ORD on operational safety.	on operational safety compared to distance based separation in segregated runways mode operations under nominal conditions.	A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3
		CRT-PJ2.01-V3-VALP-SA3-002: To collect partial supporting evidence that TBS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#R1
		CRT-PJ2.01-V3-VALP-SA3-003: To collect partial supporting evidence that TBS with ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1
RTS04a – Please see Departures section			
RTS04b - Conducted by EUROCONTROL The first aim is to assess the 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	**OBJ-PJ2.02-V3-VALP-SA2:** To assess the impact of static pairwise separations for arrivals with ORD on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of arrivals PWS-A with the ORD in CSPR environment on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in a non CSPR environment under nominal conditions.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
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 using g the Paris CDG airport and approach environment.		**CRT-PJ2.01-V3-VALP-SA2-002:** To collect partial supporting evidence that S-PWS with ORD tool for arrivals in a CSPR environment does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4
		CRT-PJ2.01-V3-VALP-SA2-003: To collect partial supporting evidence that time based Static Pair Wise separations for arrivals PWS-A with ORD under CSPR maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario.	A-SAC#R1
RTS5 – Please see Departures section			
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	**OBJ-PJ2.02-V3-VALP-SA1:** To assess the impact of weather dependent separations on the final approach on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA1-001:** There is evidence that the level of operational safety is maintained and not negatively impacted under weather dependent separations on the final approach compared to the current operations applying wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
Characteristics (S-PWS-D)			
FTS09 – conducted by EUROCONTROL to support the CBA for the wake separation concepts. To assess the performance impact of the different wake separation solutions on arrivals of the different concepts both when solutions are deployed in combination (e.g. PWS-A with ORD tool) and/or when solutions are deployed individually. The FTS takes as input the expected traffic sequence at IAF and different parameters (WV separation, MRS, ROT, etc.) to provide an estimate of the expected throughput and spacing between landing aircraft.	No Safety Validation Objective needed to be set for this FTS		

Table 8 PJ02.01 exercise safety validation objectives and the related success criteria

3.1.11 Validation & Verification of the Safety Specification for the Arrivals Concepts Solutions

This section describes the processes by which safety criteria and objectives were derived as well as details of the competencies of the personnel involved.

The Safety Criteria and the functionality and performance SOs (normal conditions) have been derived based on information collected during the P06.08.01 TB S-PWS Safety Assessment[6], and were subsequently updated with the developments in this iteration. More specifically, the functionality and performance SOs (normal conditions) have been mapped on the up to date EATMA Process Models (Appendix I) describing the OSED Use Cases.

The hazards were initially derived in the SAF/HP workshop organised in December 2014 with the support of operational people including controllers and pilots, which addressed TBS operations and DBS operations with indicators in normal, abnormal and failure conditions (see the TBS HAZID table in Appendix E). A further PJ02.01 SAF/HP HAZID session was organised at EUROCONTROL Bretigny on the 30th of October 2018, in order to address the concepts to date. The workshop was facilitated by SAF and HP experts from EUROCONTROL and it included APP, TWR ATCOs and Supervisors, together with safety, human performance and concept experts. For the full list of participants and more details about the workshop results please see Appendix F.

Additionally, 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 project PJ02.01. The full outcome of the workshop can be found in Appendix G.

3.2 Departures Concepts Solutions

3.2.1 Scope for the Departures Concepts Solutions[7]

This section addresses the following activities:

- Identification of the pre-existing hazards that affect traffic in the relevant operational environment (airspace, airport) and the risks which are reasonably expected to be mitigated to some degree and extent by the operational services provided by the Departures Concepts Solutions
- Setting of the SAfety Criteria (SAC) for the Departures Concepts Solutions (from the Safety Plan[27])[8]
- Determination of the operational services that are provided by the Departures Concepts Solutions to address the relevant pre-existing hazards and derivation of Safety Objectives (success approach) to mitigate the pre-existing risks under normal operational conditions
- Assessment of the adequacy of the operational services provided by the Departures Concepts Solutions under abnormal conditions of the Operational Environment
- Assessment of the adequacy of the operational services provided by the Departures Concepts Solutions in the case of internal failures and mitigation of the System-generated hazards (derivation of Safety Objectives (failure approach))
- Achievability of the SAC for the Departures Concepts Solutions
- Validation & verification of the safety specification for the Departures Concepts Solutions

3.2.2 Departures Concepts Solution Operational Environment and Key Properties

This section describes the key properties of the Operational Environment that are relevant to the SESAR Solution PJ02-01 safety assessment (information summarized from SPR-INTEROP/OSED Part I Section 3.2[22]) relevant for the Departures Concepts Solutions.

3.2.2.1 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[9]. 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.

[7] The key properties of the Operational Environment which are relevant to the safety assessment are covered in the SPR-INTEROP/OSED Part 1 Section 3.2

[8] Amended in line with the revised Wake AIM (Departures)

[9] London Heathrow Airport

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

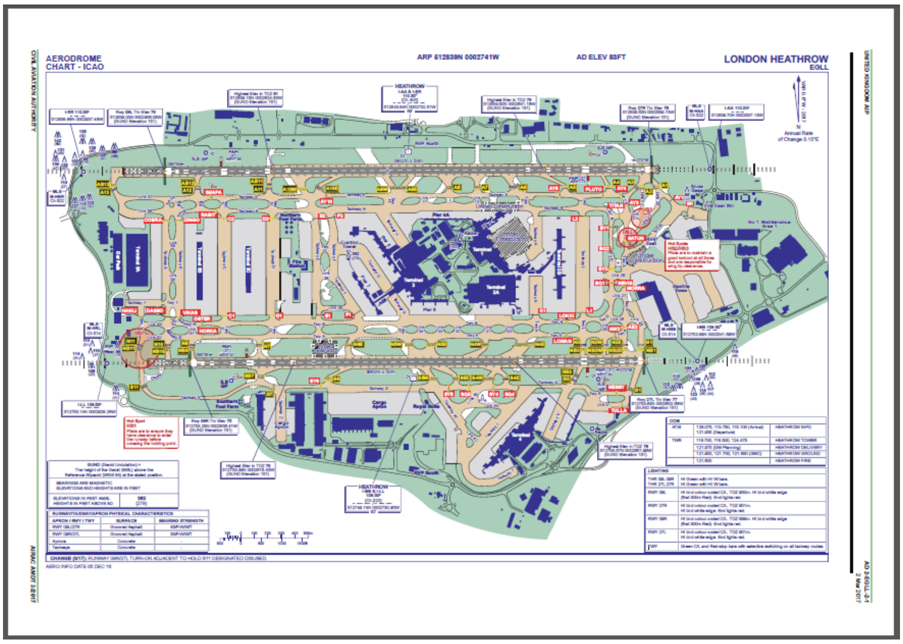

Figure 5: London Heathrow Airport

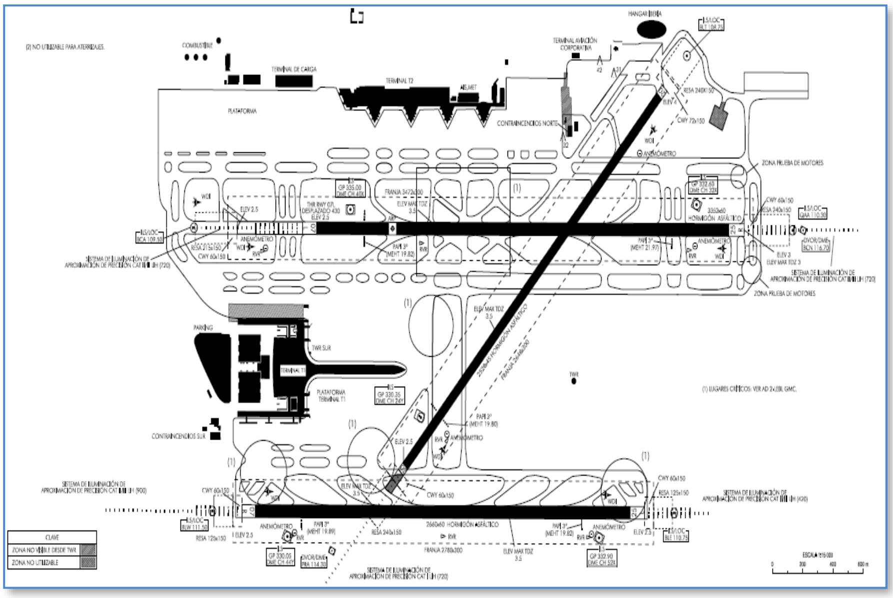

Figure 6: Barcelona Airport

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

Controlled airspace associated with the reference airports.

3.2.2.3 Airspace Users – Flight Rules for the Departures Concepts Solutions

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

3.2.2.4 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, Large and Medium airports.
- With Solution Scenarios: level of traffic in peak hours as per the increased RWY throughput enabled by the Solutions.

3.2.2.5 Aircraft ATM capabilities for the Departures Concepts Solutions

The Aircraft ATM capabilities are as per the Reference Scenario IFR/VFR/SVFR[10] operations at the respectively Very Large, Large and Medium airports. No additional aircraft capabilities (other than those already needed to enable IFR departures from the reference airports) were identified during V3.

3.2.2.6 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 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.

3.2.2.7 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)

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

- 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

3.2.2.8 Separation Minima for the Departures Concepts Solutions

3.2.2.8.1 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[11] (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.

3.2.2.8.2 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

3.2.2.8.3 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 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.

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[11] The Total Wind (Tw) concept has not been developed or validated as part of PJ02.01

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.**

3.2.2.8.4 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[12]:

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 9 Summary of WT Separation Modes

3.2.2.9 Operational Services for the Departures Concepts Solutions

3.2.2.9.1 Ground ATM capabilities

All capabilities for the Departures thread can be found in the SPR/INTEROP OSED Part 1 Section 3.2.3.2 with regards to technical characteristics and constraints.

3.2.3 Airspace Users Requirements for the Departures Concepts Solutions

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[13]

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

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

[13] 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

3.2.4 Relevant Pre-existing Hazards for the Departures Concepts Solutions[14]

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 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)[15] [16]
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 10: Pre-existing hazards relevant for PJ02.01 Departures Concepts Solutions

3.2.5 SAfety Criteria for the Departures Concepts Solutions

This section defines the SAC applicable to the operational scenarios for the Departures Concepts Solutions. These are defined and formulated in the same way as described in Section 3.1.5 of this document[17].

The following (amended) SAC[18] apply to all departure concepts[19]:

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

[15] 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.

[16] See footnote 12

[17] Safety Criteria for the Arrivals Concepts Solutions

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

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

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)
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 11: Safety Criteria for the Departures Concepts

3.2.6 Mitigation of the Pre-existing Risks – Normal Operations for the Departures Concepts Solutions

3.2.6.1 Operational Services to Address the Pre-existing Hazards for the Departures Concepts Solutions[20]

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) [21]	**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"
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 12: Relevant ATM/ANS services and Pre-existing Hazards for the PJ02-01 Departures Concepts Solutions

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

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

3.2.6.2 Derivation of Safety Objectives (Functionality & Performance – success approach) for Normal Operations for the Departures Concepts Solutions

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). [22]

[22] 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,

			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 13: Objectives under Normal Conditions

3.2.7 Safety Objectives for Departures Concepts Solutions under Abnormal Conditions

3.2.7.1 Identification of Abnormal Conditions for the Departures Concepts Solutions

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[23] 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.

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

[23] 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.

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 14: 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 15: Other Abnormal/Non-nominal events

3.2.7.2 Safety Objectives for Abnormal Conditions for the Departures Concepts Solutions

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[24]	In the event of an aborted take-off, ensure the runway is unobstructed before any subsequent departures are permitted	2	SAC#D5
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 16 Safety Objectives for Abnormal Conditions (Departures)

[24] See Table 17

3.2.8 Mitigation of System-generated Risks (failure approach) for the Departures Concepts Solutions

This section provides the list of operational hazards, effects and where possible, any associated severity. [25]

3.2.8.1 Identification and Analysis of System-generated Hazards for the Departures Concepts Solutions

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 4.2.5 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 4.2.4.1.3 for detailed Bow-tie analysis

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

ID	Hazard Description	High Level Cause(s)	Operational Effects	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
	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[26]	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[27]	Well defined airborne procedures, HMI design and training to prevent, and/or recover from, any aircraft deviation from expected departure track	SC3B

Table 17: High level description of Departure Concept Operational Hazards

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

[27] Applicable to WDS-D-Xw

Requirements (as a result of the hazard analysis)

Requirement	Details
SR#D01[28] 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.[29]
SR#D04 DEP0.0023	ATCOs shall, when possible, instruct aircraft to stop a premature take-off roll.[30] (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 18: Safety Requirements (as a result of Dep HazId) Failure Case

[28] See recommended Objectives in 3.2.8.2

[29] 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

[30] 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

3.2.8.2 Derivation of Safety Objectives (integrity/reliability) for the Departures Concepts Solutions[31]

It is recommended:[32] 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
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 19: 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 24. This will include the following for each departure runway:

The following system requirements are derived in order to support the objectives in Table 24.

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	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.

[31] The Severity Classification Scheme for the Wake ID AIM Model was not available when this SAR was completed and that the figures of these integrity SOs shall be updated when the Severity Classification Scheme is made available.

[32] These objectives must be reviewed at local level

	and Provision of reliable tool-based information regarding departure intervals	SR#D09 DEP3.0003	The tool shall be provided with the Aircraft Type and RECAT-EU Wake Turbulence Category of each departure aircraft.[33]
		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 DEP3.0005	The Tower ATCOs shall be trained to ensure the integrity of the aircraft SID information.
		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.

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

		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	The tool shall take into account staleness criteria with respect to determining the DDI-D position for distance-

		DEP3.0029	based separation procedures

Table 20: System Integrity Requirements – Departures

Safety Requirements (integrity/reliability) for the Departures Concepts Solutions[34]

It is recommended that the following requirements realised as a result of the work carried out in CREDOS are further investigated.[35] They are not to be used specifically for PJ02.01 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.
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	For the WDS-D Xw concept the probability that the SID used

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

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

SID to WDS-D planning DEP2.0046	by an aircraft is not the SID used in WDS-D planning shall be no greater than 4×10-6 per take-off.

Table 21: Integrity (CREDOS) Requirements

3.2.9 Achievability of the Safety Criteria for the Departures Concepts Solutions

3.2.9.1 Safety Assurance Strategy for the Departures Concepts Solutions

Table 26 below presents, for each SAC, the safety assurance strategy for the departures concepts solutions that will be adopted along the Project lifecycle, with reference to the appropriate pieces of safety evidence that are already available or that need to be further produced.

Safety Criteria ID	Safety assurance strategy	Available safety evidence	New evidence to be documented
SAC#D01	Analysis during RTS	None.	RTS conducted by NATS suggest that the probability of under separation (wake), as a result of the concept, is not increased. Further (local) detailed analysis of MORs to determine the number of under-separations as a result of premature take off clearance, or pilots initiating take-off without a clearance.
SAC#D02	The RECAT-EU-PWS (distance-based static pair-wise and time-based static pair-wise separation minima applicable for Departures result work performed by EUROCONTROL and submitted to EASA for validation.	Wake Turbulence Re-Categorisation and Pair-Wise Separation Minima on Approach and Departure (RECAT-PWS-EU) Safety Case Ed.1.2[36].	Safety Case for TB-PWS-D consisting of the time separation variant of the 96x96 aircraft type pairwise matrix for departures and the time separation variant of the 20x20 wake category matrix for departures. Additional (local) analysis of possible catch-up scenarios and/or deviations on departure by 1st or 2nd aircraft

[36] Note that this safety case did not address PWS-D time separations for departures (96x96 or 20x20 matrices)

Safety Criteria ID	Safety assurance strategy	Available safety evidence	New evidence to be documented
SAC#D03	Qualitative demonstration that the use of the tool will involve a significant reduction of the frequency of unmanaged under-separations, which will compensate for the possibility of encountering a stronger wake vortex due to the more optimised wake turbulence separation	None	RTS Validation Report
SAC#D04	Analysis during RTS	Where practicable, make use of outcomes from CREDOS SAR Make extensive use of outcomes from ongoing NATS PWS-D, WDS-D & OSD safety assessment	The RTS conducted did not identify any increase in the number of ATC tactical conflicts
SAC#D05	As above	As above	As above

Table 22: Safety Assurance Strategy for the Departures Concepts Solutions driven by the Safety Criteria

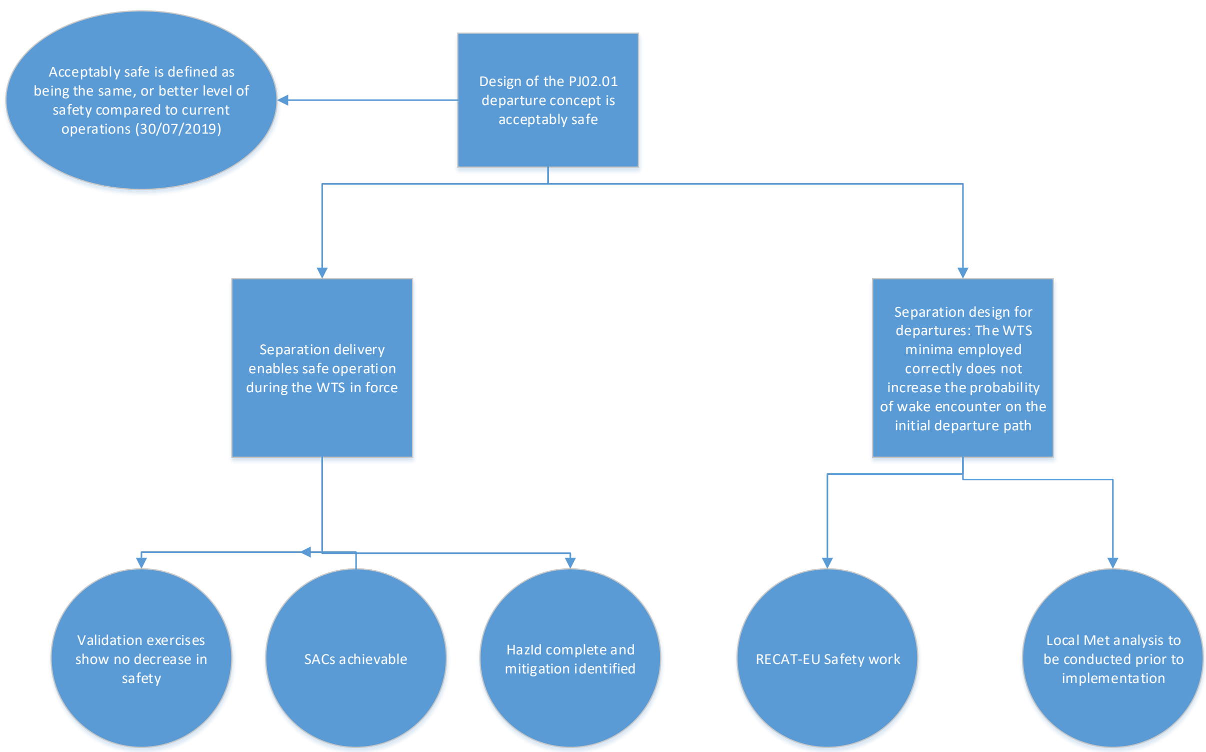


Figure 7: Safety Strategy to support the argument that the Departures Concept shall be acceptably safe

3.2.9.2 Real Time Simulations Safety Validation Objectives for the Departures Concepts Solutions[37]

Safety validation objectives, which consider the Safety Criteria and Safety Objectives presented in this report, were developed to be tested in Real Time Simulation (RTS) validation exercises. The objectives, from a safety perspective, are reproduced below with further details in section 4.2.5:

OBJ-PJ2.02-V3-VALP-SA4 - To confirm the impact of WDS-D Crosswind concept on operational safety compared to current wake vortex separation scheme.
OBJ-PJ2.02-V3-VALP-SA5 - To confirm the impact of PWS-D concept on operational safety compared to reference scenario.
OBJ-PJ2.02-V3-VALP-SA6 - To assess the impact of the use of OSD tool with RECAT-EU 6-CAT wake time separations on operational safety compared to current operations with no OSD tool.

Table 23: Validation Objectives (Safety)

This section concerns operations in the case of internal failures. Before any conclusion can be reached concerning the adequacy of the safety specification at the OSED level, it is necessary to assess the possible adverse effects that failures internal to the end-to-end Functional System supporting the new WT separation modes and ATC tools might have upon the provision of the relevant operations and to derive safety objectives (failure approach) to mitigate against these effects.

[37] The results from the RTS can be found in Section 4.2.6

3.3 Wake Decay Enhancing Concept Solution

3.3.1 Wake Decay Enhancing Concept - Operations Environment and Key Properties

3.3.1.1 Airspace and Airport characteristics for the Wake Decay Enhancing Concept

Decay enhancing devices can be installed at the ends of runways used for arrivals at any busy large and medium airports employing runway configurations and modes of operations listed in EUROCONTROL thread above.

3.3.1.2 Airspace Users – Flight Rules for the Wake Decay Enhancing Concept

Instrument Flight Rules and Visual Flight Rules associated with arrivals.

3.3.1.3 Traffic Levels and complexity for the Wake Decay Enhancing Concept

Level of traffic in peak hours as per the increased RWY throughput enabled by the Solutions.

3.3.1.4 Separation Minima for the Wake Decay Enhancing Concept

As per section 3.1.3.5 in the arrivals section.

3.3.1.5 Aircraft ATM capabilities for the Wake Decay Enhancing Concept

N/A

3.3.1.6 Ground ATM capabilities for the Wake Decay Enhancing Concept

N/A

3.3.1.7 Terrain Features – Obstacles for the Wake Decay Enhancing Concept

The decay enhancing devices are obstacles that will be installed at the runway ends. They consist of plates with a height of 4.5 m that must be compatible with airport requirements concerning criteria like obstacle clearance, stability, and frangibility.

3.3.1.8 CNS Aids for the Wake Decay Enhancing Concept

N/A

3.3.2 Relevant Pre-existing Hazards for the Wake Decay Enhancing Concept

N/A

3.3.3 SAfety Criteria for the Wake Decay Enhancing Concept

This section defines the set of SAfety Criteria applicable to the operational scenarios related to Wake Decay Enhancing Concept.

- With regards to the potential positive contribution for reducing the risk of wake encounter at low altitude:

Wake-Decay-Enhancement-SAC#1: The lifetime of the longest-lived wake vortices for a given aircraft type and similar environmental conditions within a safety corridor at the runway ends shall **decrease or at least not increase** by the introduction of decay enhancing devices.

- With regards to the risk of aircraft colliding with the wake decay plate lines, this SAC was not defined at the level of the CFIT AIM model, it is rather connected to a regulatory requirement (regarding obstacle clearance) placed on the decay enhancing devices:

Wake-Decay-Enhancement-SAC#2: The decay enhancing devices shall comply with the requirements set forth by ICAO regarding obstacle clearance and frangibility.

4 Safe Design at SPR Level

This Section covers the following Concepts Solutions:

- Arrivals Concepts Solution in Section 4.1
- Departures Concepts Solutions in Section 4.2
- Wake Decay Enhancing in Section 4.3

Each group of Concepts Solutions have independent Operational Improvements that should be selectable with respect to deployment at capacity constrained Very Large, Large and Medium sized airports.

4.1 Arrivals Concepts Solutions

4.1.1 Scope for the Arrivals Concepts Solutions

This section addresses the following activities:

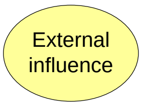
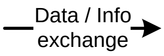
- Description of the SPR-level model of the end-to-end Solution ATM System for the Arrivals Concepts Solutions- Section 4.1.2
- Derivation, from the Safety Objectives (Functionality and Performance) in Section 3, of Safety Requirements for the SPR-level design for the Arrivals Concepts Solutions – Section 4.1.2.3
- Analysis of the operation of the SPR-level design under normal operational conditions for the Arrivals Concepts Solutions – Section 4.1.3
- Analysis of the operation of the SPR-level design under abnormal conditions of the Operational Environment for the Arrivals Concepts Solutions – Section 4.1.4
- Assessment of the adequacy of the SPR-level design in the case of internal failures and mitigation of the System-generated hazards for the Arrivals Concepts Solutions – Section 4.1.5
- Justification that the SAfety Criteria are capable of being satisfied in a typical implementation for the Arrivals Concepts Solutions – Section 4.1.6
- Realism of the SPR-level design for the Arrivals Concepts Solutions– Section 4.1.7
- Validation & Verification of the Specification for the Arrivals Concepts Solutions – Section 4.1.8

4.1.2 The Arrivals Concepts Solutions SPR-level Model

The Arrivals Concepts Solutions SPR-level Model in this context is a high-level architectural representation of the Solution System design. This model is the equivalent of the SESAR 2020 NSV-4 EATMA diagram (shown in section 4.1.2.2 and in Appendix I) and it is entirely independent of the eventual physical implementation of the design. The SPR-level Model describes the main human tasks, machine functions and airspace design. In order to avoid unnecessary complexity, human-machine interfaces are not shown explicitly on the model – rather they are implicit between human actors and machine-based functions.

4.1.2.1 Description of SPR-level Model for the Arrivals Concepts Solutions

The symbols used in the model are as follows:

	Human actor – ground-based
	Equipment function – ground-based
	Human actor – airborne
	Equipment function – airborne
	External influence (outside ATM control domain)
	Main data / information flow

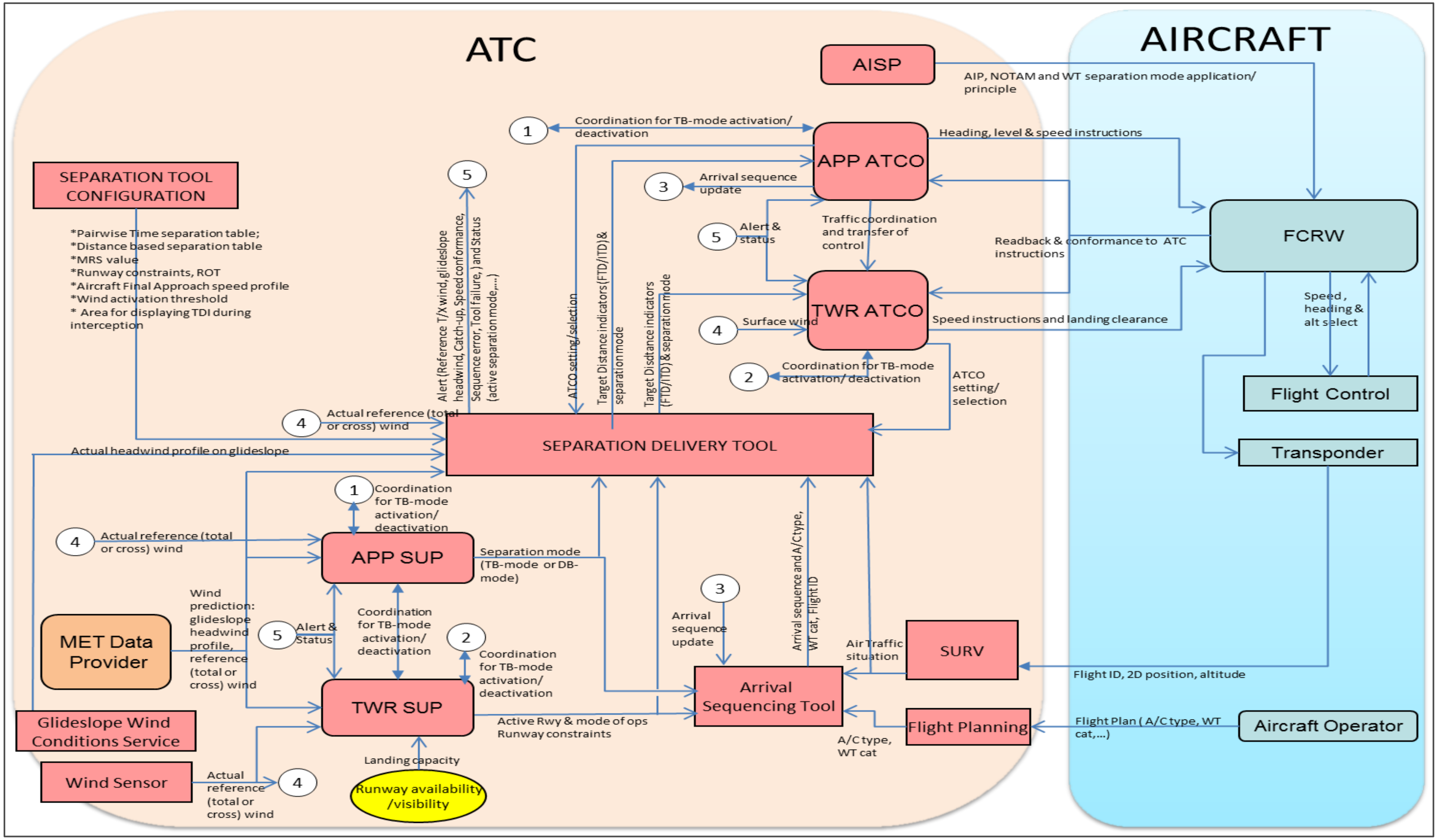


Figure 8: The SPR-level Model for the PJ02.01 Arrivals Concepts Solutions

4.1.2.1.1 Human Actors in the Model

Actor	Current Responsibility	Specific/additional role
Approach ATC supervisor (APP SUP)	Plans, monitors and supervises tactical traffic management in the TMA	Is aware of the wind conditions for deciding and agreeing to the application of TB-modes or DB-modes, in consultation with the Tower ATC supervisor. Responsible to activate and de-activate TB-mode in collaboration with the Tower supervisor and informing controllers of change in mode of operations (e.g. via HMI or verbally). Responsible for ensuring the duty runways-in-use information, and the separation policy information, and planned changes to these, are available, set up, and maintained consistently in the Separation Delivery and Arrival Sequencing tools supporting Approach ATC. Responsible for ensuring that flight crew are informed of the application of the WT separation mode, for example, through ATIS.
Intermediate and Final approach controllers (APP ATCO)	Are in charge of safe and efficient processing of arrivals to the runway	Responsible for ensuring that a correct arrival sequence order is provided to the separation tool. This requires maintaining an up to date sequence order in the Arrival Sequencing tool in line with the actual sequence changes. Responsible to instruct the aircraft in order to intercept properly the final approach and to monitor the trajectory following these instructions. Uses the Separation Delivery tool to ensure final approach separations are set up consistently and efficiently. Uses the Separation Delivery tool to monitor that separations remain consistent as aircraft descend on final approach, so as to enable timely intervention action to be taken when there is imminent separation infringement. Interacts manually with the Separation Delivery tool to e.g. select parameters or display mode (ATCO setting and selection).
Flight Crew (FCRW)	Conduct the approach safely	The Flight Crew remains ultimately responsible for the safe and orderly operation of the flight in compliance with the ICAO Rules of the Air, other relevant ICAO and EASA provisions, and within airline standard operating procedures. The Flight Crew ensures that the aircraft operates in accordance with ATC clearances and instructions. The Flight Crew is aware of WT separation mode and the impact on the distance separation set up on final approach. Is informed of what WT separation mode is being employed on final approach, for example, through ATIS. Reports critical weather and wake information to ATC.

Actor	Current Responsibility	Specific/additional role
Tower ATC supervisor (TWR SUP)	Has overall responsibility for the planning of the tower operation. Monitors operations. Decides on arrival and departure rates. Proposes runway configuration. Gives permission for runway maintenance, etc.	Is aware of the wind conditions for determining and deciding on the application of TB-modes or DB-modes in consultation with the Approach ATC supervisor. Responsible to activate and de-activate TB-mode in collaboration with the Approach supervisor and informing controllers of change in mode of operations (e.g. via HMI or verbally). Responsible for ensuring the duty runways-in-use information, runway constraints and the separation policy information, and planned changes to these are available, set up and maintained consistently in the Separation Delivery and Arrival Sequencing tools. Responsible for ensuring that the runway conditions, and planned and forecast changes to the runway conditions, are reflected in the separation policy information.
Tower controller (TWR ATCO)	In charge of landings.	Uses the Separation Delivery tool to monitor that separations remain consistent as aircraft descend on final approach, so as to enable timely intervention action to be taken when there is imminent separation infringement. Monitors runway occupancy, and runway conditions, and ensures separation policy is consistently maintained to support the runway conditions, and changes to the runway conditions. Receives, from different sources, and disseminates to the flight deck, critical wake vortex and weather information, when needed. Responsible to provide the landing clearance. Interacts manually with the Separation Delivery tool to e.g. select parameters or display mode (ATCO setting and selection).
Aircraft Operator	Responsible for the aircraft operation. Responsible to file flight plan.	Flight plan includes the A/C type which is essential for any WT separation mode.
MET Data Provider	Measure, predict and provides the relevant weather information for the TB-modes.	Provides wind prediction (glideslope headwind profile, reference -total or cross- wind) to APP and TWR supervisor to plan operation in TB-modes or DB-modes. Provides short term wind prediction (glideslope headwind profile, reference -total or cross- wind) to the Separation Delivery tool for computing the FTD in TBS and TB-PWS-A modes and the ITD in any mode.
AISP	Provides Aeronautical Information (AIP, approach charts NOTAMs, etc.).	Aeronautical information includes information regarding operations in WT separation modes.

Table 24: Human Actors for the new WT Separation Modes of the PJ02.01 Arrivals Concepts Solutions

4.1.2.1.2 Machine-based elements in the Model

Equipment / Tool	Current relevant function	Specific/additional function
Flight Planning	Provides the information for arrival traffic identification, A/C type and its WT category	A/C type and WT category are essential for the TB-PWS-A concept.
Transponder	MANDATORY: ELS (Elementary Surveillance) Provides the aircraft identification and position.	
	OPTIONAL: EHS (Enhanced Surveillance) Airborne parameters from the aircraft (Magnetic Heading, Indicated Airspeed, Roll Angle, Rate of Turn, Vertical rate, True Track angle, Ground Speed, Selected Altitude, True Airspeed, True Track Angle, Roll Angle/Rate of Turn) can be downlinked	The downlinked EHS airborne parameters (IAS, GS) could be used for enhancing the approach speed profile monitoring. The downlinked actual wind direction & speed extracted by the surveillance system might be used to validate MET data and for deriving the glideslope headwind profile on final approach (vector difference between the air vector - airspeed and heading- and the ground vector -ground speed and track angle) if that information is shown to be sufficiently accurate at low altitude.
Flight Control	Control the flight to support planned and tactical navigation to destination.	
Ground surveillance (SURV)	MANDATORY: ELS (Elementary Surveillance) SURV provides the aircraft Identification, Position and Altitude information to the Controller Working Positions.	Provides the aircraft Identification, Position and Altitude information to the Separation Delivery and Arrival Sequencing tools.
	OPTIONAL: EHS (Enhanced Surveillance) SURV could provide actual Wind direction & speed and GS/IAS for a given aircraft.	See “Transponder” above.
Wind sensors	Measure the prevailing wind speed and direction at the runway surface level.	Measure the actual reference (total or cross) wind and provide it to the Separation Delivery tool in order to trigger alert for TB-mode deactivation (in case of conditional application of TB-mode).
Glideslope Wind Conditions Service (GWCS)		Determine the actual headwind on the glideslope from the ground until the localizer altitude interception and provides it to the Separation Delivery tool in view of the glideslope headwind monitoring function and alert for TBS or TB-PWS-A mode deactivation (case of conditional application of TB-mode) and for managing compression

Equipment / Tool	Current relevant function	Specific/additional function
		without ITD. Note: Might be used in complement or replacement of glideslope headwind profile prediction from MET Data.
Arrival Sequencing Tool		Provide an optimized arrival sequence for the Separation Delivery tool considering: • runways-in-use • final approach separation and runway spacing constraints that are required to be applied on each runway-in-use • scenario for specific spacing (e.g. runway inspection spacing) • departure gap spacing requirements for a runway supporting interlaced/mixed mode operations
Separation Delivery tool		Computes and displays the separation indicators (FTD and ITD) to ATCO for separation provision: • Final Target Distance (FTD) which is the minimum distance in trail separation to be maintained down to the point of separation delivery. • Initial Target Distance (ITD) which is the distance to be applied at x NM from the threshold to ensure the follower meets the FTD when the leader reaches the point of separation delivery. The ITD considers the compression effect that will take place in the last x NM of the approach. The Separation Delivery tool operates in TB-modes or DB-modes, with possibility of transition between these modes in case of conditional application of TB-modes. The initial and final target distance "indicators" are proposed to be displayed on the extended runway centre-line as soon as the lead aircraft enters a locally defined zone. The Separation Tool warns ATCOs and Supervisors in case of failure or abnormal situations (alerts for Reference total or cross wind, glideslope headwind, Catch-up, Speed conformance, Sequence error, Tool failure) and provides them Status information (active WT separation mode).
Separation Delivery tool Configuration		Configuration module for the Separation Delivery tool with parameters fine-tuned for the local environment. This configuration is essential for the Separation Delivery tool computation by providing the following: the Pairwise time separation table; the distance-based pairwise separation table, the MRS value applicable for the final approach; the Runway constraints per runway end,

Equipment / Tool	Current relevant function	Specific/additional function
		optionally the ROT per A/C category; the aircraft type approach speed profile; the wind activation threshold; the defined volume in the interception area where a leader inside this zone will have Target Distance Indicators displayed on the extended runway centreline.

Table 25: Machine-based elements for the new WT Separation Modes of the PJ02.01 Arrivals Concepts Solutions

4.1.2.2 SESAR 2020 SPR level Model (EATMA NSV-4 Diagram)

Figure 9 shows the EATMA NSV4 diagram, which is the equivalent of the SPR-level Model in PJ02.01. This diagram was used to check the completeness of the high level and the refined safety requirements against the latest developments of PJ02.01:

Note that, at the time when this report was written, the EATMA NSV-4 Diagrams for Arrivals were still being updated. Therefore, please refer to the NSV-4 stored in EATMA in the PJ02.01 Folder for the latest version of the EATMA NSV-4 Use Cases for arrivals.

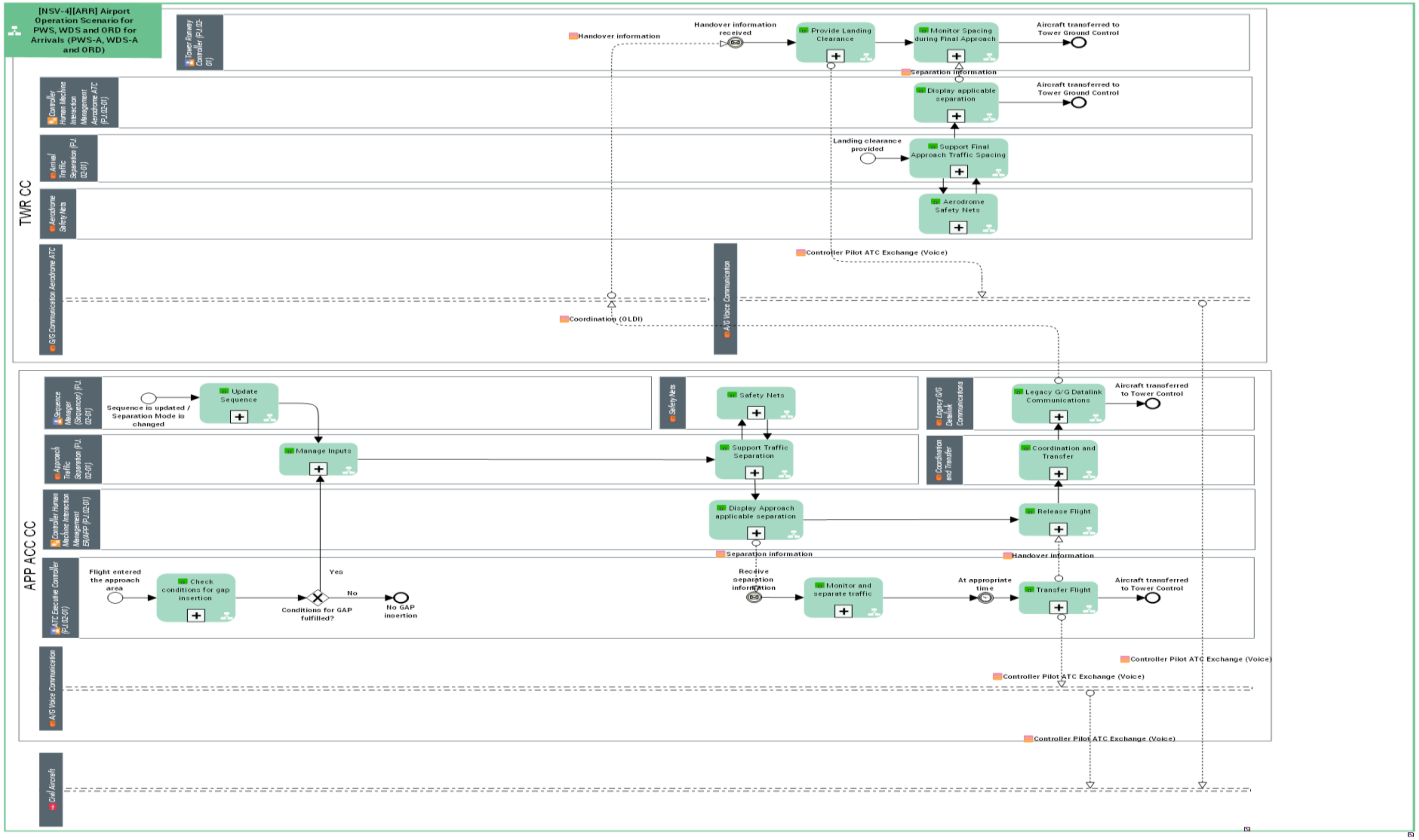


Figure 9: NSV-4 Diagram for PWS-A, WDS-A and ORD for Arrivals

4.1.2.3 Derivation of Safety Requirements (Functionality and Performance – success approach) for the Arrivals Concepts Solutions

Table 26 below shows how the Safety Objectives (Functionality and Performance) derived in Section 3 map on to the Safety Requirements. All provisions from ICAO Annexes and procedures in Doc 4444 PANS-ATM still apply as operational baseline.

The safety requirements address the ATM changes related to the new WT separation modes and ATC tools (with indicators) made possible by the TBS, ORD, PWS-A and WDS for Arrivals and Departures concepts. The fact that a Safety Requirement addresses only one or a sub-set of WT separation modes is indicated in the requirement text, otherwise the requirement is considered as relevant for all the WT separation modes.

SO Description	SRs	SR Description
SO 001 ATC shall be able to apply consistent and accurate DBS, TBS, PWS-A or WDS-A wake turbulence separation rules on final approach (encompassing interception) and landing, through operating under Distance Based modes (DBS, DB-PWS-A) and Time Based modes (TBS, T-PWS-A, A-WDS-Tw and A-WDS-Xw), with the possibility to safely switch between a TB-mode and the corresponding DB-mode.	SR1.002 REQ-02.01-SPRINTEROP-ARR0.0100	The tool shall operate under Distance Based modes (DB- modes: DBS, S-PWS) and Time Based modes (TB- modes: TB S-PWS, TB-WDS-Tw, TB-WDS-Xw, TB-WD-PWS-TW, TB-WD-PWS-XW), with the possibility to switch between DB- modes and corresponding TB- modes.
	SR1.007 REQ-02.01-SPRINTEROP-ARR0.1030	The Approach or Tower Controller shall be able to safely perform their separation duties during transition between separation modes.

	SR1.008 REQ-02.01-SPRINTEROP-ARR0.1080	The frequency of separation mode switches shall be done in a way that would avoid controller confusion and unnecessary workload.
	SR1.009 REQ-02.01-SPRINTEROP-ARR0.1120	The mode of operation shall be clearly displayed to the controllers (Tower and Approach) and Supervisors (Tower and Approach) at all times.
	SR1.010 REQ-02.01-SPRINTEROP-ARR0.1390	Consideration shall be given to the impact of mode changes on external systems and processes such as AMAN and flow management.
	SR1.011 REQ-02.01-SPRINTEROP-ARR0.0530	The system architecture shall ensure all applicable Controller Working Positions (e.g. per runway) operate in the same mode(s).
	SR1.120 REQ-02.01-SPRINTEROP-ARR0.1040	All licenced Approach and Tower controllers (and Supervisors) shall be fully trained to switch between the time based and distance based modes of operation.
	SR1.123 REQ-02.01-SPRINTEROP-ARR0.1290	Regular trainings shall ensure ATCOs maintain sufficient competency to safely revert to and manage air traffic in DBS operations without Target Distance Indicators (i.e. implementation of the separation tool shall not adversely affect the controller's air traffic- vectoring skills- using DBS WT Category without Target Distance Indicators).

	SR1.126 REQ-02.01-SPRINTEROP-ARR0.1021	The transition tasks (activation and deactivation of TB modes) shall be defined for all actors involved, for both a spontaneous transition (e.g. sudden change of wind conditions, etc.) as well as for a planned transition, where a collaborative approach for the ATCO and SUPs in APP and TWR shall apply.
	SR1.127 REQ-02.01-SPRINTEROP-ARR0.1031	Mode transitions (planned) should take place outside peak hours.
	SR1.128 REQ-02.01-SPRINTEROP-ARR2.1222	Timely reversion from conditional mode to standard mode of operations shall be triggered by the Supervisor or automatically by the system depending on the local implementation. The possibility for the ATCOs spontaneous reversal (e.g. in case of sudden loss of indicators) shall be locally defined.
SO 002 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).	SR1.012 REQ-02.01-SPRINTEROP-ARR2.1060	For TB- modes the Approach and Tower Supervisors shall collaboratively decide when the conditional (TB) mode should be activated or de activated based on meteorological data information and predefined activation criteria and on prior coordination with Controllers. Note: Activation of a WT separation mode encompasses both starting operations at the beginning of the day and transition to a different WT separation mode during the day.
	SR1.013 REQ-02.01-SPRINTEROP-ARR0.0980	The Tower Supervisor in coordination with the Approach Supervisor (and occasionally the Tower and Approach Controllers - in line with defined local procedures) shall determine the final approach separation mode and runway spacing constraints that

		are to be applied at any time by the separation delivery tool.
	SR1.015 REQ-02.01-SPRINTEROP-ARR0.1222	The Approach and Tower Supervisors shall inform the respective Controller when the conditional (TB) mode will be activated or de activated by indicating the first aircraft in the arrival sequence to be separated according to the new mode. (e.g. at least 2 min before interception- to be locally defined)
	SR1.017 REQ-02.01-SPRINTEROP-ARR0.1223	The ATCOs and the Supervisors shall always have a clear indication in the CWP from which aircraft in the sequence the new mode of operations or the reversion to standard mode are applied.
	SR1.020 REQ-02.01-SPRINTEROP-ARR2.1170	The Wind Forecast Service shall be provided to the users to plan or execute WDS-A (Xw or Tw) concept operations. The service shall include standard meteorological information and WDS-A (Xw or respectively Tw) concept specific information with respect to wind nowcast and forecast, wind speed, direction and trends, in particular the crosswind component (glide-slope and surface cross winds) or respectively the total wind (glide-slope and surface total winds) with respect to each runway direction.
	SR1.023 REQ-02.01-SPRINTEROP-ARR2.1160	In order to enable the modes activation/deactivation, the Tower Supervisor and the Approach supervisor shall be provided with a meteorological situation picture that includes the nowcast and forecast data regarding the wind speed and direction at different locations and altitudes covering the area encompassing the final approach phase of arrival flights. Such information shall in particular display the relevant wind component for the application of WDS-A concept reduced wake separations.

	SR1.027 REQ-02.01-SPRINTEROP-ARR0.1110	The Approach and Tower Runway ATCO shall continue to use the TDIs that are already displayed (as per the previous separation mode) for the aircraft in the arrival sequence preceding the first one to be separated according to the new mode.
SO 003 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	SR1.003 REQ-02.01-SPRINTEROP-ARR0.0131	For the time based separation modes (TB-modes i.e. TBS, TB-PWS-A, TB-WDS-A or A-TB-WD-PWS), for which FTD (Final Target Distance standing for the separation indication) is computed based on a time separation, the risk of under-separation induced by the uncertainty in glideslope headwind prediction and in the actual final approach speed profile shall be mitigated.
	SR1.004 REQ-02.01-SPRINTEROP-ARR0.0132	For the Time based separation modes the risk of under-separation induced by the uncertainty in glideslope headwind prediction and in the actual final approach speed profile shall be mitigated by one or a combination of the following means: • Adding a time separation buffer in the design of the FTD indicators displayed to Controllers. These buffers may vary depending on the considered applicable separation minima and wind conditions • The conditional application of any TB-mode (e.g. WDS shall be locally pre-determined and used as a wind-based criterion for the activation of that mode • For the TB- mode, taking a buffer in the design of TBS minima (e.g. higher headwind conditions when selecting reference baseline minima) • The selection of most appropriate mean(s) shall be based on the local

		operational conditions, local wind behaviour, wind profile and aircraft speed profile prediction system accuracy
	SR1.005 REQ-02.01-SPRINTEROP-ARR3.0151	For all separation modes, for which an ITD (Initial Target Distance standing for the compression indication) is used, the risk of under-separation after Deceleration Fix induced by the uncertainty in glideslope headwind prediction and in the actual final approach speed profile shall be mitigated.
	SR1.006 REQ-02.01-SPRINTEROP-ARR3.0152	For all separation modes, for which an ITD is used, the risk of under-separation after Deceleration Fix induced by the uncertainty in glideslope headwind prediction and in the actual final approach speed profile shall be mitigated by adding a time separation buffer in the design of the ITD indicators displayed to Controllers. These buffers may vary depending on the considered applicable separation minima and wind conditions.
	SR1.018 REQ-02.01-SPRINTEROP-ARR2.1130	The WDS-TW mode shall be activated only when the runway surface and glide-slope reference total wind (as used in the separation minima design) is equal or greater than the WDS-Tw threshold
	SR1.019 REQ-02.01-SPRINTEROP-ARR2.1140	The WDS-Xw mode shall be activated only when the runway surface and glide-slope reference cross wind (as used in the separation minima design) is equal or greater than the WDS-Xw threshold

	SR1.021 REQ-02.01-SPRINTEROP-ARR2.1150	The WDS-Tw and WDS-Xw activation thresholds shall be determined to mitigate the risk of wake vortex encounter due to the uncertainties on the wind prediction data and on the lateral aircraft deviation from RWY extended centreline.
SO 004 In case of conditional application of 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-A modes or respectively TB-PWS-A and A-TB-WD-PWS modes are not met anymore	SR1.007 REQ-02.01-SPRINTEROP-ARR0.1030	The Approach or Tower Controller shall be able to safely perform their separation duties during transition between separation modes.
	SR1.008 REQ-02.01-SPRINTEROP-ARR0.1080	The frequency of separation mode switches shall be done in a way that would avoid controller confusion and unnecessary workload.
	SR1.009 REQ-02.01-SPRINTEROP-ARR0.1120	The mode of operation shall be clearly displayed to the controllers (Tower and Approach) and Supervisors (Tower and Approach) at all times.
	SR1.014 REQ-02.01-SPRINTEROP-ARR0.1070	Supervisor must reconsider the mode of operation if they receive WTE reports from Pilots over a short period of time via Controllers. Rationale: Several WTE reports in a short space of time may mean the incorrect mode of operation is activated hence Supervisors should reassess the decision.

	SR1.016 REQ-02.01-SPRINTEROP-ARR0.1090	In case the reversion from a TB mode is triggered automatically by the Separation Delivery Tool (e.g. due to the wind falling below the applicable minima), the Separation Delivery Tool shall indicate to the ATCO the aircraft to be separated according to the new separation mode. A notification shall indicate to the Controller and the Supervisor the change and preferably the reason behind it.
	SR1.017 REQ-02.01-SPRINTEROP-ARR0.1223	The ATCOs and the Supervisors shall always have a clear indication in the CWP from which aircraft in the sequence the new mode of operations or the reversion to standard mode are applied.
	SR1.020 REQ-02.01-SPRINTEROP-ARR2.1170	The Wind Forecast Service shall be provided to the users to plan or execute WDS-A (Xw or Tw) concept operations. The service shall include standard meteorological information and WDS-A (Xw or respectively Tw) concept specific information with respect to wind nowcast and forecast, wind speed, direction and trends, in particular the crosswind component (glide-slope and surface cross winds) or respectively the total wind (glide-slope and surface total winds) with respect to each runway direction.
	SR1.023 REQ-02.01-SPRINTEROP-ARR2.1160	In order to enable the modes activation/deactivation, the Tower Supervisor and the Approach supervisor shall be provided with a meteorological situation picture that includes the nowcast and forecast data regarding the wind speed and direction at different locations and altitudes covering the area encompassing the final approach phase of arrival flights. Such information shall in particular display the relevant wind component for the application of WDS-A concept reduced wake separations.

	SR1.024 REQ-02.01-SPRINTEROP-ARR0.1760	In case of conditional application in TB-modes, the Supervisors (Tower and Approach) and Controllers (Tower and Approach) shall be alerted automatically in advance when the predefined activation criteria will not be met anymore hence the imminent need to transition from one separation mode to another, in order to temporarily limit or regulate the flow of inbound traffic (e.g. through metering) prior to the switch of separation mode in order to manage the change and controllers workload
	SR1.025 REQ-02.01-SPRINTEROP-ARR2.1190	If the Wind Forecast service detects WDS-A concept suspension, the information shall be transmitted to the Separation Delivery tool and a corresponding alert shall be displayed to the CWPs of the Controllers and Supervisors.
	SR1.026 REQ-02.01-SPRINTEROP-ARR0.1100	Upon reversion to (activation of) a new separation mode, the separation delivery tool shall display the adequate FTD (separation indication) and ITD (compression indications) to the Approach ATCO for all aircraft starting with the first aircraft in the arrival sequence to be separated according to the new mode.
	SR1.027 REQ-02.01-SPRINTEROP-ARR0.1110	The Approach and Tower Runway ATCO shall continue to use the TDIs that are already displayed (as per the previous separation mode) for the aircraft in the arrival sequence preceding the first one to be separated according to the new mode.
SO 005 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	SR1.001 REQ-02.01-SPRINTEROP-ARR0.0050	The Intermediate Approach, Final Approach and Tower Controllers shall be provided with a Separation Delivery Tool displaying Target Distance Indicators (TDI) to enable consistent and accurate application of TBS, PWS-A, DBS and/or WDS-A wake turbulence separation rules on final approach and landing.

Distance Indicators corresponding to that separation mode		
	SR1.022 REQ-02.01-SPRINTEROP-ARR0.0670	Local implementation shall define the latest time that a stable TDI is required by the Controller for spacing, so that the FTD and ITD indicators may be re-calculated due to changing glideslope wind conditions
	SR1.028 REQ-02.01-SPRINTEROP-ARR0.0300	The approach arrival sequence information shall be provided to the Separation Delivery tool.
	SR1.029 REQ-02.01-SPRINTEROP-ARR0.0910	The separation delivery tool shall be given the arrival runway intent including eventual updates for each aircraft such that it is considered for the computation of the Target Distance Indicators
	SR1.030 REQ-02.01-SPRINTEROP-ARR0.0920	The runway final approach sequence order shall be displayed on the HMI so that it is visible to the Approach, Tower and Supervisor positions.
	SR1.032 REQ-02.01-SPRINTEROP-ARR0.0550	If there is a change to the sequence order or runway intent, the Approach Controller should check that each indicator for each affected aircraft pair has been updated.
	SR1.033 REQ-02.01-SPRINTEROP-ARR0.0940	In case of a change of the arrival sequence order position of an aircraft, the Approach controller shall check that the arrival sequence order has been updated to reflect the change
	SR1.034 REQ-02.01-SPRINTEROP-ARR0.0941	The sequence manager shall ensure that for the change of the sequence order there is no overlap (or lack of awareness) between the actions taken by the Intermediate Approach Controller and the Final Approach Controller, by allowing

		only one change at a time.
	SR1.037 REQ-02.01-SPRINTEROP-ARR0.0110	The Separation Delivery tool shall provide to ATCOs a visualisation (FTD indicator) of the required minimum separation or spacing on final approach that needs to be delivered after considering all in-trail and if applicable not-in-trail constraints.
	SR1.038 REQ-02.01-SPRINTEROP-ARR3.0120	If the ORD concept is considered, the Separation Delivery tool shall provide to ATCOs a visualisation (ITD indicator) of the required spacing on final approach to be delivered at the deceleration fix in order to deliver the required minimum separation / spacing at the delivery point.
	SR1.039 REQ-02.01-SPRINTEROP-ARR0.0890	The separation delivery tool shall support ATCOs in the delivery of wake separations that are allowed only when leader and follower aircraft are aligned on the centreline.
	SR1.040 REQ-02.01-SPRINTEROP-ARR0.0190	There shall be surveillance coverage down to the separation delivery point to allow the separation tool to display Target Distance Indicators on the runway extended centreline including the last part of the final approach.
	SR1.045 REQ-02.01-SPRINTEROP-ARR0.0690	TDI display shall be robust to ensure they do not keep switching on and off as aircraft perform normal manoeuvres

	SR1.046 REQ-02.01-SPRINTEROP-ARR0.0490	The follower TDI shall be linked to the actual aircraft position of the leader: - If the leader is aligned with the runway axis, then the follower TDIs are to be displayed behind the actual leader position; - If the leader is not yet aligned with the runway axis and the perpendicular projected position on the runway extended centreline is behind its own ITD then the follower TDIs are to be displayed behind the perpendicular projected position on the runway extended centreline; - If the leader is not yet aligned with the runway axis and the perpendicular projected position on the runway extended centreline is ahead its own ITD, then the follower TDIs are to be displayed behind the position of ITD ahead. In case several aircraft have not yet intercepted the glide, this leads to a train of ITDs, each one being attached to the previous one and all moving at the speed of the last aircraft on the extended runway centreline.
	SR1.047 REQ-02.01-SPRINTEROP-ARR0.0480	The TDIs shall be displayed to the Intermediate and Final Approach Controllers sufficiently early in order to allow correct interception
	SR1.048 REQ-02.01-SPRINTEROP-ARR0.0630	Criteria to determine the time for displaying indicators for each CWP shall be specified depending upon the local operation's needs.
	SR1.049 REQ-02.01-SPRINTEROP-ARR0.0470	The Separation Delivery tool and associated procedures shall support the Controller decision to turn onto final approach.

	SR1.050 REQ-02.01-SPRINTEROP-ARR3.1000	If the ORD concept is implemented, the Final Approach Controller shall maintain the aircraft on or behind the ITD on the final approach and reduce to the final approach procedural airspeed until the transfer to the Tower controller.
	SR1.051 REQ-02.01-SPRINTEROP-ARR3.0170	If the ORD concept is implemented, the Approach controller shall vector the follower aircraft so that it stays on or behind the corresponding ITD.
	SR1.052 REQ-02.01-SPRINTEROP-ARR0.0710	The tool shall automatically display the FTD (if not already displayed) if the aircraft comes within a defined distance of the computed FTD. This distance shall be configurable within the tool.
	SR1.056 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a high priority separation (WAKE, MRS) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner adequate to an alert (e.g. red colour)
	SR1.058 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the second and/or third most constraining ITD corresponding to a low/high priority spacing/separation is infringed the system shall display the corresponding FTDs in addition to the already displayed first most constraining FTD (FTD displayed according to the rules defined for the high priority separation and low priority spacing indicators)
	SR1.059 Example of REQ-02.01-SPRINTEROP-ARR0.0796	For the APP HMI, if the second and/or third most constraining ITD is no longer infringed, the corresponding FTDs shall be hidden by the system

	SR1.060 REQ-02.01-SPRINTEROP-ARR0.0850	The HMI design shall allow ATCO to hide/unhide indicators for a specific aircraft pair, and current and forthcoming alerts/warnings for that aircraft as a follower (e.g. infringement, catch-up, speed,..)
	SR1.061 REQ-02.01-SPRINTEROP-ARR0.0900	Following the ATCO action to suppress the TDIs for specific aircraft the tool shall • remove any information on the spacing/separation (ITD and FTD) • remove its ongoing or not display the forthcoming Separation Delivery Tool alerts (e.g. Catchup/Speed/SeqNumber/Infringement)
	SR1.062 REQ-02.01-SPRINTEROP-ARR0.0720	The Approach controller shall be able to remove the FTD from the radar display, but not when the FTD has been automatically displayed by the System.
	SR1.063 REQ-02.01-SPRINTEROP-ARR0.1350	Procedures shall be defined regarding required actions if catching up or infringing the ITD or FTD.
	SR1.064 REQ-02.01-SPRINTEROP-ARR0.0870	The Approach controller shall maintain applicable surveillance separation minima at any point during approach. This includes the case of a leader aircraft established on the final approach axis and a follower not yet established
	SR1.065 REQ-02.01-SPRINTEROP-ARR0.1340	The current operational procedures for transitioning from intermediate separations (3NM) to final approach separations (e.g. 2.5NM MRS) shall continue to apply.
	SR1.066 REQ-02.01-SPRINTEROP-ARR3.0500	Once the follower aircraft has been positioned w.r.t ITD and before the leader reaches its deceleration point, the Controller shall apply speed instructions in accordance to the reference glide slope air speed used for ITD calculation.

	SR1.097 REQ-02.01-SPRINTEROP-ARR0.0970	If ORD is not implemented, the Final Approach Controller shall maintain the aircraft behind the FTD with sufficient buffer due to the effect of compression caused by different leader and follower groundspeed profiles, and shall reduce aircraft's speed to the final approach procedural airspeed.
	SR1.098 REQ-02.01-SPRINTEROP-ARR0.0167	If both the FTD and ITD are available, the ITD indication ("compressions indicator") shall be the main indicator to be used by the final approach controller.
	SR1.099 REQ-02.01-SPRINTEROP-ARR0.0651	In case the ITD is the main display on the final approach, the ATCOs shall be able to display the FTD , depending upon the local operation's needs.
	SR1.114 REQ-02.01-SPRINTEROP-ARR0.0166	Clear guidelines with regard to the list of possible actions to be made in the case of an FTD infringement (in the APP and in the TWR) shall be described per position for the local implementation.
	SR1.117 REQ-02.01-SPRINTEROP-ARR0.1250	Approach and Tower Controllers shall be fully trained to apply the procedures for the new separation modes and to use of the Separation Delivery Tool and supporting systems (e.g. alerts) with indicators prior to deployment.
	SR1.118 REQ-02.01-SPRINTEROP-ARR0.1260	All Approach and Tower controllers and Supervisors shall be fully trained in the operating procedures for the new WT separation modes prior to deployment.
	SR1.129 REQ-02.01-SPRINTEROP-ARR0.1351	In a dual approach arrival environment, ATCOs shall have supporting alert, for identifying vertical and horizontal infringements for the crossing aircraft (e.g. North runways to South runways)

SO 006 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 (e.g. departure gaps)	SR1.031 REQ-02.01-SPRINTEROP-ARR0.0570	If there is a change to the separation / spacing constraint (e.g. Gap) the TDI for the affected aircraft pair shall be re-computed.
	SR1.035 REQ-02.01-SPRINTEROP-ARR0.0139	TDIs shall be displayed on the extended runway centreline behind each lead aircraft established on final approach and shall be linked to the actual lead aircraft position along the runway axis.
	SR1.036 REQ-02.01-SPRINTEROP-ARR0.0133	TDI position shall provide the accurate information about the required separation/spacing for each aircraft pair
	SR1.067 REQ-02.01-SPRINTEROP-ARR0.0080	In DB- modes the separation delivery tool shall be provided with a range of wake turbulence distance-based separation rules based on ICAO Aircraft Type (e.g. ICAO, RECAT-EU, RECAT-EU-PWS) depending upon the airport needs.
	SR1.068 REQ-02.01-SPRINTEROP-ARR0.0230	All applicable Minimum Radar Separation (MRS) rules shall be provided to the Separation Delivery tool.

	SR1.069 REQ-02.01-SPRINTEROP-ARR0.0251	The separation delivery tool shall provide ATCOs the possibility to manage gap spacing between consecutive arrival flights.
	SR1.070 REQ-02.01-SPRINTEROP-ARR0.0240	All applicable runway-related spacing rules other than those related to runway configuration shall be provided to the Separation Delivery tool.
	SR1.072 REQ-02.01-SPRINTEROP-ARR0.0253	The separation delivery tool shall provide confirmation to ATCO that the gap spacing insertion is successful or not.
	SR1.073 REQ-02.01-SPRINTEROP-ARR0.0254	The ATCOs shall be able to insert automatic gap spacing based on pre-defined scenarios in the sequence manager
	SR1.074 REQ-02.01-SPRINTEROP-ARR0.0255	The tool shall provide ATCOs the ability to update and cancel any gap spacing previously inserted.
	SR1.075 REQ-02.01-SPRINTEROP-ARR0.0310	An expected aircraft speed or time-to-fly profile model on the final approach glide-slope shall be provided to the Separation Delivery tool for the FTD calculation.
	SR1.076 REQ-02.01-SPRINTEROP-ARR1.0320	An expected aircraft speed or time-to-fly profile model on the final approach glide-slope shall be provided to the Separation Delivery tool for the ITD calculation.

	SR1.077 REQ-02.01-SPRINTEROP-ARR0.0060	In TBS mode, the separation delivery tool shall be provided with time separation rules.
	SR1.078 REQ-02.01-SPRINTEROP-ARR1.0070	S-PWS wake separation rules shall be provided to the Separation Delivery tool.
	SR1.079 Example of REQ-02.01-SPRINTEROP-ARR2.0030	In TB-modes where WDS is applied (WDS-Xw and WDS-Tw) the separation delivery tool shall be provided with time separation tables (for each cross-wind and respectively total wind value and each aircraft pair category) derived from: - the time required for a sufficient vortex decay - the time required for the vortex to be transported away from the path of the follower aircraft - the reference speed profile for the leader and follower aircraft
	SR1.080 REQ-02.01-SPRINTEROP-ARR0.0130	In TB mode, the FTD computed by the tool to indicate the wake separation applicable at the delivery point shall take into consideration: • The time separation from the wake turbulence separation table (for WDS the separation tables might be more than one depending on the total/cross wind values); • The aircraft pair (from the arrival sequence list); • The glideslope headwind profile; • The follower time-to-fly profile obtained either from modelled time-to-fly profile in the considered headwind conditions • The time separation buffer considering uncertainties of final approach speed profiles of the a/c pair and of the glide slope wind prediction

	SR1.081 REQ-02.01-SPRINTEROP-ARR0.0161	The spacing constraint computation shall take into consideration the same inputs as for the ITD and FTD plus: • The time separation value representing the spacing constraint (ROT, GAP, scenario specific spacing, etc.)
	SR1.082 REQ-02.01-SPRINTEROP-ARR0.0321	Aircraft time-to-fly profiles used in the FTD and ITD calculations shall be based on a time-to-fly model representative of nominal aircraft speed behaviour on final approach, in the local environment.
	SR1.083 REQ-02.01-SPRINTEROP-ARR3.0150	The ITD computed by the tool for all separation and spacing constraints (wake separation in DB and TB modes, MRS, ROT and other spacing constraints) shall take in consideration: • The FTD for the considered aircraft pair • The glideslope headwind profile • The leader and follower time-to-fly profiles obtained either from modelled time-to-fly profile in the considered headwind conditions • The time separation buffer considering uncertainties of final approach speed profiles of the a/c pair and of the glide slope wind prediction
	SR1.084 REQ-02.01-SPRINTEROP-ARR3.0163	If the ITD calculation is smaller than the FTD (e.g. pull away scenario) then it shall be changed to the same value as the FTD.
	SR1.085 REQ-02.01-SPRINTEROP-ARR0.0220	Aircraft identifier, ICAO aircraft type and wake category for all arrival aircraft, including subsequent updates to this information, shall be provided to the Separation Delivery tool.

	SR1.086 REQ-02.01-SPRINTEROP-ARR0.0280	The Separation Delivery tool shall be provided with the predicted headwind profile on the glideslope (ideally from ground to the published localiser interception altitude) to compute the ITD in all modes and the FTD in TB-modes. The used profiles shall ensure smooth temporal evolution of the ITD on the final approach.
	SR1.087 REQ-02.01-SPRINTEROP-ARR0.0290	If in a local implementation the tool is required to consider the actual runway surface wind conditions, then the runway surface wind conditions shall be provided to the Separation Delivery tool.
	SR1.088 REQ-02.01-SPRINTEROP-ARR2.0141	In WDS modes (total wind/cross wind) the Separation Delivery tool shall use the relevant separation table for the FTD computation based on the measured total/cross wind
	SR1.089 REQ-02.01-SPRINTEROP-ARR0.0162	The tool in any mode shall display TDIs representing the greatest constraint out of all applicable in-trail or not in-trail separation constraints. The constraints can be the high priority separation (e.g. Wake and MRS) and the low priority runway spacing (ROT) and other spacing constraints (e.g. departure GAP, runway inspections, etc.).
	SR1.090 REQ-02.01-SPRINTEROP-ARR0.0691	The Controllers shall be able to visually distinguish (via colour or symbol) if Target Distance Indicators are relative to WT, MRS or ROT (or other spacing constraint).
	SR1.091 REQ-02.01-SPRINTEROP-ARR0.0580	The display option for the indicator shall be configurable depending on the type of separation / spacing.

	SR1.092 REQ-02.01-SPRINTEROP-ARR0.0681	The design of the TDIs shall be made in order to ensure they are easy to read and interpret, being in line with the design philosophy (shape, colour etc.) of the other ATC tools used in the local environment.
	SR1.093 REQ-02.01-SPRINTEROP-ARR0.0800	The HMI design shall allow Controllers to identify the aircraft associated with each displayed indicator.
	SR1.098 REQ-02.01-SPRINTEROP-ARR0.0167	If both the FTD and ITD are available, the ITD indication (“compressions indicator”) shall be the main indicator to be used by the final approach controller.
	SR1.099 REQ-02.01-SPRINTEROP-ARR0.0651	In case the ITD is the main display on the final approach, the ATCOs shall be able to display the FTD , depending upon the local operation's needs.
	SR1.100 REQ-02.01-SPRINTEROP-ARR0.0590	TDIs shall be displayed on all applicable ATCO and SUP CWPs (Tower Runway, Final Approach and Intermediate Approach), according to the local implementation rules.
	SR1.101 REQ-02.01-SPRINTEROP-ARR0.0700	Approach and Tower shall have access to consistent information (on their CWP HMI) relating to separation delivery to be able to communicate effectively with each other.
	SR1.102 REQ-02.01-SPRINTEROP-ARR0.0770	The displayed indicator distance and shape shall be consistent between all applicable CWPs.

	SR1.104 REQ-02.01-SPRINTEROP-ARR0.0650	The Approach controller shall have the possibility to globally select the display of the FTD, however the FTD shall automatically be displayed when some alerts are active (e.g. risk of imminent FTD infringement).
	SR1.105 REQ-02.01-SPRINTEROP-ARR0.0164	The FTD indicator shall be the main TDI to be used by the Tower Controller.
	SR1.106 REQ-02.01-SPRINTEROP-ARR3.0660	The Tower controller shall have the possibility to globally select the display of the ITD (in addition to FTD which shall always be displayed).
	SR1.107 REQ-02.01-SPRINTEROP-ARR3.0160	Before the Leader reaches its Deceleration Fix (DF), the ITD shall be “static” (i.e. the separation distance between the Leader position and the displayed ITD shall be static, the ITD shall hence move at the leader speed). It shall be computed accounting for the compression/ pull-away effect for the aircraft pair expected from the leader DF until the separation delivery point. After the Leader passes the DF, the ITD shall move towards the FTD, accurately account for compression/pull-away effect for the aircraft pair expected from the actual leader position until the separation delivery point.
	SR1.108 REQ-02.01-SPRINTEROP-ARR0.0140	Before the Leader reaches the separation delivery point, the FTD shall be “static” (i.e. the separation distance between the Leader position and the displayed FTD shall be static, the FTD shall hence move at the Leader speed). It shall be computed accounting for the expected time-to-fly of the Follower aircraft until the separation delivery point. After the Leader passes the separation delivery point and until the Follower reaches the separation delivery point, the FTD shall be disconnected from

		the Leader (e.g. move at the expected Follower speed to reach zero when the Follower is expected to reach the delivery point).
	SR1.111 REQ-02.01-SPRINTEROP-ARR0.0200	All applicable runway configuration spacing rules shall be provided to the Separation Delivery tool.
	SR1.112 REQ-02.01-SPRINTEROP-ARR0.0270	The tool shall allow the runway occupancy time (ROT) constraints to be configurable for each aircraft based on multiple parameters.
	SR1.115 REQ-02.01-SPRINTEROP-ARR0.0441	In case of a change of runway configuration, the Approach and/or Tower supervisors shall coordinate prior to inserting the new arrival runway into the tool.
	SR1.116 REQ-02.01-SPRINTEROP-ARR0.0440	In case of a change of runway configuration, the Approach and/or Tower supervisors shall be able to input to the separation tool the new arrival runway to be considered for Target Distance Indicators computation. ISSUE 2: In case of a late landing runway change, it should be verified if the arrival sequencing tool can be timely reconfigured in order to display the Approach Arrival Sequence for the switched runway and update the TDIs accordingly.

	SR1.121 REQ-02.01-SPRINTEROP-ARR0.0370	Local implementation shall ensure that roles and responsibilities are clearly defined regarding the management of data inputs into the Separation Delivery tool including runway policy, runway spacing constraints, visibility conditions and runway conditions.
	SR1.122 REQ-02.01-SPRINTEROP-ARR0.0180	The Surveillance system shall provide the Separation Delivery Tool with aircraft position and altitude for all arrival aircraft.
SO 007 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	SR1.094 REQ-02.01-SPRINTEROP-ARR0.1410	The Flight Crew shall be made aware of the locally applied separation mode and minima via appropriate means (e.g. from ATIS, AIP, NOTAM, information campaigns).
	SR1.095 REQ-02.01-SPRINTEROP-ARR0.1421	Information campaigns shall familiarise the flight crew/ airspace users with all novel concepts associated to the implementation of reduced separations.
	SR1.096 REQ-02.01-SPRINTEROP-ARR0.1400	An overview of the key principles of the TBS, S-PWS, WDS and / or ORD concept of operations (ConOps) shall be published in AIP.
SO 008 In a given WT separation mode, ATC shall provide correct spacing minima delivery from final approach path acquisition until landing based on	SR1.001 REQ-02.01-SPRINTEROP-ARR0.0050	The Intermediate Approach, Final Approach and Tower Controllers shall be provided with a Separation Delivery Tool displaying Target Distance Indicators (TDI) to enable consistent and accurate application of TBS, PWS-A, DBS and/or WDS-A wake turbulence separation rules

separation indicators correctly computed for that separation mode.		on final approach and landing.
	SR1.037 REQ-02.01-SPRINTEROP-ARR0.0110	The Separation Delivery tool shall provide to ATCOs a visualisation (FTD indicator) of the required minimum separation or spacing on final approach that needs to be delivered after considering all in-trail and if applicable not-in-trail constraints.
	SR1.038 REQ-02.01-SPRINTEROP-ARR3.0120	If the ORD concept is considered, the Separation Delivery tool shall provide to ATCOs a visualisation (ITD indicator) of the required spacing on final approach to be delivered at the deceleration fix in order to deliver the required minimum separation / spacing at the delivery point.
	SR1.039 REQ-02.01-SPRINTEROP-ARR0.0890	The separation delivery tool shall support ATCOs in the delivery of wake separations that are allowed only when leader and follower aircraft are aligned on the centreline.
	SR1.040 REQ-02.01-SPRINTEROP-ARR0.0190	There shall be surveillance coverage down to the separation delivery point to allow the separation tool to display Target Distance Indicators on the runway extended centreline including the last part of the final approach.
	SR1.041 REQ-02.01-SPRINTEROP-ARR0.0730	The TDIs corresponding to the high priority MRS separation constraint shall remain visible on the radar display until the leader aircraft reaches the separation delivery point.
	SR1.042 REQ-02.01-SPRINTEROP-ARR0.0740	The TDIs corresponding to the high priority Wake separation constraint shall remain visible on the radar display until the leader aircraft reaches the separation delivery point.
	SR1.043 REQ-02.01-SPRINTEROP-ARR0.0750	The TDIs corresponding to the low priority Runway Occupancy Time constraint shall remain visible on the radar display until the leader aircraft reaches the separation

		delivery point.
	SR1.044 REQ-02.01-SPRINTEROP-ARR0.0760	The TDIs corresponding to the low priority Gap spacing constraint shall remain visible on the radar display until the follower aircraft reaches the separation delivery point.
	SR1.045 REQ-02.01-SPRINTEROP-ARR0.0690	TDI display shall be robust to ensure they do not keep switching on and off as aircraft perform normal manoeuvres
	SR1.050 REQ-02.01-SPRINTEROP-ARR3.1000	If the ORD concept is implemented, the Final Approach Controller shall maintain the aircraft on or behind the ITD on the final approach and reduce to the final approach procedural airspeed until the transfer to the Tower controller.
	SR1.051 REQ-02.01-SPRINTEROP-ARR3.0170	If the ORD concept is implemented, the Approach controller shall vector the follower aircraft so that it stays on or behind the corresponding ITD.
	SR1.052 REQ-02.01-SPRINTEROP-ARR0.0710	The tool shall automatically display the FTD (if not already displayed) if the aircraft comes within a defined distance of the computed FTD. This distance shall be configurable within the tool.
	SR1.053 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0792	For the TWR HMI, if the first most constraining ITD corresponding to a high priority separation indicator (e.g. WAKE or MRS) is infringed, then its already displayed corresponding FTD shall be accompanied by the distance countdown to the FTD of the corresponding aircraft such that the TWR controller is aware that a high priority ITD has been infringed Note this countdown to the FTD applies only to the high priority separation indicators (WAKE and MRS). The scope of this distance is to show the TWR ATCO when an ITD has been infringed keeping in mind that the ITD is not displayed by

		default for the TWR controller.
	SR1.054 Example of REQ-02.01-SPRINTEROP-ARR0.0792	For the TWR HMI, if the second most constraining ITD corresponding to a high priority separation is infringed, the system shall display the corresponding FTD accompanied by the distance countdown to the FTD, in addition to the already displayed first most constraining FTD such that the TWR controller is aware that a high priority ITD has been infringed (FTD displayed according to the rules defined for the high priority separation indicators)
	SR1.055 Example of REQ-02.01-SPRINTEROP-ARR0.0793	For the TWR HMI, if the high priority ITD is no longer infringed: - In case the FTD corresponding to this high priority ITD is the first most constraining FTD the corresponding countdown distance to the FTD shall be hidden by the system and - In case the FTD corresponding to this high priority ITD is the second most constraining FTD, the FTD shall be hidden together with the countdown to the FTD
	SR1.056 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a high priority separation (WAKE, MRS) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner adequate to an alert (e.g. red colour)

	SR1.058 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the second and/or third most constraining ITD corresponding to a low/high priority spacing/separation is infringed the system shall display the corresponding FTDs in addition to the already displayed first most constraining FTD (FTD displayed according to the rules defined for the high priority separation and low priority spacing indicators)
	SR1.059 Example of REQ-02.01-SPRINTEROP-ARR0.0796	For the APP HMI, if the second and/or third most constraining ITD is no longer infringed, the corresponding FTDs shall be hidden by the system
	SR1.060 REQ-02.01-SPRINTEROP-ARR0.0850	The HMI design shall allow ATCO to hide/unhide indicators for a specific aircraft pair, and current and forthcoming alerts/warnings for that aircraft as a follower (e.g. infringement, catch-up, speed,..)
	SR1.061 REQ-02.01-SPRINTEROP-ARR0.0900	Following the ATCO action to suppress the TDIs for specific aircraft the tool shall • remove any information on the spacing/separation (ITD and FTD) • remove its ongoing or not display the forthcoming Separation Delivery Tool alerts (e.g. Catchup/Speed/SeqNumber/Infringement)
	SR1.062 REQ-02.01-SPRINTEROP-ARR0.0720	The Approach controller shall be able to remove the FTD from the radar display, but not when the FTD has been automatically displayed by the System.
	SR1.063 REQ-02.01-SPRINTEROP-ARR0.1350	Procedures shall be defined regarding required actions if catching up or infringing the ITD or FTD.
	SR1.064 REQ-02.01-SPRINTEROP-ARR0.0870	The Approach controller shall maintain applicable surveillance separation minima at any point during approach. This includes the case of a leader aircraft established on the final approach axis and a follower not yet established

	SR1.066 REQ-02.01-SPRINTEROP-ARR3.0500	Once the follower aircraft has been positioned w.r.t ITD and before the leader reaches its deceleration point, the Controller shall apply speed instructions in accordance to the reference glide slope air speed used for ITD calculation.
	SR1.097 REQ-02.01-SPRINTEROP-ARR0.0970	If ORD is not implemented, the Final Approach Controller shall maintain the aircraft behind the FTD with sufficient buffer due to the effect of compression caused by different leader and follower groundspeed profiles, and shall reduce aircraft's speed to the final approach procedural airspeed.
	SR1.098 REQ-02.01-SPRINTEROP-ARR0.0167	If both the FTD and ITD are available, the ITD indication ("compressions indicator") shall be the main indicator to be used by the final approach controller.
	SR1.099 REQ-02.01-SPRINTEROP-ARR0.0651	In case the ITD is the main display on the final approach, the ATCOs shall be able to display the FTD , depending upon the local operation's needs.
	SR1.103 REQ-02.01-SPRINTEROP-ARR0.0165	The Tower Controller shall monitor and ensure that there is no infringement of the FTD.
	SR1.105 REQ-02.01-SPRINTEROP-ARR0.0164	The FTD indicator shall be the main TDI to be used by the Tower Controller.
	SR1.114 REQ-02.01-SPRINTEROP-ARR0.0166	Clear guidelines with regard to the list of possible actions to be made in the case of an FTD infringement (in the APP and in the TWR) shall be described per position for the local implementation.
	SR1.117 REQ-02.01-SPRINTEROP-ARR0.1250	Approach and Tower Controllers shall be fully trained to apply the procedures for the new separation modes and to use of the Separation Delivery Tool and supporting systems (e.g. alerts) with indicators prior to deployment.

	SR1.118 REQ-02.01-SPRINTEROP-ARR0.1260	All Approach and Tower controllers and Supervisors shall be fully trained in the operating procedures for the new WT separation modes prior to deployment.
	SR1.124 REQ-02.01-SPRINTEROP-ARR2.0971	The Tower Controller shall ensure that the actual spacing behind the leader aircraft is not infringing the FTD and in case of imminent infringement he shall apply adequate corrective action like delegating visual separation to Flight Crew or instructing go-around.
	SR1.125 REQ-02.01-SPRINTEROP-ARR0.0990	The Approach and Tower Runway Controllers shall remain responsible for monitoring for separation infringements and for timely intervention actions to resolve or prevent them.
	SR1.129 REQ-02.01-SPRINTEROP-ARR0.1351	In a dual approach arrival environment, ATCOs shall have supporting alert, for identifying vertical and horizontal infringements for the crossing aircraft (e.g. North runways to South runways)
SO 009 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	SR1.109	For all modes (where FTD and/or ITD are based on a pre-defined aircraft speed profile of the follower), the APP and TWR Controllers shall be made aware with respect to the impact on the TDIs correctness when actual aircraft speed profile is different from the pre-defined TAS profile used by the separation delivery tool.
	SR1.110 REQ-02.01-SPRINTEROP-ARR0.1420	For all modes (where FTD and/or ITD are based on a pre-defined aircraft speed profile of the follower), Flight Crew shall be briefed and reminded (e.g. via information campaigns) on the importance to respect on the Final Approach path the ATC speed instructions until the start of the deceleration and/or the published procedural airspeed on final

		approach and to notify Controller in a timely manner in case of inability to conform to one of those.
SO 010 ATC (and potentially Flight Crew/Aircraft) shall consider the potential for WDS separation infringement due to lateral deviation from final approach path (e.g. dog leg when WDS crosswind is operated)	SR1.113 REQ-02.01-SPRINTEROP-ARR0.1430	With regards to WDS modes (total wind or cross wind) Flight Crew shall be briefed and reminded on the importance to respect the Final Approach path in terms of lateral deviation from the glide path and to notify Controller in a timely manner in case of inability to conform to it.
SO 011 The runway spacing or other spacing constraint (e.g. departure gaps) shall be input to and accounted for the Separation Delivery Tool (in support of SO 006)	SR1.013 REQ-02.01-SPRINTEROP-ARR0.0980	The Tower Supervisor in coordination with the Approach Supervisor (and occasionally the Tower and Approach Controllers - in line with defined local procedures) shall determine the final approach separation mode and runway spacing constraints that are to be applied at any time by the separation delivery tool.
	SR1.089 REQ-02.01-SPRINTEROP-ARR0.0162	The tool in any mode shall display TDIs representing the greatest constraint out of all applicable in-trail or not in-trail separation constraints. The constraints can be the high priority separation (e.g. Wake and MRS) and the low priority runway spacing (ROT) and other spacing constraints (e.g. departure GAP, runway inspections, etc.).
	SR1.121 REQ-02.01-SPRINTEROP-ARR0.0370	Local implementation shall ensure that roles and responsibilities are clearly defined regarding the management of data inputs into the Separation Delivery tool including runway policy, runway spacing constraints, visibility conditions and runway conditions.

SO 012 TWR ATC shall request the insertion of departure gaps from APP ATC, and shall coordinate with APP the modification and cancellation of these gaps as operationally needed	SR1.031 REQ-02.01-SPRINTEROP-ARR0.0570	If there is a change to the separation / spacing constraint (e.g. Gap) the TDI for the affected aircraft pair shall be re-computed.
	SR1.044 REQ-02.01-SPRINTEROP-ARR0.0760	The TDIs corresponding to the low priority Gap spacing constraint shall remain visible on the radar display until the follower aircraft reaches the separation delivery point.
	SR1.072 REQ-02.01-SPRINTEROP-ARR0.0253	The separation delivery tool shall provide confirmation to ATCO that the gap spacing insertion is successful or not.
	SR1.073 REQ-02.01-SPRINTEROP-ARR0.0254	The ATCOs shall be able to insert automatic gap spacing based on pre-defined scenarios in the sequence manager
	SR1.074 REQ-02.01-SPRINTEROP-ARR0.0255	The tool shall provide ATCOs the ability to update and cancel any gap spacing previously inserted.

Table 26: Mapping of Safety Objectives to Safety Requirements for the PJ02.01 Arrivals Concepts Solutions

4.1.3 Analysis of the SPR-level Model – Normal Operations for the Arrivals Concepts Solutions

4.1.3.1 Effects on Safety Nets – Normal Operational Conditions for the Arrivals Concepts Solutions

The new WT separation modes and ATC tools do not impact the safety net associated to ground collision avoidance (e.g. MSAW, TAWS); since obstacle clearances are not modified with these concepts.

The application of the new separation modes is reducing the distance separation between aircraft therefore it might impact STCA, ACAS, RIMCAS or ASMGCS level 2. However, the Safety Requirement **SR1.089** specifies that the TDIs display the greatest constraint out of the applicable separation minima's and other applicable constraints, which includes the minimum radar separation, ROT and other runway constraints. Therefore the performance of STCA, ACAS, RIMCAS and ASGCMS level 2 should not be impacted by the new WT separation modes. See also SR1.064 during the interception phase.

4.1.4 Analysis of the SPR-level Model – Abnormal Operational Conditions for the Arrivals Concepts Solutions

This section ensures that the Arrivals Concepts Solutions SPR-level Design is complete, correct and internally coherent with respect to the Safety Requirements (Functionality and Performance) derived for the abnormal operating conditions that were used to derive the corresponding Safety Objectives (success approach) in Section 3.1.8.2.

4.1.4.1 Scenarios for Abnormal Conditions for the Arrivals Concepts Solutions

Table 27 below recalls the different scenarios relative to the abnormal conditions identified in Section 3.1.8.1 and for which new Safety Objectives have been derived in Section 3.1.8.2, analyses the causal factors or possible influences and presents the risk mitigation.

ID	Scenario	Possible influences or causal factors	Mitigation
1	Change of Aircraft landing runway intent.	Pilot's request.	Inform Arrival Sequencing (and thus the Separation Delivery) tool about late change of the sequence order in order to have correct separation indications.
2	Abnormal procedural aircraft airspeed and/or abnormal stabilized approach speed.	Pilot basic airmanship not respected. Aircraft problem.	Detect abnormal airspeed (through alerting), manage compression manually and, in TB-modes, apply adequate corrective actions for the affected pairs: airspeed instructions, path stretching instructions (if allowed after localiser interception), delegation of visual separation to Flight Crew and, if necessary, missed approach instruction.
3	Lead aircraft go-around.	Loss of separation on final. Severe Wake Encounter. Runway not in sight at minima. Loss of ILS guidance in IFR. Insufficient spacing between successive landings. Landing runway occupied. Late landing clearance. Unstable approach below 500ft.	Inform separation tool about the sequence order change due to the missed approach (if not automatic) in order to have correct separation indications.
4	Delegation of separation to Flight Crew.	Final APP or TWR ATCO needs to delegate the WT separation to Flight Crew (e.g. in case the FTD is going to be infringed, in order to avoid initiating a go around).	Request Flight Crew if they can apply a visual separation. Upon acceptance, the responsibility to maintain separation will be passed to the Flight Crew.
5	Actual Wind on final approach different	External influence, not under	Ensure anticipation of change in wind

	from the wind used for FTD/ITD computation.	ATM managerial control.	conditions by forecast and monitoring Detect change in wind condition (through wind condition monitoring and alerting) and revert to the correspondent DB- mode (in case of change in glideslope wind, ITDs will be inhibited and compression managed as per today operations).
6	Flight Crew Notification of Aircraft Speed non-conformance.	Pilot reasons. Aircraft problem detected by Pilot.	ATCO takes into account, for the merging on to final approach, the notified speed-related aspects to determine the additional spacing that is required to be set up behind the ITD indication.
7	Unexpected drop of reference wind below safe threshold.	External influence, not under ATM managerial control.	TB-mode is deactivated (revert to correspondent DB- mode).
8	Late change of landing runway (not planned).	Runway blocked.	Ensure coordination, update landing runway in Separation Delivery and Arrival Sequencing tools in order to get updated arrival sequence and separation indicators.
9	Scenario specific spacing requests.	Unplanned Runway inspection. Pilot reporting difficulty to brake.	Allow individual definition of spacing constraint and display of associated TDIs.

Table 27: Operational Scenarios Analysis – Abnormal Conditions for the PJ02.01 Arrivals Concepts Solutions

4.1.4.2 Derivation of Safety Requirements (Functionality and Performance) for Abnormal Conditions for the Arrivals Concepts Solutions

Table 28 below, uses the outcome of the previous sub-section (Table 27) and the Safety Objectives from Section 3.1.8.2 to derive the corresponding Safety Requirements (Functionality and Performance).

SO	SO Description	SRs	SR Description
SO 101	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 wind in TB-modes only; for the ITD – glideslope wind in all modes (TB and DB).	SR1.208	In WDS total wind modes (A-TB-WDS-Tw), the Approach and Tower Controllers and Supervisors shall be alerted by the total wind monitoring function about a significant difference between actual reference total wind and the reference total wind used for the TB computation, i.e. when the predicted allowed time separation (based on the total wind prediction used for Target Distance Indicator computation) compared to the actual allowed time separation (based on the actual total wind measurement) exceeds a threshold to be determined locally.

	SR1.209	In WDS cross wind modes (A-TB-WDS-Xw), the Approach and Tower Controllers and Supervisors shall be alerted by the cross wind monitoring function about a significant difference between actual reference cross wind and the reference cross wind used for the TB computation, i.e. when the predicted allowed time separation (based on the cross wind prediction used for Target Distance Indicator computation) compared to the actual allowed time-separation (based on the actual cross wind measurement) exceeds a threshold to be determined locally.
	SR1.210	In WDS total wind modes (A-TB-WDS-Tw), in case of total wind monitoring alert, the Approach and Tower Controllers shall revert to the correspondent distance based or time based (e.g. TB-PWS) separation mode using the FTD and ITD indicators and when needed take corrective actions during the transition phase like instructing go-around.
	SR1.211 REQ-02.01-SPRINTEROP-ARR2.1680	In WDS crosswind modes (WDS-Xw), in case of cross wind monitoring alert, the Approach and Tower Controllers shall revert to the correspondent distance based or time based (e.g. TB-PWS) separation mode, using the FTD and ITD indicators and when needed take corrective actions during the transition phase like instructing go-around.
	SR1.212	In TBS and TB-PWS-A modes, in case there is a significant difference between actual glideslope headwind profile and the glideslope headwind profile used for the TDI computation, the Separation Delivery Tool shall re-compute the TDIs based on the correct headwind value and inform the ATCO about the re-computation.
	SR1.213 REQ-02.01-SPRINTEROP-ARR2.1690	The triggering values of the headwind, total wind and cross wind monitoring alerts shall be determined on the basis of the used buffers in the TDI computation
SO 102 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	SR1.214 REQ-02.01-SPRINTEROP-ARR0.1500	The Approach and/or Tower controller shall be alerted by the speed conformance alert function when the actual aircraft speed differs by more than a locally-defined threshold from the aircraft speed profile used for the TDIs computation.
	SR1.215 REQ-02.01-SPRINTEROP-ARR0.1700	In TB-modes, in case of speed conformance alert before the stabilisation fix, the Final Approach or Tower Controllers shall check whether the actual spacing behind the leader aircraft is below the distance-based WTC separation minima and if positive shall apply adequate corrective actions: airspeed instructions, path stretching instructions (if allowed after localiser interception), delegation of visual separation to Flight Crew and, if necessary, missed approach instruction, and shall manage the impact on

		subsequent aircraft in the arrival sequence.
	SR1.217 REQ-02.01-SPRINTEROP-ARR0.1710	For all modes, in case of speed conformance alert the Final Approach and Tower Controllers shall be aware that ITD indicators are no longer accurate if the same speed is kept until the deceleration fix (ITD computation impacted by pre-defined glideslope airspeed profile of both follower and leader) thus shall manage compression without indicators as per today operations.
	SR1.218 REQ-02.01-SPRINTEROP-ARR0.1510	The triggering value used for the speed conformance alert shall be determined on the basis of the used buffers in the TDI computation. The region on the glideslope where the alert is active shall be defined locally (e.g. 8 NM from RWY threshold).
SO 103 ATC shall maintain an updated arrival sequence order following a late change of aircraft runway intent or a go-around	SR1.200 Example of REQ-02.01-SPRINTEROP-ARR0.0852	The Intermediate and Final Approach controllers shall be the masters of the Final Approach arrival sequence and shall be able in a simple and timely way to update the sequence, insert or remove an aircraft and amend the sequence when there is a go-around in accordance with their strategy for the interception with no adverse impact on workload.
	SR1.201 REQ-02.01-SPRINTEROP-ARR0.0560	For every change in the arrival sequence (aircraft swapping positions, aircraft removed or missed approach, late change of the runway intent, etc.) the tool shall immediately re-compute all affected TDIs and reflect the change on the HMI accordingly.
	SR1.204 REQ-02.01-SPRINTEROP-ARR0.0851	Local procedures shall define the procedures related to the use of the TDIs and the specific instances in which they can be removed.
	SR1.205 REQ-02.01-SPRINTEROP-ARR0.0960	The Target Distance Indicators associated to a leader aircraft executing a go-around shall be removed from the sequence and new Target Distance Indicators shall be computed for the following a/c, considering the new arrival pairs created due to this go-around. The aircraft could be removed from the sequence manually by the ATCO or automatically.

SO 104 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	SR1.216 REQ-02.01-SPRINTEROP-ARR0.1370	Pilots shall notify ATC of an inability to fly the standard approach procedure, and of any non-conformant final approach procedural airspeed issues, in a timely manner.
	SR1.219 REQ-02.01-SPRINTEROP-ARR0.1360	The Approach Controller shall take into account any notified inability to fly the standard approach procedure and any non-conformant final approach procedural airspeed issues when setting up the spacing on final approach.
SO 105 The Target Distance Indicators shall be correctly updated in case of late (not planned) change of landing runway	SR1.202 REQ-02.01-SPRINTEROP-ARR0.0561	For a late change of the runway intent, the tool shall immediately re-compute all affected TDIs and reflect the change on the HMI accordingly (i.e. the TDIs corresponding to the affected aircraft disappear from the extended runway centreline of the old runway and is displayed on the extended runway centreline of the new runway).
	SR1.203 REQ-02.01-SPRINTEROP-ARR0.0950	When the aircraft is already inserted into the sequence with a runway intent and there is a change of aircraft landing runway intent, the Approach controller shall check that Target Distance Indicators reflect the change of aircraft landing runway intent
SO 106 ATC shall be able to handle scenario specific spacing requests while using the separation delivery tool	SR1.206 REQ-02.01-SPRINTEROP-ARR0.0250	Scenario specific spacing gaps between aircraft pairs shall be provided to the Separation Delivery tool.
	SR1.220 REQ-02.01-SPRINTEROP-ARR0.1380	Procedures shall be locally defined for the handling of scenario specific spacing requests and runway changes.

Table 28: Safety Requirements or Assumptions to mitigate Abnormal Conditions for the PJ02.01 Arrivals Concepts Solutions

4.1.5 Design Analysis – Case of Internal System Failures for the Arrivals Concepts Solutions

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.

Fault tree analysis is used to identify the causes of hazards and combinations thereof, accounting for safeguards already specified in the current standards and for any indication on their effectiveness but also accounting for the safety requirements derived in Section 4.1.3 and 4.1.4 during the design analysis in normal and abnormal conditions.

Quantitative Safety Requirements will not be derived in this safety assessment. This will however need to be done by the industry in the validation stages prior to implementation (i.e. V4 onwards).

Fault tree analysis is also used to identify additional mitigations to reduce the likelihood that specific failures occur or would propagate up to the Hazard (i.e. operational level). These mitigations are then captured as additional Qualitative Safety Requirements (Functionality and Performance).

4.1.5.1 Causal Analysis for the Arrivals Concepts Solutions

For each system-generated hazard (see chapter 3.1.9.1), a top-down identification of internal system failures that could cause the hazard was conducted. The hazards are:

- Hazards applicable to Interception and Final Approach (based on common mode failures):
  - **Hz#05**: One or multiple imminent infringements not detected and not recovered due to undetected corruption of separation indicator
  - **Hz#06**: One or multiple imminent infringements due to lack of separation indicator for multiple or all aircraft
- Hazards relative to the approach interception and associated to ATC instructions:
  - **Hz#01b**: Separation not being recovered following imminent infringement of A/C pair instructed by ATC to merge on the Final Approach interception
  - **Hz#01a**: Inadequate separation management of a pair of aircraft instructed by ATC to merge on the Final Approach interception
- Hazards relative to the approach interception and originated by Crew/Aircraft:
  - **Hz#02b**: Separation not being recovered following imminent infringement 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
- Hazards during the Final Approach and associated to ATC instructions:
  - **Hz#03b**: Separation not being recovered following imminent infringement by an aircraft pair instructed by ATC on the Final Approach
  - **Hz#03a**: Inadequate separation management of an aircraft pair naturally catching-up as instructed by ATC on the Final Approach
- Hazards during the Final Approach and originated by Crew/Aircraft:
  - **Hz#04b**: Separation not being recovered following imminent infringement 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
- Hazard applicable to the management of separation mode:

  - **Hz#07:** Large under-separation induced by ATC through inadequate selection & management of the separation mode

- Hazard applicable to mixed mode of operations:
  - **Hz#08:** Runway conflict due to landing clearance in conflict with another landing (ROT not respected) or with cleared line-up/take-off (GAP not respected)

The purpose of the causal analysis is to increase the detail of risk mitigation strategy through the identification of all possible causes. This way it will be possible to identify the corresponding Safety Requirements to meet the Safety Objective of the Operational Hazard under consideration.

A fault tree is produced for each selected hazard that provides a detailed overview of the contribution of all domains to that hazard. Fault trees are elaborated by decomposing the hazard in a combination of failures (i.e. Basic Causes and failure of mitigations) linked by different gates: "AND" gates and "OR" gates. Once the fault tree is built, the safety objective assigned to the hazard is apportioned among the failures identified and safety requirements are allocated.

Existing mitigations (i.e. already captured as safety requirements in sections 4.1.3 and 4.1.4) are identified and, where necessary, additional mitigation means are proposed in order to reduce the likelihood of occurrence of the Operational Hazard. The additional mitigation means are formalized as Safety Requirements.

4.1.5.1.1 Hz#05 (SO 209): One or multiple separation minima infringements due to undetected corruption of separation indicator

This hazard affects both the Final approach interception and the Final Approach down to separation delivery at RWY threshold. It is caused by the undetected corruption of the separation indicator (for one or multiple aircraft) which is a common mode failure impacting all the Wake AIM barriers up to and including the B3a: ATC separation recovery. Multiple aircraft might be impacted and exposed to large under-separation before the failure is detected (significant exposure time). Consequently, the residual risk of wake alive ahead is significantly higher compared to the occurrence of a single large under-separation (as per Hz#01b, 02b, 03b, 04b), thus a more demanding SO has been allocated via an impact modification factor IM=20.

The basic causes of this hazard are captured in the Hz#05 Fault Tree (See Figure 10).

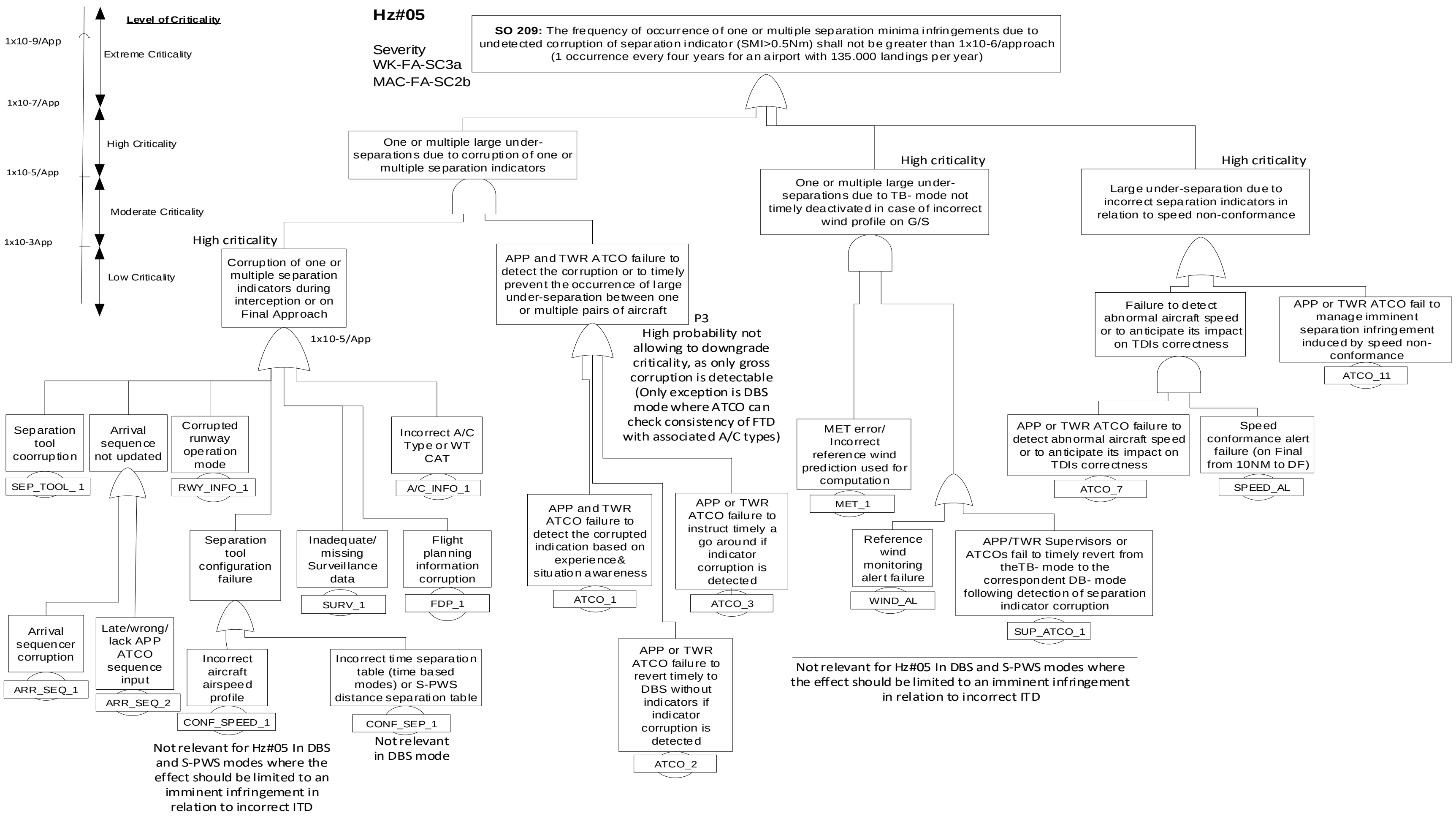


Figure 10: Hz#05 Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#05 Fault Tree and identifies the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Corruption of one or multiple separation indicators during interception or on Final Approach			
Separation Tool corruption.	SEP_TOOL_1	The separation tool despite correct inputs computes corrupted separation indicator(s) (for one or multiple aircraft).	Mitigated through the software assurance process which defines the acceptably safe level of confidence in the separation delivery tool prior to implementation. **SR1.317:** The software assurance level of the Separation Delivery tool and supporting tools shall be determined by the V4 safety assessment
Arrival sequencer corruption.	ARR_SEQ_1	The arrival sequencer does not provide the correct sequence to the separation delivery tool despite the arrival sequence displayed to the controller is correct.	**SR1.028, SR1.201**, "normal and abnormal conditions" Also mitigated through the software assurance process which defines the acceptably safe level of confidence in the arrival sequence service prior to implementation. **SR1.317:** The software assurance level of the Separation Delivery tool and supporting tools shall be determined by the V4 safety assessment
Late, Wrong or Lack of arrival sequence input by the APP controller.	ARR_SEQ_2	The approach controller does not timely update the arrival sequence following a change in the sequence (according to his strategy for the interception, late change of aircraft landing runway intent, missed approach etc.) or makes a mistake when she/he	**SR1.300, SR1.032, SR1.034, SR1.093 and SR1.033** "normal conditions". **SR1.200** "abnormal conditions"

		updates the sequence or does not update the sequence in the tool whilst considering an order different from the one provided by the tool.	
Corrupted runway operation mode.	RWY_INFO_1	The information about the active runway and/or mode of operation (segregated or mixed mode) sent to the arrival sequencer are corrupted.	No specific SR for the new concepts because it is assumed that this failure will be detected by the tower and/or the approach supervisor before aircraft are vectored to the final approach.
Incorrect aircraft airspeed profile. Not relevant for Hz#05 in DBS and S-PWS modes where the effect should be limited to an imminent infringement.	CONF_SPEED_1	The aircraft speed profile used by the separation delivery tool to compute separation indicator is incorrect. In DBS and DB-PWS-A modes the effect should be limited to an imminent infringement, as the TWR ATCO would initiate a Go Around to manage the compression effect (ITD is computed using the wind profile on the glideslope therefore the indication could be corrupted but FTD will remain correct).	**SR1.080** “normal conditions”. **SR1.320:** Separation delivery tool verification shall be carried-out after modification of the time-to-fly/airspeed profile configuration file (new A/C types or modification of existing A/C speed profiles) before the system returns in operational service **SR1.319:** A quality assurance process shall be put in place to validate the separation time table configuration file (in TB- modes) or the distance separation table configuration file of the separation delivery tool **SR1.318:** Separation delivery tool verification shall be carried-out after modification of the separation time table configuration file (in TB- modes) or the distance separation table configuration file before the system returns in operational service **SR1.317:** The software assurance level of the

			Separation Delivery tool and supporting tools shall be determined by the V4 safety assessment
Incorrect time separation table (time-based modes) or S-PWS distance separation table. Not relevant in DBS mode.	CONF_SEP_1	The separation time table in time-based modes (that correspond to the application of equivalent distance-based separations either DBS or DB-PWS-A) or the DB-PWS distance separation table in DB-PWS-A mode, which are used by the separation delivery tool to compute separation indicator are incorrect. Not relevant in DBS mode.	**SR1.077, SR1.078, SR1.088, SR1.079** "normal conditions". **SR1.319:** A quality assurance process shall be put in place to validate the separation time table configuration file (in TB- modes) or the distance separation table configuration file of the separation delivery tool **SR1.317:** The software assurance level of the Separation Delivery tool and supporting tools shall be determined by the V4 safety assessment **SR1.318:** Separation delivery tool verification shall be carried-out after modification of the separation time table configuration file (in TB- modes) or the distance separation table configuration file before the system returns in operational service
Inadequate/missing surveillance data.	SURV_1	Surveillance information sent to the arrival sequencer is corrupted including flight ID information.	No specific SR because reliability of the surveillance system is considered sufficient for all the WT separation modes and ATC tools considered.
Flight planning information corruption. Incorrect A/C Type or WT CAT.	FDP_1 A/C_INFO_1	Fight plan information sent to the arrival sequencer and the separation delivery tools is corrupted or incorrect. This includes incorrect aircraft types and/or the Wake Turbulence Categories.	**SR1.085** "normal conditions". **SR1.315:** It shall be demonstrated that the data inputs including flight data, approach arrival sequence information and glideslope wind conditions to the Separation Delivery are sufficiently robust.

			Aircraft type and wake turbulence category are essential parameters for all the concepts using the separation delivery tool: **SR1.316:** At the first contact with the Approach, the flight crew shall provide the Aircraft type or alternatively this information could be provided to the Approach Controller via data link and the Approach Controller shall cross check this information with the information displayed on the CWP. **SR1.304:** Wake category and aircraft type information shall be always available in the aircraft labels so that this information remains visible for Controllers. **SR1.321:** When a flight data input error (e.g. missing or wrong ICAO aircraft type or wake category) is detected, it shall be possible to update the corresponding information into the input for the separation delivery tool. **SR1.330:** Approach control shall check the validity of Flight Plan information displayed on the CWP (ICAO aircraft type, wake category) Note the following assumption is conservatively taken:

			A015: Controllers cannot have detailed knowledge of separations for each pair of aircraft in all modes except for DBS therefore checking that Target Distance indications are consistent with the associated aircraft types and WT category is not realistic
TWR and APP ATCO failure to detect the corruption or to timely prevent the occurrence of large under-separation between one or multiple pairs of aircraft			
APP and TWR ATCO failure to detect the corrupted indication.	ATCO_1	APP and TWR ATCO do not detect the corrupted indication: • low probability in DBS mode where ATCO can check consistency of FTD with associated A/C types or WTC, • high probability in all other modes where only large errors can be detected by checking consistency of FTD with associated A/C types or WTC	**SR1.322:** In TB modes, relevant wind information shall be displayed on Approach / Tower Controller working positions for awareness purposes (e.g. to enable significant discrepancy check with the displayed TDI). Note the following assumption is conservatively taken: **A015:** Controllers cannot have detailed knowledge of separations for each pair of aircraft in all modes except for DBS therefore checking that Target Distance indications are consistent with the associated aircraft types and WT category is not realistic
APP or TWR ATCO failure to revert timely to DBS without indicators if indicator corruption is detected.	ATCO_2	APP or TWR ATCO does not revert timely to DBS minima without indicators when indicator corruption is detected.	**SR1.123** in "normal conditions" **SR1.304:** Wake category and aircraft type information shall be always available in the aircraft labels so that this information remains visible for Controllers

			SR1.323: Approach and Tower Controllers shall be provided with look-up tables for DBS minima to support DBS operations with no TDIs when necessary. **SR1.324:** ATCOs shall continue to have a 'click and drag' distance measuring tool so they can accurately measure inter a/c spacing when required (e.g. for building confidence in the tool or during degraded modes).
APP or TWR ATCO failure to instruct timely a go around if indicator corruption is detected	ATCO_3	APP or TWR ATCO does not instruct timely a go around in case the indicator(s) corruption has been detected (e.g. corruption involving gross error). Given the detection latency, the probability is nevertheless higher than when indicators are correctly displayed (see APP_ATCO_10 during interception and ATCO_6 on Final approach).	No specific SR because it is assumed that this is a normal ATCO procedure considering that the problem is detected.
One or multiple large under-separations due to Time-based mode not timely deactivated in case of incorrect wind profile on G/S			
MET error/ Incorrect reference wind prediction used for computation. Not relevant for DBS and DB-PWS-A modes.	MET_1	The reference wind prediction used for the separation computation (glideslope headwind profile In TBS and TB-PWS-A, total wind in A-WDS-Tw and crosswind in A-WDS-Xw modes) is different from the actual reference wind. The respective wind monitoring alerts specific to each of the TB-modes have been derived as mitigation during Abnormal modes analysis, allowing the reversion to the correspondent distance-based separation mode (for WDS) or a re-computation of the TDIs (for TBS and TB-PWS-A). For DBS and DB-PWS-A modes only relevant for ITD computation (if problem is detected, ATCO need to	**SR1.086** “normal conditions”. **SR1.207, SR1.208, SR1.209, SR1.210, SR1.211, SR1.212** and **SR1.213** in “abnormal conditions”

		manage compression manually but FTD continues to be correct).	
Reference wind monitoring alert failure.	WIND_AL	The reference wind monitoring alert fails to timely detect and trigger warning about the significant discrepancy between the reference wind prediction used for the computation and the actual reference wind (glideslope headwind profile in TBS and TB-PWS-A, total wind in A-TB-WDS-Tw and cross wind in A-TB-WDS-Xw modes) Not relevant for DBS and DB-PWS-A modes.	**SR1.325:** Approach and Tower Supervisors shall be alerted when the wind monitoring function for the conditional application of the TB modes (glideslope headwind, total wind, cross wind) are lost or inoperative (encompassing loss of wind input)
APP/TWR Supervisors or ATCOs fail to timely revert from the time-based mode to the correspondent distance-based mode following detection of separation indicator corruption.	SUP_ATCO_1	APP/TWR Supervisors or ATCOs fail to timely revert from the time-based mode to the correspondent distance-based mode following wind monitoring alert when in WDS (error in detection of the alert, coordination or correct and timely execution of the mode reversion). Not relevant for DBS and DB-PWS-A modes.	**SR1.210, SR1.211** "abnormal conditions".
APP or TWR ATCO failure to detect abnormal aircraft speed or to anticipate its impact on TDIs correctness.	ATCO_7	APP or TWR ATCO does not detect that one of the aircraft involved in an imminent infringement situation is not respecting the instructed or procedural speed, or they do not anticipate the impact of the Follower speed non-conformance on the TDIs correctness. In case the follower speed is higher than the value used for TDIs computation (e.g. 160 KIAS) on the last part of the Final Approach (e.g. last 10 NM) the FTD indicator is incorrect in TB-modes and the ITD indicator is incorrect in all modes. That might involve the follower getting too close to the leader with risk for loosing separation as the compression would not have been correctly anticipated and managed.	**SR1.109, SR1.124 and SR1.110** "normal conditions". **SR1.214, SR1.215, SR1.217, SR1.218** "abnormal conditions". It is assumed that the approach and the tower controller verify the actual speed of the aircraft and the speed trend when aircraft are established on the final approach.

Speed conformance alert failure.	SPEED_AL	In case APP or TWR ATCO do not detect that one of the aircraft involved in an imminent infringement situation is not respecting the procedural speed instructions or any other ATC speed instructions, the speed conformance alert warns in case actual Follower air speed is different from the air speed profile used by the separation tool computation. The current event is the speed conformance alert failing to timely detect and trigger the warning about the follower aircraft speed non-conformance (too fast).	**SR1.306:** Approach and Tower Supervisors shall be made aware if any tool / monitoring / alerting features are lost or inoperative.
APP or TWR ATCO fail to manage imminent separation infringement induced by speed non-conformance	ATCO_11	APP or TWR ATCO fail to manage imminent separation infringement induced by speed non-conformance, via speed adjustment, delegation of visual separation to Flight Crew or instructing go around.	**SR1.215, SR1.124** "abnormal and normal conditions".

Table 29: Derivation of Mitigation/Safety Requirements for Hazard Hz#05 for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.2 Hz#06 (SO 210): One or multiple imminent infringements due to lack/loss of separation indicator for multiple or all aircraft

This hazard affects both the Final approach interception and the Final Approach down to separation delivery at RWY threshold. It is caused by the lack or loss (initially displayed and subsequently removed) of the separation indicator (for multiple or all concerned aircraft) which is a common mode failure impacting the barriers B3 to B5 (dealing with separation management of aircraft pairs merging to the Final Approach or naturally catching up on the Final Approach, or with spacing conflicts due to A/C deviation).

Given the need for ATCOs to manage the unplanned reversion to DBS minima without indicators for multiple or all aircraft it is assumed, as a worst effect, that for at least a pair of aircraft the separation management as per barriers B3 to B5 fails. Nevertheless, the barrier B3a: ATC separation recovery will mitigate this hazard, as ATCOs will be able to detect the problem and revert to DBS minima without indicators, before large under-separation would occur.

However, given the expected occurrence of multiple imminent infringements the risk is considered higher compared to the lack of a single separation indicator (addressed in Hz#01a, Hz#03a), thus a more demanding SO has been allocated via an impact modification factor IM=10.

The basic causes of this hazard are captured in the Hz#06 Fault Tree (See Figure 11).

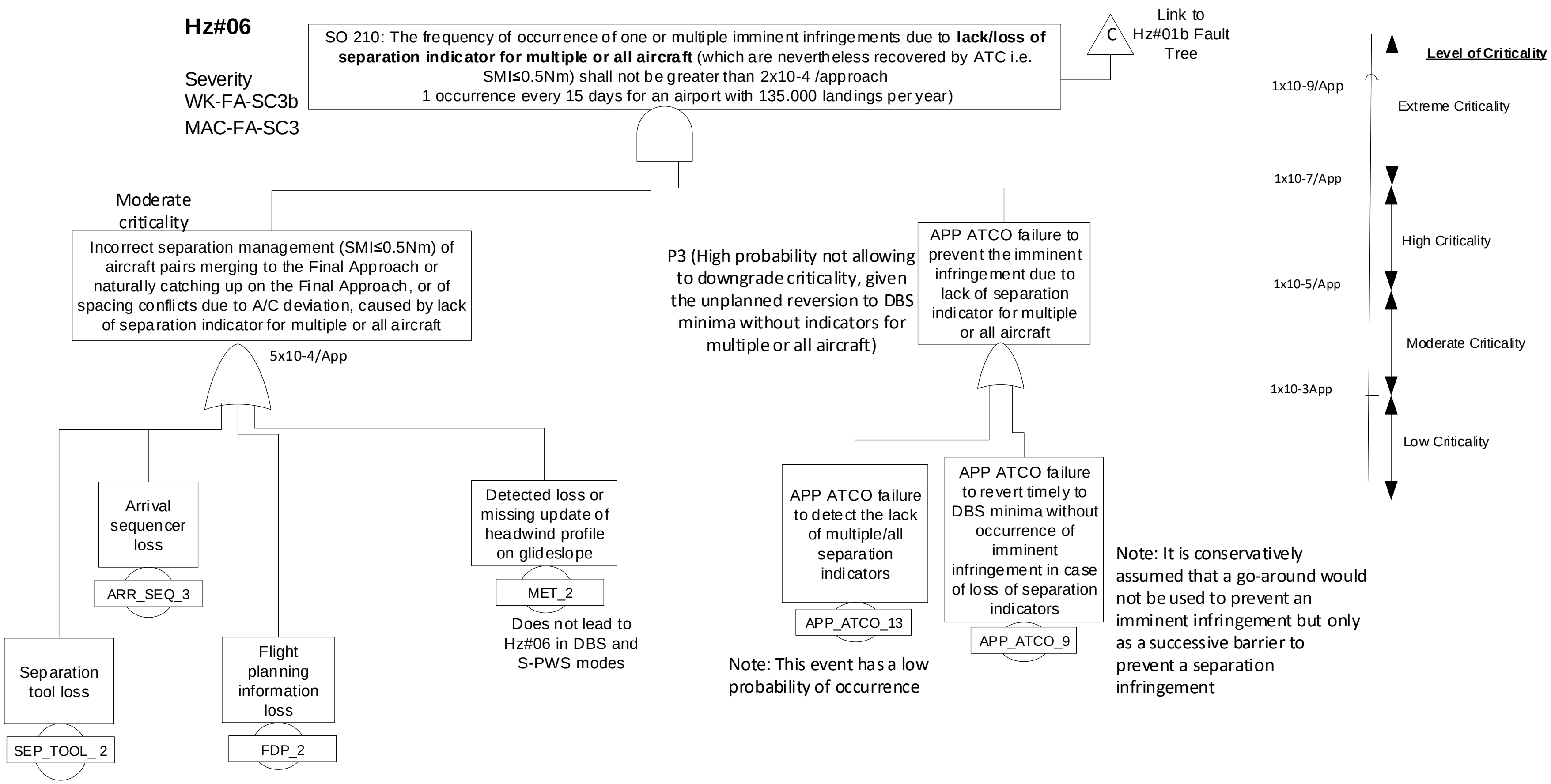


Figure 11: Hz#06 Fault tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#06 Fault Tree and identifies the mitigations/safety requirements necessary to satisfy the associated Safety Objective:

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Incorrect separation management (SMI≤0.5NM) of aircraft pairs merging to the Final Approach or naturally catching up on the Final Approach, or of spacing conflicts due to A/C deviation, caused by lack of separation indicator for multiple or all aircraft			
Separation Tool loss.	SEP_TOOL_2	The separation tool does not display multiple or all the separation indicators or display them too late for the interception of the final approach. ATCOs need to revert to DBS minima without indicators; however, one or several imminent infringements might occur in relation to the high workload peak.	**SR1.048 and SR1.037** "normal conditions". **SR1.123, SR1.323, SR1.324, SR1.304** (reversion to DBS minima without indicators, as specified at Hz#05 for ATCO_2). **SR1.331**: In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be instructed to break-off) **SR1.327:** In case of Separation Tool Failure, the Supervisors and Controllers shall receive a message containing the source of the tool failure **SR1.306:** Approach and Tower Supervisors shall be made aware if any tool / monitoring / alerting features are lost or inoperative.
Arrival sequencer loss.	ARR_SEQ_3	The arrival sequencer does not provide information to the separation tool for multiple or all aircraft despite inputs are correct (e.g. sequence frozen). ATCOs need to revert to DBS minima without	**SR1.028** "normal conditions". **SR1.123, SR1.323, SR1.324, SR1.304** (reversion to DBS minima without indicators, as specified at Hz#05 for ATCO_2)

		indicators; however, one or several imminent infringements might occur in relation to the high workload peak.	**SR1.300:** Controllers shall be trained to check the aircraft landing runway intent and that the aircraft order is correct and coherent with the arrival sequence list. They shall check if and that the aircraft order is displayed in the arrival sequence list and/or if the aircraft sequence number is displayed in the radar label in accordance with their intended sequence. **SR1.314:** If the Approach Arrival Sequence Service fails, the Separation Delivery tool shall continue displaying TDIs for aircraft already established and shall stop displaying TDIs for all other aircraft **SR1.306:** Approach and Tower Supervisors shall be made aware if any tool / monitoring / alerting features are lost or inoperative.
Flight planning information loss.	FDP_2	Fight plan information sent to the arrival sequencer and the separation delivery tool is missing. This includes aircraft types and/or the Wake Turbulence Categories. ATCOs need to revert to DBS minima without indicators; however, one or several imminent infringements might occur in relation to the high workload peak.	**SR1.085** in "normal conditions" **SR1.313**: If there is insufficient information to calculate a TDI then that TDI shall not be provided, together with a visual warning. **SR1.306:** Approach and Tower Supervisors shall be made aware if any tool / monitoring / alerting features are lost or inoperative. **SR1.123, SR1.323, SR1.324, SR1.304** (reversion to DBS minima without indicators, as specified at Hz#05 for ATCO_2). No specific SR associated to the flight plan system because its current availability is considered sufficient for the new

			WT separation modes.
Detected loss or missing update of Headwind Profile on Glideslope. (Does not lead to Hz#06 in DBS and DB-PWS=A)	MET_2	Headwind profile on the Glideslope is lost or is not updated, but that is alerted according to SRs proposed in the mitigation column. In TB- modes the reversion to correspondent DB- mode is coordinated between Supervisors and ATCOs and can be performed smoothly; however, a certain risk of imminent infringement is pessimistically assumed, which is lower than the one related to an abrupt reversion needed in case of loss of separation tool. Not relevant for this hazard in DBS and DB-PWS-A modes (ITD is computed using the wind profile on the glideslope therefore the indication could be lost but it cannot lead to a spacing conflict because FTD is correctly displayed in such case). Meanwhile in these modes the Approach Controller shall use FTD only for the turn-on decision for merging on to final approach, vectoring the follower aircraft to intercept the final approach and further spacing management during interception whilst adding extra buffer to the FTD to account for compression.	**SR1.305**: For all modes, in case of loss of glideslope headwind profile input to the separation tool, the alert for loss of glideslope headwind profile service shall be displayed to the Controllers and Supervisors. **SR1.325**: Approach and Tower Supervisors shall be alerted when the wind monitoring function for the conditional application of the TB modes (glideslope headwind, total wind, cross wind) are lost or inoperative (encompassing loss of wind input) **SR1.308**: In DB- modes, in the degraded situation where glideslope headwind profile input is missing, the Approach Controller shall use only the FTD for the turn-on decision for merging on to final approach (whilst ITDs shall no more be displayed), vectoring the follower aircraft to intercept the final approach and further spacing management during interception whilst adding extra buffer to the FTD to manually account for compression or shall revert to an acceptably safe DB-mode with ITD and FTD computed using a conservative wind profile (until the glideslope headwind profile is available again) **SR1.307:** In TB-modes, in the degraded situation where glideslope headwind profile input is missing: - The Controllers shall revert to the correspondent DB-mode (DBS or S-PWS) with use of FTDs only whilst ITDs shall no more be displayed (manual management of compression) or shall revert to an acceptably safe TB-mode

			with ITD and FTD computed using a conservative wind profile (until the glideslope headwind profile is available again); OR - The Separation Delivery Tool shall automatically revert to the correspondent DB-mode or to an acceptably safe TB-mode (FTD and ITD computed using a conservative wind profile). A notification of the automatic switch shall be provided to the ATCOs and Supervisors.
APP ATCO failure to prevent the imminent infringement due to lack of separation indicator for multiple or all aircraft			
APP ATCO failure to detect the lack of multiple/all separation indicators.	APP_ATCO_13	APP ATCO failure to detect the lack of multiple/all separation indicators (low probability of occurrence).	No specific mitigation required.
APP ATCO failure to revert timely to DBS minima without occurrence of imminent infringement in case of loss of separation indicators.	APP_ATCO_9	APP ATCO failure to revert timely to DBS minima without occurrence of imminent infringement in case of loss of separation indicators. ATCO will easily detect the lack of indicators for the new arrivals (see above), but his decision to revert to DBS without indicators might be delayed if a clear information about the tool failure is not available.	**SR1.327:** In case of Separation Tool Failure, the Supervisors and Controllers shall receive a message containing the source of the tool failure **SR1.326**: In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point. **SR1.331:** In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be

			instructed to break-off) **SR1.303:** Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors. **SR1.329:** Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.) **SR1.123, SR1.323, SR1.324, SR1.304** (reversion to DBS minima without indicators, as specified at Hz#05 for ATCO_2).

Table 30: Derivation of Mitigation/Safety Requirements for Hazard Hz#06 for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.3 Hz#01b (SO 202): Separation not being recovered following imminent infringement of A/C pair instructed by ATC to merge on the Final Approach interception

This hazard occurs during the Final Approach interception and its basic causes have been captured in the Hz#01b Fault Tree (See Figure 12).

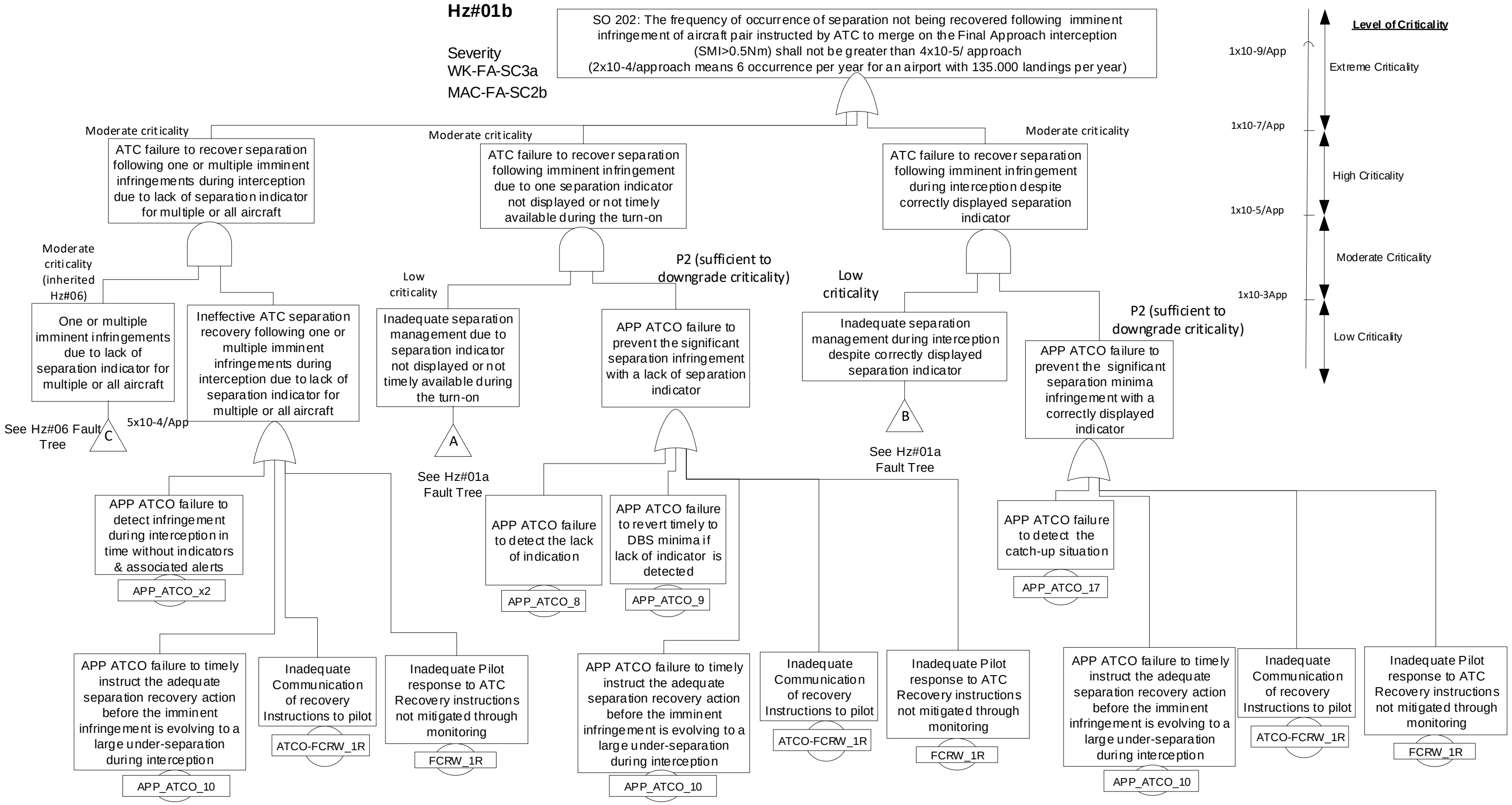


Figure 12: Hz#01b Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#01b Fault Tree and identifies the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
ATC failure to recover separation following one or multiple imminent infringements during interception due to lack of separation indicator for multiple or all aircraft			
One or multiple imminent infringements due to lack of separation indicator for multiple or all aircraft	See Hz#06 Fault Tree (ref C)	See Hz#06 table One or multiple imminent infringements due to lack of separation indicator for multiple or all aircraft, if not timely managed by ATC, evolve into large under-separation (SMI>0.5NM).	
APP ATCO failure to detect infringement during interception in time without indicators & associated alerts	APP_ATCO_x2	Not having the indicators and associated alerts, APP ATCO fails to detect in time the infringement at interception	**SR1.326:** In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point **SR1.327:** In case of Separation Tool Failure, the Supervisors and Controllers shall receive a message containing the source of the tool failure **SR1.303:** Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors.

			SR1.329: Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.) **SR1.331:** In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be instructed to break-off)
APP ATCO failure to timely instruct the adequate separation recovery action before the imminent infringement is evolving to a large under-separation during interception	APP_ATCO_10	APP ATCO does not instruct timely a go around before the imminent infringement due to the missing indicator is evolving to a large under-separation (SMI>5NM) during interception.	All the mitigations from APP_ATCO_x2 apply
Inadequate Communication of recovery Instructions to pilot	ATCO-FCRW_1R	APP ATCO inadequately communicates the recovery instructions to the crew	All the mitigations from APP_ATCO_x2 apply.
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	The APP ATCO does not detect the inadequate pilot response (to the recovery instruction) through readback and fails to monitor the situation such that to apply a corrective mitigation	No new requirement derived for the ATCO because it is considered that the monitoring of what the crew does after is given an instruction does not change compared to today's operations.
ATC failure to recover separation following imminent infringement due to one separation indicator not displayed or not timely available during the turn-on			
Inadequate separation management due to separation indicator not displayed or not timely available	See Hz#01a Fault Tree (ref A)	See Hz#01a table. The lack of separation indicator leads to separation minima infringement during the merging of the aircraft onto the final approach, which if not timely managed by ATC evolves into large under-separation	

during the turn-on.		(SMI>0.5NM).	
APP ATCO failure to detect the lack of indication affecting one aircraft.	APP_ATCO_8	APP ATCO does not detect the missing separation indicator and merges the aircraft onto the final approach without the required separation (missing indicator affecting one aircraft).	**SR1.093** in "normal conditions" **SR1.313:** If there is insufficient information to calculate a TDI then that TDI shall not be provided, together with a visual warning. **SR1.301:** If the required wind input to calculate a time based wake separation (TBS or WDS) is not available for an interval longer than a specific duration (to be determined based on local wind evolution analysis), then: • The Separation Delivery Tool shall continue displaying TDIs for aircraft that are already established on the final approach path and for which the last available TDIs computation includes a safety buffer managing the acceptable failure rate of the wind measurement; • The Separation Delivery Tool shall display TDIs for non-established aircraft based on conservative wind inputs for TDIs computation
APP ATCO failure to revert timely to DBS minima if lack of indicator is detected.	APP_ATCO_9	APP ATCO does not revert timely to DBS minima when missing indicator is detected.	Same mitigations as for APP_ATCO_x2 apply plus the following: **SR1.123** in "normal conditions"
APP ATCO failure to timely instruct	APP_ATCO_10	See above.	As for APP_ATCO_10 above

the adequate separation recovery action before the imminent infringement is evolving to a large under-separation during interception			
Inadequate Communication of recovery Instructions to pilot	ATCO-FCRW_1R	See above.	As for ATCO-FCRW_1R above
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	See above.	As for FCRW_1R above
ATC failure to recover separation following imminent infringement during interception despite correctly displayed separation indicator			
Inadequate separation management during interception despite correctly displayed separation indicator.	See Hz#01a Fault Tree (ref B)	See Hz#01a table. The inadequate separation management during interception (despite a correct display of the separation indicator) leads to separation minima infringement, which if not timely managed by ATC evolves into large under-separation (SMI>0.5NM).	
Inadequate Communication of recovery Instructions to pilot	ATCO-FCRW_1R	See above.	As for ATCO-FCRW_1R above
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	See above.	All mitigations from FCRW_1R above apply, plus the following additional mitigation: **SR1.310:** The Approach Controllers shall be alerted in case the aircraft instructed to turn onto the Target Distance Indicator on the runway extended centreline is not the one planned in the Arrival Sequencing Tool list. **SR1.311:** In case of sequence error alert the Approach Controllers shall perform corrective action to re-establish consistency between the

			actual sequence order and the Arrival Sequencing Tool list.
APP ATCO failure to timely instruct the adequate separation recovery action before the imminent infringement is evolving to a large under-separation during interception	APP_ATCO_10	ATCO fails to instruct speed adjustment instruction (depending on the triggering event) in order to solve the imminent infringement.	**SR1.080, SR 108, SR1.056, SR1.057, SR1.058** in "normal conditions" **SR1.328:** When spacing ITD is infringed by the aircraft, the ATCOs shall be aware of the next most constraining separation factor ITD and FTD (e.g. Wake or MRS) on the APPROACH and TOWER positions.

Table 31: Derivation of Mitigation/Safety Requirements for Hazard Hz#01b for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.4 Hz#01a (SO 201): Inadequate separation management of a pair of aircraft instructed by ATC to merge on the Final Approach interception

This hazard occurs during the Final approach interception.

Basic causes for such failures have been captured in the Hz#01a Fault Tree (See Figure 13).

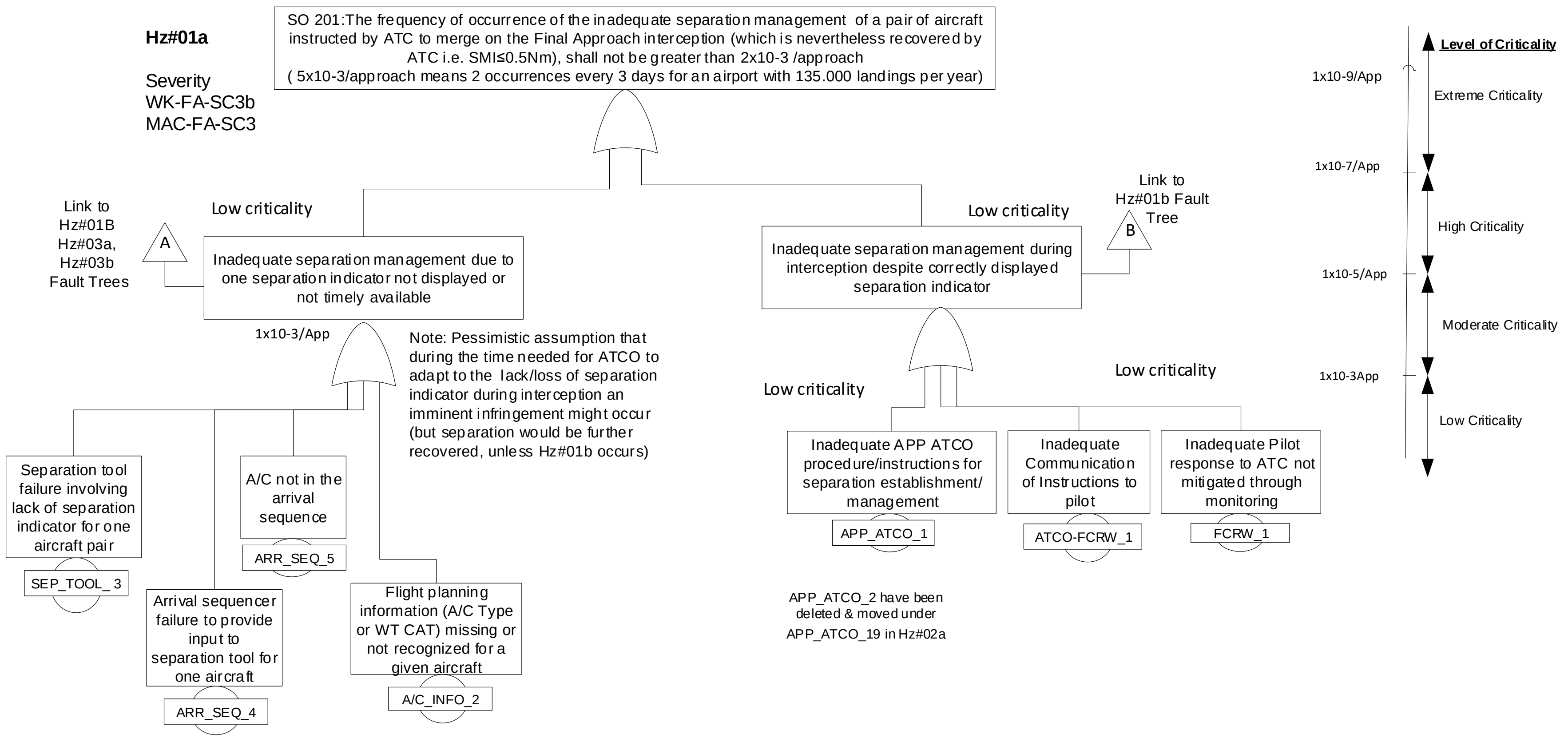


Figure 13: Hz#01a Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#01a Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Inadequate separation management due to one separation indicator not displayed or not timely available during the turn-on			
Separation tool failure involving lack of separation indicator for one aircraft pair.	SEP_TOOL_3	The separation tool fails to display the separation indicator for one aircraft or display it too late for the interception of the final approach.	**SR1.048 and SR1.037** in "normal conditions" **SR1.303:** Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors.
Arrival sequencer failure to provide input to separation tool for one aircraft.	ARR_SEQ_4	The arrival sequencer does not provide information to the separation tool for one aircraft despite inputs being correct.	**SR1.028** in "normal operations" **SR1.314**: If the Approach Arrival Sequence Service fails, the Separation Delivery tool shall continue displaying TDIs for aircraft already established and shall stop displaying TDIs for all other aircraft **SR1.315:** It shall be demonstrated that the data inputs including flight data, approach arrival sequence information and glideslope wind conditions to the Separation Delivery are sufficiently robust.
A/C not in the arrival sequence.	ARR_SEQ_5	An aircraft not planned for this arrival is authorized to land (e.g. aircraft in emergency).	**SR1.309:** If an aircraft that needs to be inserted in the arrival sequence cannot be input into the

			Arrival Sequence Service, the Approach Controller shall inhibit the Target Distance Indicator corresponding to the follower aircraft whose position in the actual sequence is taken by the newly inserted aircraft and the Approach Controller shall observe DBS WT Category separation for the impacted pairs of aircraft
Flight planning information (A/C Type or WT CAT) missing or not recognized for a given aircraft.	A/C_INFO_2	The separation tool does not receive or not recognize the aircraft type and/or the Wake Turbulence Category for one aircraft.	**SR1.085** in "normal conditions" **SR1.316:** At the first contact with the Approach, the flight crew shall provide the Aircraft type or alternatively this information could be provided to the Approach Controller via data link and the Approach Controller shall cross check this information with the information displayed on the CWP. **SR1.330:** Approach control shall check the validity of Flight Plan information displayed on the CWP (ICAO aircraft type, wake category). **SR1.321:** When a flight data input error (e.g. missing or wrong ICAO aircraft type or wake category) is detected, it shall be possible to update the corresponding information into the input for the separation delivery tool. **SR1.315:** It shall be demonstrated that the data inputs including flight data, approach arrival sequence information and glideslope wind

			conditions to the Separation Delivery are sufficiently robust. **SR1.326:** In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point.
Inadequate separation management during interception despite correctly displayed separation indicator			
Inadequate APP ATCO procedure/instructions for separation establishment/management	APP_ATCO_1	Approach controller is not aware or sufficiently informed on the new WT separation modes.	**SR1.117**, **SR1.050 and SR1.051** in "normal conditions"
Inadequate Communication of Instructions to pilot	ATCO-FCRW_1	As for ATCO-FCRW_1R in Hz#01b	
Inadequate Pilot response to ATC not mitigated through monitoring	FCRW_1		No new requirement derived for the ATCO because it is considered that the monitoring of what the crew does after is given an instruction does not change compared to today's operations.

Table 32: Derivation of Mitigation/Safety Requirements for Hazard Hz#01a for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.5 Hz#02b (SO 204): Separation not being recovered following imminent infringement due to aircraft deviation from Final Approach interception profile without ATC instruction given

This hazard occurs during the Final approach interception and its causes have been captured in the Hz#02b Fault Tree (See Figure 14).

Note: The combination between the occurrences of a Crew/Aircraft induced conflict and its inadequate separation management or separation recovery due to separation indicator not displayed or not timely available during the turn-on, for one or multiple aircraft, is not further analysed. Given that it displays a low probability, it is not dimensioning for the derivation of Safety Requirements

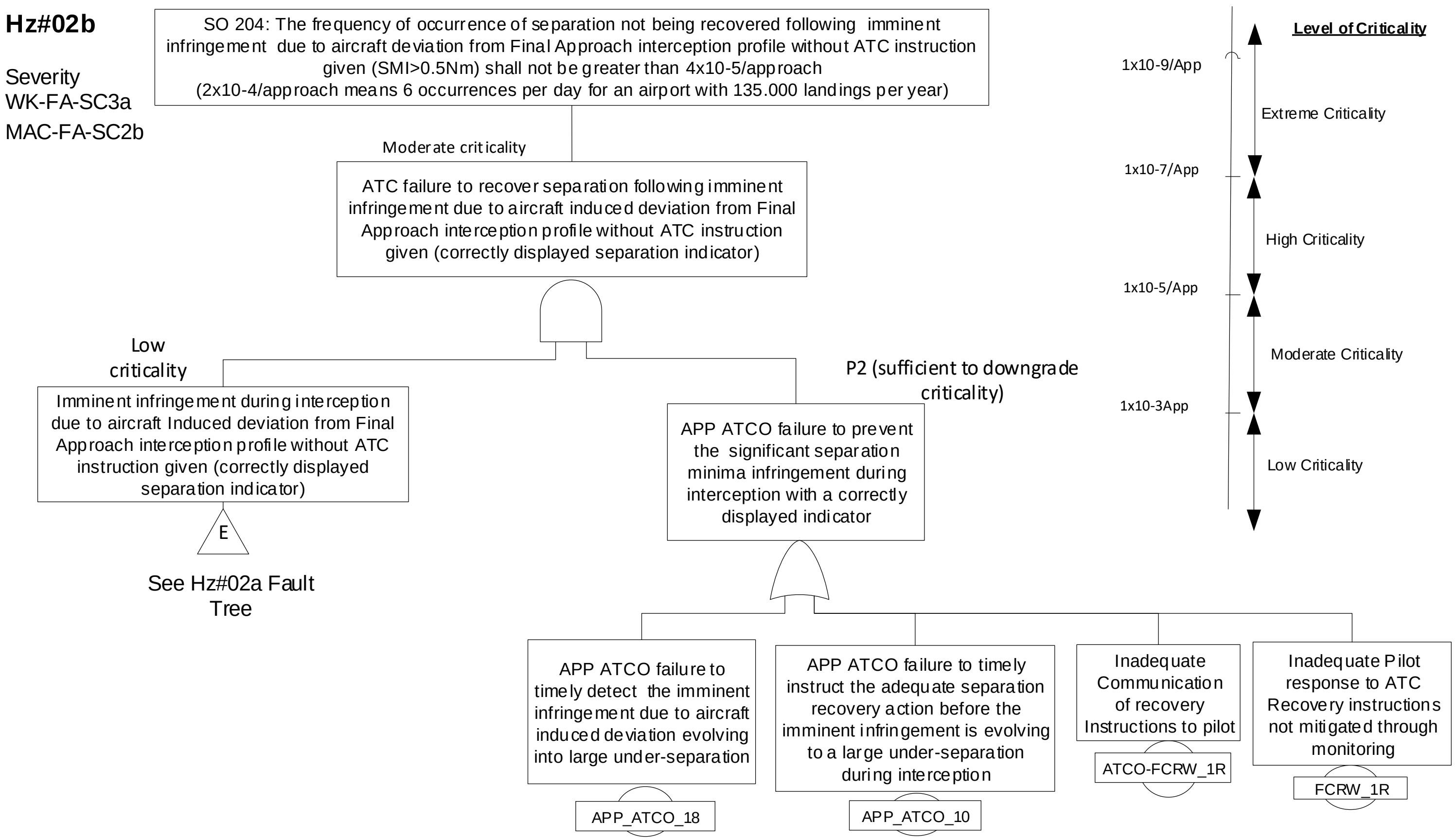


Figure 14: Hz#02b Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#02b Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Imminent infringement during interception due to aircraft Induced deviation from Final Approach interception profile without ATC instruction given (correctly displayed separation indicator)	See Hz#02a Fault Tree (ref E)	See Hz#02a table. The aircraft deviation from the cleared trajectory leads to an imminent infringement (SMI<0.5NM).	
APP ATCO failure to prevent the significant separation minima infringement during interception with a correctly displayed indicator			
APP ATCO failure to timely detect the imminent infringement due to aircraft induced deviation evolving into large under-separation	APP_ATCO_18	APP ATCO failure to timely detect the imminent infringement evolving into large under-separation (A/C deviation from cleared trajectory).	It is assumed that the approach controller verifies the adherence to the radar vectoring instruction, the actual aircraft speed and speed trend during the interception on the radar display (as per Baseline operations). **SR1.063, SR1.056, SR1.057, SR1.058, SR1.052** in “normal conditions” **SR1.328**: When spacing ITD is infringed by the aircraft, the ATCOs shall be aware of the next most constraining separation factor ITD and FTD (e.g. Wake or MRS) on the APPROACH and TOWER positions.

APP ATCO failure to timely instruct the adequate separation recovery action before the imminent infringement is evolving to a large under-separation during interception	APP_ATCO_10	APP ATCO failure to instruct timely a go around before the imminent infringement is evolving to a large under-separation during interception.	**SR1.080, SR1.083** in "normal conditions" **SR1.037:** The Separation Delivery tool shall provide to ATCOs a visualisation (FTD indicator) of the required minimum separation or spacing on final approach that needs to be delivered after considering all in-trail and if applicable not-in-trail constraints. SR1.038: If the ORD concept is considered, the Separation Delivery tool shall provide to ATCOs a visualisation (ITD indicator) of the required spacing on final approach to be delivered at the deceleration fix in order to deliver the required minimum separation / spacing at the delivery point.
Inadequate Communication of recovery Instructions to pilot	ATCO-FCRW_1R	As for ATCO-FCRW_1R in Hz#01b when the indicators are correctly displayed	
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	As for FCRW_1R in Hz#01b	

Table 33: Derivation of Mitigation/Safety Requirements for Hazard Hz#02b for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.6 Hz#02a (SO 203): Inadequate separation management of a spacing conflict due to aircraft deviation from final approach interception profile without ATC instruction given

This hazard occurs during the Final approach interception and its causes have been captured in the Hz#02a Fault Tree (See Figure 15).

Note: The combination between the occurrences of a Crew/Aircraft induced conflict and its inadequate separation management due to separation indicator not displayed or not timely available during the turn-on, for one or multiple aircraft, is not further analysed. Given that it displays a low probability, it is not dimensioning for the derivation of Safety Requirements.

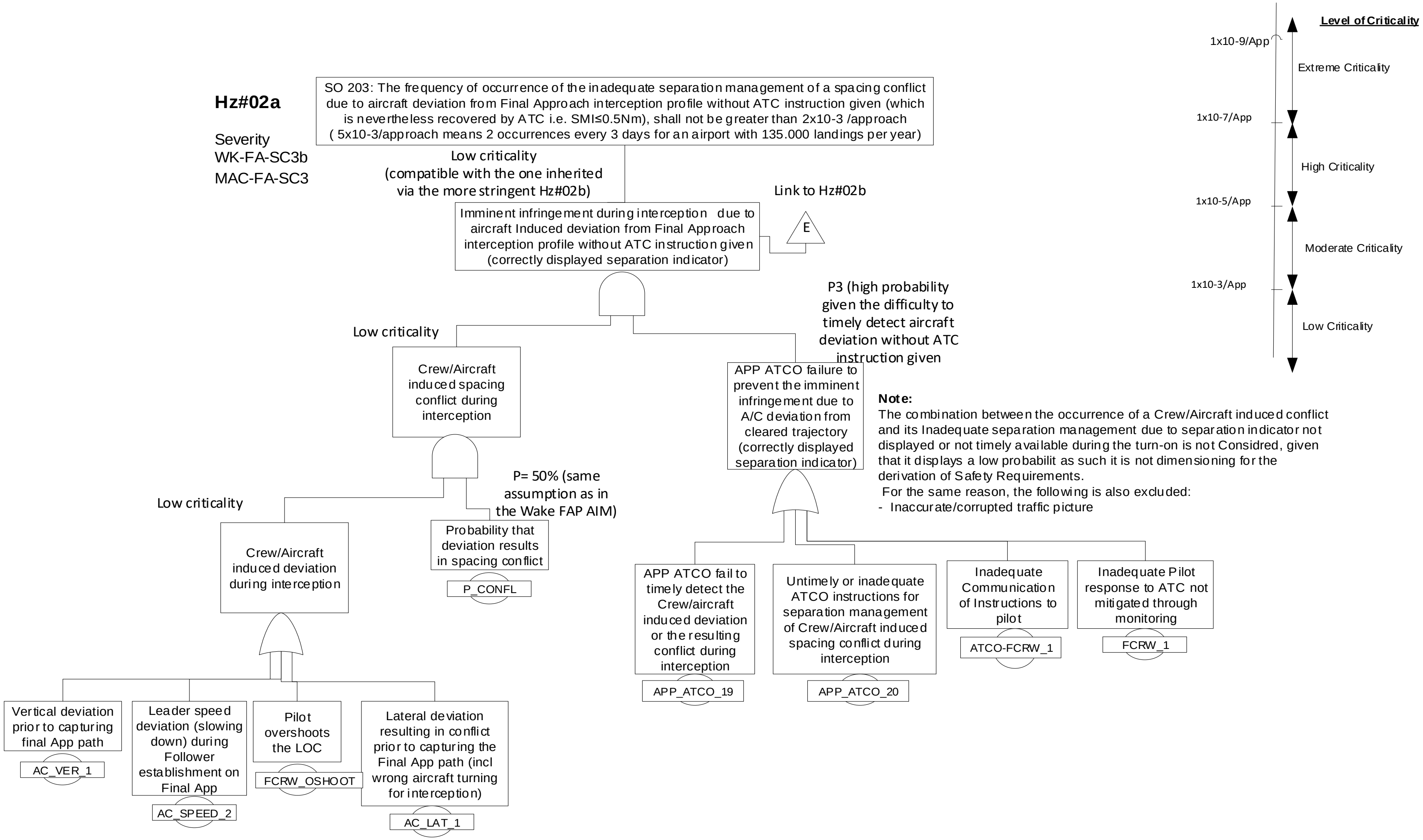

Hz#02a
Severity
WK-FA-SC3b
MAC-FA-SC3
SO 203: The frequency of occurrence of the inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach interception profile without ATC instruction given (which is nevertheless recovered by ATC i.e. SMI≤0.5Nm), shall not be greater than 2x10-3 /approach (5x10-3/approach means 2 occurrences every 3 days for an airport with 135.000 landings per year)
Low criticality (compatible with the one inherited via the more stringent Hz#02b)
Link to Hz#02b
E
Imminent infringement during interception due to aircraft Induced deviation from Final Approach interception profile without ATC instruction given (correctly displayed separation indicator)
Low criticality
Crew/Aircraft induced spacing conflict during interception
P3 (high probability given the difficulty to timely detect aircraft deviation without ATC instruction given
APP ATCO failure to prevent the imminent infringement due to A/C deviation from cleared trajectory (correctly displayed separation indicator)
P= 50% (same assumption as in the Wake FAP AIM)
Low criticality
Crew/Aircraft induced deviation during interception
Probability that deviation results in spacing conflict
P_CONFL
APP ATCO fail to timely detect the Crew/Aircraft induced deviation or the resulting conflict during interception
APP_ATCO_19
Untimely or inadequate ATCO instructions for separation management of Crew/Aircraft induced spacing conflict during interception
APP_ATCO_20
Inadequate Communication of Instructions to pilot
ATCO-FCRW_1
Inadequate Pilot response to ATC not mitigated through monitoring
FCRW_1
Vertical deviation prior to capturing final App path
AC_VER_1
Leader speed deviation (slowing down) during Follower establishment on Final App
AC_SPEED_2
Pilot overshoots the LOC
FCRW_OSHOOT
Lateral deviation resulting in conflict prior to capturing the Final App path (incl wrong aircraft turning for interception)
AC_LAT_1
Note:
The combination between the occurrence of a Crew/Aircraft induced conflict and its Inadequate separation management due to separation indicator not displayed or not timely available during the turn-on is not Considred, given that it displays a low probabilit as such it is not dimensioning for the derivation of Safety Requirements.
For the same reason, the following is also excluded:
- Inaccurate/corrupted traffic picture
Level of Criticality
1x10-9/App
Extreme Criticality
1x10-7/App
High Criticality
1x10-5/App
Moderate Criticality
1x10-3/App
Low Criticality

Figure 15: Hz#02a Fault tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#02a Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Crew/Aircraft induced spacing conflict during interception			
Vertical deviation prior to capturing final App path.	AC_VER_1	The vertical deviation from instructed interception altitude might involve capturing final approach path from above or below with impact on the actual speed profile (which will be different from the TAS profile used by the separation tool). As a consequence in TB-modes the FTD computation will be erroneous and the ITD will be erroneous in all modes.	**SR1.110** in "normal conditions"
Leader speed deviation (slowing down) during Follower establishment on Final App	AC_SPEED_2	The leader aircraft slows down when the follower intercepts the final approach path	**SR1.110** in "normal conditions"
Pilot overshoots the LOC.	FCRW_OSHOOT		Same occurrence& effect as per current operations.
Lateral deviation resulting in conflict prior to capturing the Final App path (incl wrong aircraft turning for interception)	AC_LAT_1		**SR1.310:** The Approach Controllers shall be alerted in case the aircraft instructed to turn onto the Target Distance Indicator on the runway extended centreline is not the one planned in the Arrival Sequencing Tool list. **SR1.311:** In case of sequence error alert the Approach Controllers shall perform corrective action to re-establish consistency between the actual sequence order and the Arrival Sequencing Tool list.
APP ATCO failure to prevent the imminent infringement due to A/C deviation from cleared trajectory (correctly displayed separation			

indicator)			
APP ATCO fail to timely detect the deviation from the cleared trajectory or the resulting conflict during interception.	APP_ATCO_19	APP ATCO does not detect timely the aircraft deviation from the cleared trajectory because she/he is vectoring or adjusting trajectories of other aircraft merging to the final approach.	It is assumed that the Approach Controller monitors all traffic merging to the final approach to detect any deviation from instructed profile. It is assumed that the Approach Controller asks to correct the aircraft trajectory (heading, speed or altitude) during the approach interception if she/he thinks that it will solve the spacing conflict, i.e. avoid imminent infringement. If not she/he takes corrective actions like initiating missed approach. The level of APP ATCO workload and Situation Awareness in the new separation modes (with tool) during interception have been validated as acceptable; thus a reduction of APP ATCO capability to detect Crew/Aircraft induced spacing conflict during interception is not expected.
Untimely or inadequate ATCO instructions for separation management of Crew/Aircraft induced spacing conflict during interception.	APP_ATCO_20	Upon detection, APP ATCO does not instruct timely or adequately for ensuring separation management of Crew/Aircraft induced spacing conflict during interception.	The level of APP ATCO workload and Situation Awareness in the new separation modes (with tool) during interception have been validated as acceptable; thus a reduction of APP ATCO capability to detect Crew/Aircraft induced spacing conflict during interception is not expected.
Inadequate Communication of Instructions to pilot	ATCO-FCRW_1	As for ATCO-FCRW_1R in Hz#01b when the indicators are correctly displayed	
Inadequate Pilot response to ATC not mitigated through monitoring	FCRW_1	As for ATCO-FCRW_1R in Hz#01b	

Table 34: Derivation of Mitigation/Safety Requirements for Hazard Hz#02a for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.7 Hz#03b (SO 206): Separation not being recovered following imminent infringement by an aircraft pair instructed by ATC on the Final Approach

This hazard occurs during the Final approach and its basic causes and combinations thereof have been captured in the Hz#03b Fault Tree (See Figure 16).

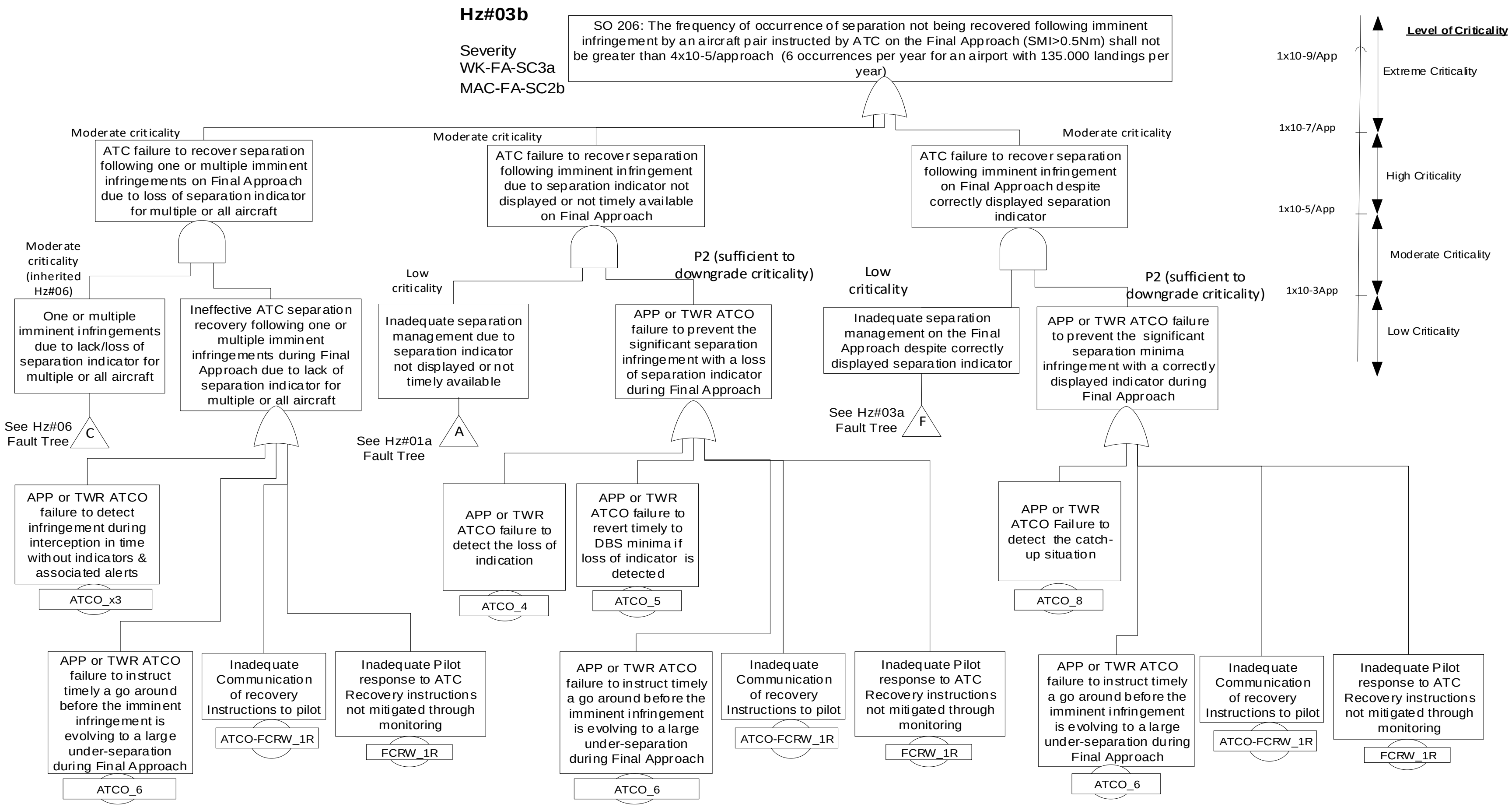


Figure 16: Hz#03b Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#03b Fault Tree and identifies the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
ATC failure to recover separation following one or multiple imminent infringements on Final Approach due to loss of separation indicator for multiple or all aircraft			
One or multiple imminent infringements due to lack/loss of separation indicator for multiple or all aircraft.	See Hz#06 Fault Tree (ref C)	See Hz#06 table.	
APP or TWR ATCO failure to instruct timely a go around before the imminent infringement is evolving to a large under-separation during Final Approach.	ATCO_6	APP or TWR ATCO failure to instruct timely a go around before the imminent infringement is evolving to a large under-separation during Final Approach.	**SR1.303:** Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors. **SR1.329:** Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.) **SR1.331:** In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be instructed to break-off)

			SR1.326: In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point. **SR1.327:** In case of Separation Tool Failure, the Supervisors and Controllers shall receive a message containing the source of the tool failure
APP or TWR ATCO failure to detect infringement during interception in time without indicators & associated alerts	ATCO_x3	Not having the indicators and associated alerts, APP or TWR ATCO fails to detect in time the infringement at interception	As for ATCO_6
Inadequate Communication of recovery Instructions to pilot	ATCO-FCRW_1R	As for ATCO-FCRW_1R in Hz#01b when the indicators are not displayed	
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	As for FCRW_1R in Hz#01b	
ATC failure to recover separation following imminent infringement due to separation indicator not displayed or not timely available on Final Approach			
Inadequate separation management due to separation indicator not displayed or not timely available.	See Hz#01a Fault Tree (ref A)	See Hz#01a table. The detected loss of separation indicator during the final approach may lead to imminent infringement.	
APP or TWR ATCO failure to detect	ATCO_4	APP or TWR ATCO does not detect the loss of	**SR1.306:** Approach and Tower Supervisors shall

the loss of indication.		separation indicator in order to prevent the separation infringement.	be made aware if any tool / monitoring / alerting features are lost or inoperative.
APP or TWR ATCO failure to revert timely to DBS minima if loss of indicator is detected.	ATCO_5	APP or TWR ATCO does not revert timely to DBS minima when the loss of indicator is detected.	**SR1.123** in "normal conditions" **SR1.329:** Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.)
APP or TWR ATCO failure to instruct timely a go around before the imminent infringement is evolving to a large under-separation during Final Approach.	ATCO_6	As above.	As for ATCO_6 above
Inadequate Communication of recovery Instructions to pilot	ATCO-FCRW_1R	As for ATCO-FCRW_1R in Hz#01b when the indicators are not displayed	
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	As for FCRW_1R in Hz#01b	
ATC failure to recover separation following imminent infringement on Final Approach despite correctly displayed separation indicator			
Inadequate separation management on the Final Approach despite correctly displayed separation indicator.	See Hz#03a Fault Tree (ref F)	See Hz#03a table. Inadequate separation management on the Final Approach despite correctly displayed separation indicator may lead to imminent infringement.	
APP or TWR ATCO Failure to detect the catch-up situation.	ATCO_8	APP or TWR ATCO does not detect the catch up situation involving imminent infringement despite correct separation indicator is displayed.	**SR1.063** in "normal conditions"

APP or TWR ATCO failure to instruct timely a go around before the imminent infringement is evolving to a large under-separation during Final Approach.	ATCO_6	As per ATCO_6 above	As per ATCO_6 above. The following mitigation also applies, when applying WDS-Xw: **SR1.302:** In case of WDS cross wind, when the leader and follower are established on the glideslope, the Approach and Tower controllers shall be able to give heading instructions (e.g. break-off) to the follower only upwind and not downwind.
Inadequate Communication of recovery Instructions to pilot	ATCO-FCRW_1R	As for ATCO-FCRW_1R in Hz#01b when the indicators are correctly displayed	
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	As for FCRW_1R in Hz#01b	

Table 35: Derivation of Mitigation/Safety Requirements for Hazard Hz#03b for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.8 Hz#03a (SO 205): Inadequate separation management of an aircraft pair naturally catching-up as instructed by ATC on the Final Approach

This hazard occurs during the Final approach and its basic causes and combinations thereof have been captured in the Hz#03a Fault Tree (See Figure 17).

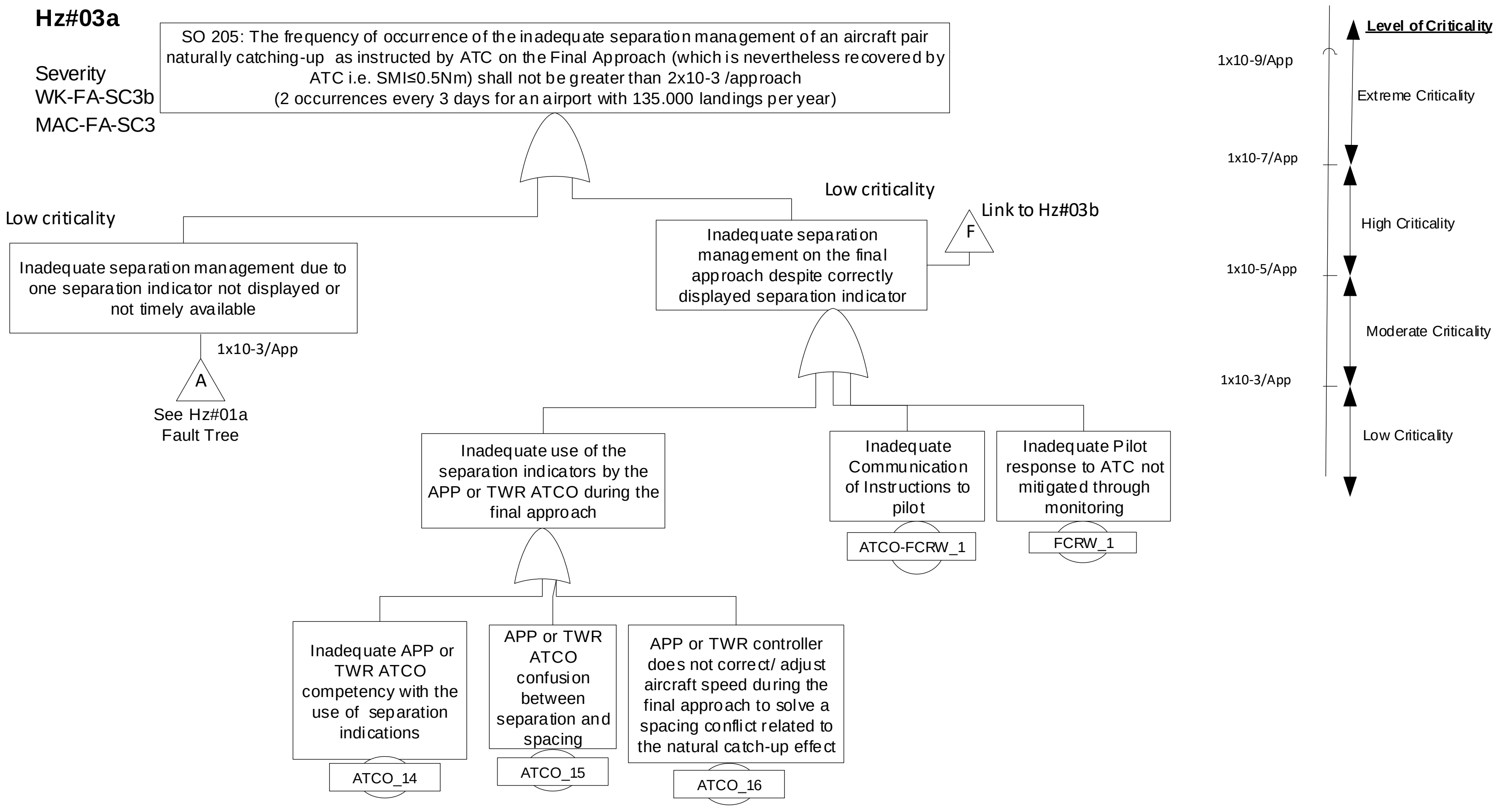


Figure 17: Hz#03a Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#03a Fault Tree and identifies the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Inadequate separation management due to separation indicator not displayed or not timely available.	See Hz#01a Fault Tree. (ref A)	See Hz#01a table. The inadequate separation management due to separation indicator not displayed or not timely available leads to an imminent infringement during the final approach considering the aircraft pair (SMI<0.5NM).	
Inadequate separation management on the final approach despite correctly displayed separation indicator			
Inadequate use of the separation indicators by the approach or Tower controller during the Final Approach.	ATCO_14	Inadequate APP or TWR ATCO competency with the use of separation indicators.	**SR1.117, SR1.118 and SR1.124** in "normal conditions"
	ATCO_15	APP or TWR ATCO confusion between separation (e.g. MRS, wake) and spacing indicators (e.g. ROT).	**SR1.090** in "normal conditions"
	ATCO_16	APP or TWR controller does not correct/ adjust aircraft speed during the final approach to solve a spacing conflict related to the natural catch-up effect.	**SR1.063**, **SR1.056, SR1.057, SR1.058, SR1.053, SR1.054, SR1.052 and SR1.103** in "normal conditions" **SR1.214 and SR1.215** in "abnormal conditions"
Inadequate Communication of Instructions to pilot	ATCO-FCRW_1	As for ATCO-FCRW_1R in Hz#01b when the indicators are correctly displayed	
Inadequate Pilot response to ATC not mitigated through monitoring	FCRW_1	As for FCRW_1R in Hz#01b	

Table 36: Derivation of Mitigation/Safety Requirements for Hazard Hz#03a for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.9 Hz#04b (SO 208): Separation not being recovered following imminent infringement due to aircraft deviation from Final Approach profile without ATC instruction given

This hazard occurs during the Final approach and its basic causes and combinations thereof have been captured in the Hz#04b Fault Tree (See Figure 18).

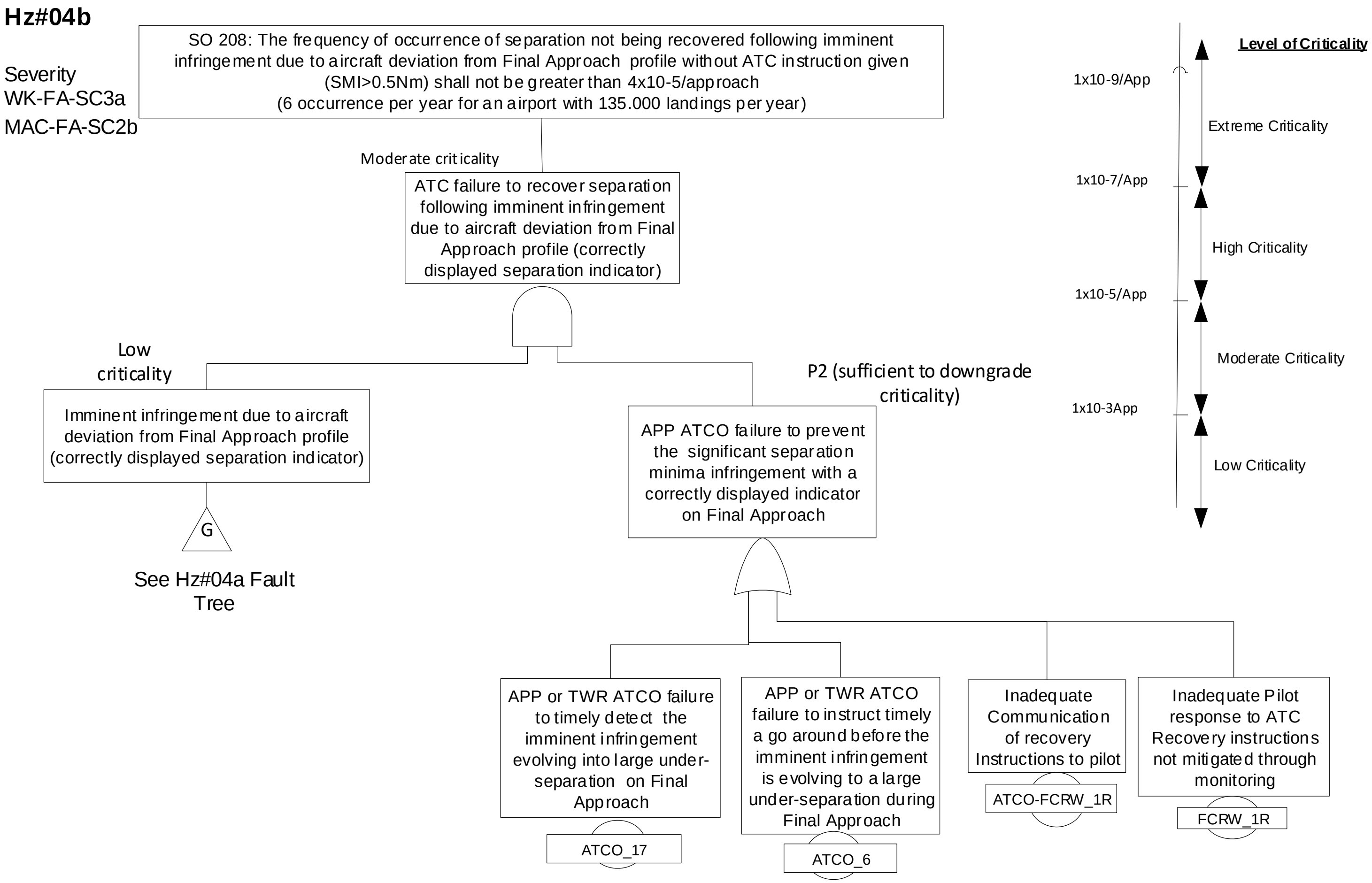


Figure 18: TB Hz#04b Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#04b Fault Tree and identifies the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Imminent infringement during interception due to aircraft deviation from Final Approach profile (correctly displayed separation indicator).	See Hz#04a Fault Tree (ref G)	See Hz#02a table.	
APP ATCO failure to prevent the significant separation minima infringement with a correctly displayed indicator			
APP or TWR ATCO failure to timely detect the imminent infringement evolving into large under-separation on Final Approach.	ATCO_17	Aircraft deviates from speed instructions or from the nominal stabilized approach speed and APP or TWR ATCO does not detect the catch up situation with imminent infringement evolving into large under-separation despite correct separation indicator is displayed.	It is assumed that the approach and tower controller verifies the actual speed of the aircraft and the speed trend during the final approach. **SR1.063, SR1.215, SR1.053, SR1.054, SR1.056, SR1.057, SR1.058, SR1.052** in "normal conditions" **SR1.214** in "abnormal conditions"
APP or TWR ATCO failure to instruct timely a go around before the imminent infringement is evolving to a large under-separation during Final Approach.	ATCO_6	APP or TWR ATCO failure to instruct timely a go around before the imminent infringement is evolving to a large under-separation during Final Approach.	As per ATCO_6 in Hz#03b
Inadequate Communication of	ATCO-FCRW_1R	As for ATCO-FCRW_1R in Hz#01b when the indicators are correctly	

recovery Instructions to pilot		displayed	
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	As for FCRW_1R in Hz#01b	

Table 37: Derivation of Mitigation/Safety Requirements for Hazard Hz#04b for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.10 Hz#04a (SO 208): Inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach profile without ATC instruction given

This hazard occurs during the Final approach and its basic causes and combinations thereof have been captured in the Hz#04a Fault Tree.

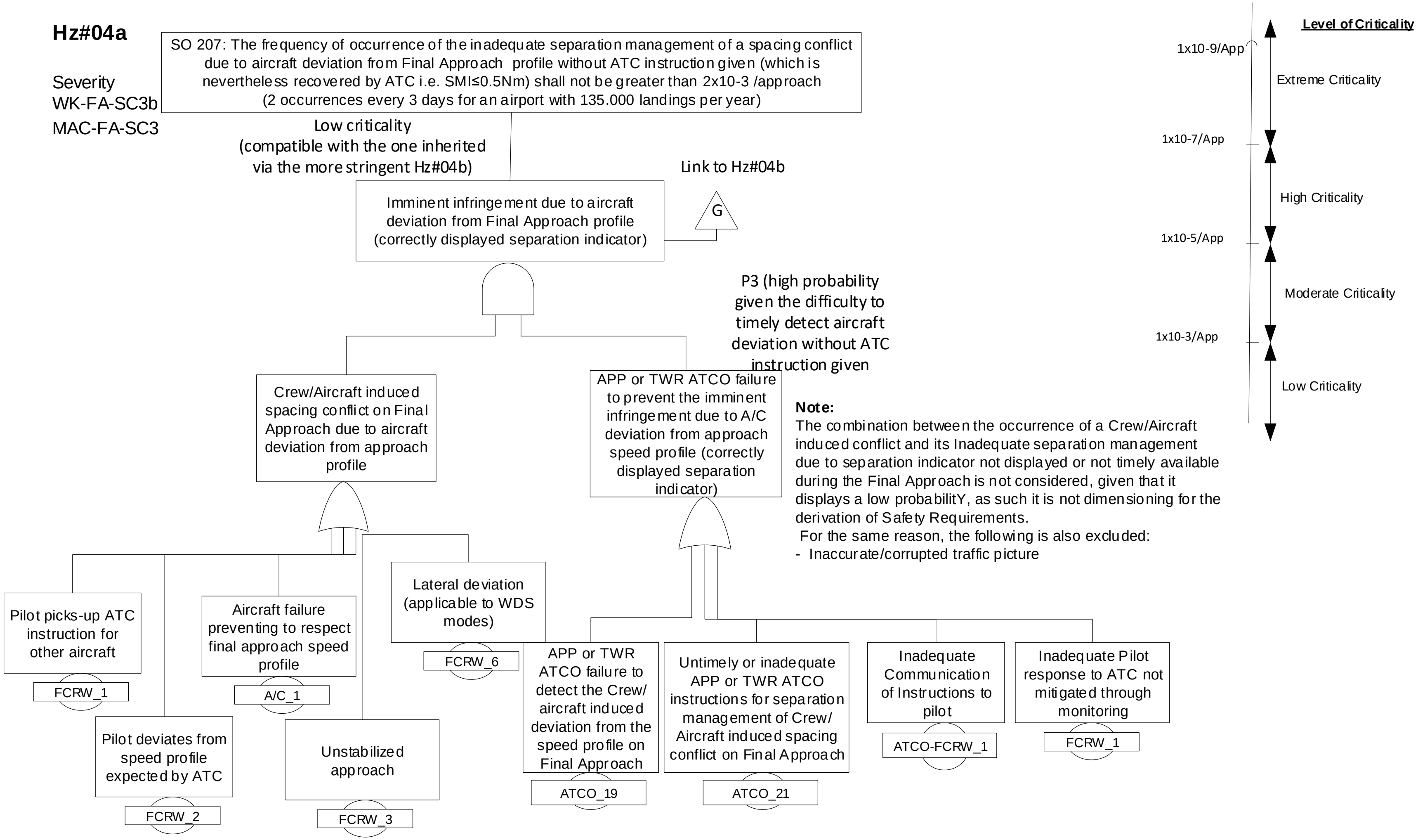


Figure 19: Hz#04a Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#04a Fault Tree and identifies the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Crew/Aircraft induced spacing conflict on Final Approach due to aircraft deviation from approach profile			
Pilot picks-up ATC instruction for other aircraft.	FCRW_1	Pilot picks-up ATC instruction for other aircraft.	No specific SR for radio communication. Current read-back/hear-back procedures to be applied.
Pilot deviates from speed profile expected by ATC.	FCRW_2	Pilot deviates from speed profile expected by ATC.	**SR1.110** in “normal conditions”
Aircraft failure preventing to respect final approach speed profile.	AC_1	Aircraft failure (slat, flap, engine,…) led to the impossibility to respect the approach speed profile.	**SR1.110** in “normal conditions”
Un-stabilized approach.	FCRW_3	Failure of the Flight crew to assess or to manage the aircraft's energy during the approach.	**SR1.119** in “normal conditions”
Lateral deviation (applicable to WDS modes)	FCRW_6	While in WDS-Xw, the flight crew deviates laterally down-wind (towards where the wake is transported) from the final approach glide path	**SR1.113** in “normal operations”
APP or TWR ATCO failure to prevent the imminent infringement due to A/C deviation from approach speed profile (correctly displayed separation indicator)			
APP or TWR ATCO failure to detect the Crew/aircraft induced deviation from the speed profile on Final Approach	ATCO_19	APP or TWR ATCO does not detect timely the aircraft deviation from the speed profile.	**SR1.214 and SR1.215** in “abnormal conditions” **SR1.110 and SR1.124** in “normal conditions”

Untimely or inadequate APP or TWR ATCO instructions for separation management of Crew/Aircraft induced spacing conflict on Final Approach	ATCO_21	Upon detection, APP or TWR ATCO does not instruct timely or adequately for ensuring separation management of Crew/Aircraft induced spacing conflict during interception.	Level of APP ATCO workload and Situation Awareness in the new separation modes (with tool) during interception have been validated as acceptable; thus a reduction of APP ATCO capability to detect Crew/Aircraft induced spacing conflict during interception is not expected.
Inadequate Communication of recovery Instructions to pilot	ATCO-FCRW_1R	As for ATCO-FCRW_1R in Hz#01b when the indicators are correctly displayed	
Inadequate Pilot response to ATC Recovery instructions not mitigated through monitoring	FCRW_1R	As for FCRW_1R in Hz#01b	

Table 38: Derivation of Mitigation/Safety Requirements for Hazard Hz#04a for the PJ02.01 Arrivals Concepts Solutions

4.1.5.1.11 Hz#08 (SO 212) runway conflict due to landing clearance in conflict with another landing (ROT not respected) or with cleared line-up/take-off (GAP not respected)

This hazard occurs during mixed mode of operation and its basic causes and combinations thereof have been captured in the Hz#08 Fault Tree.

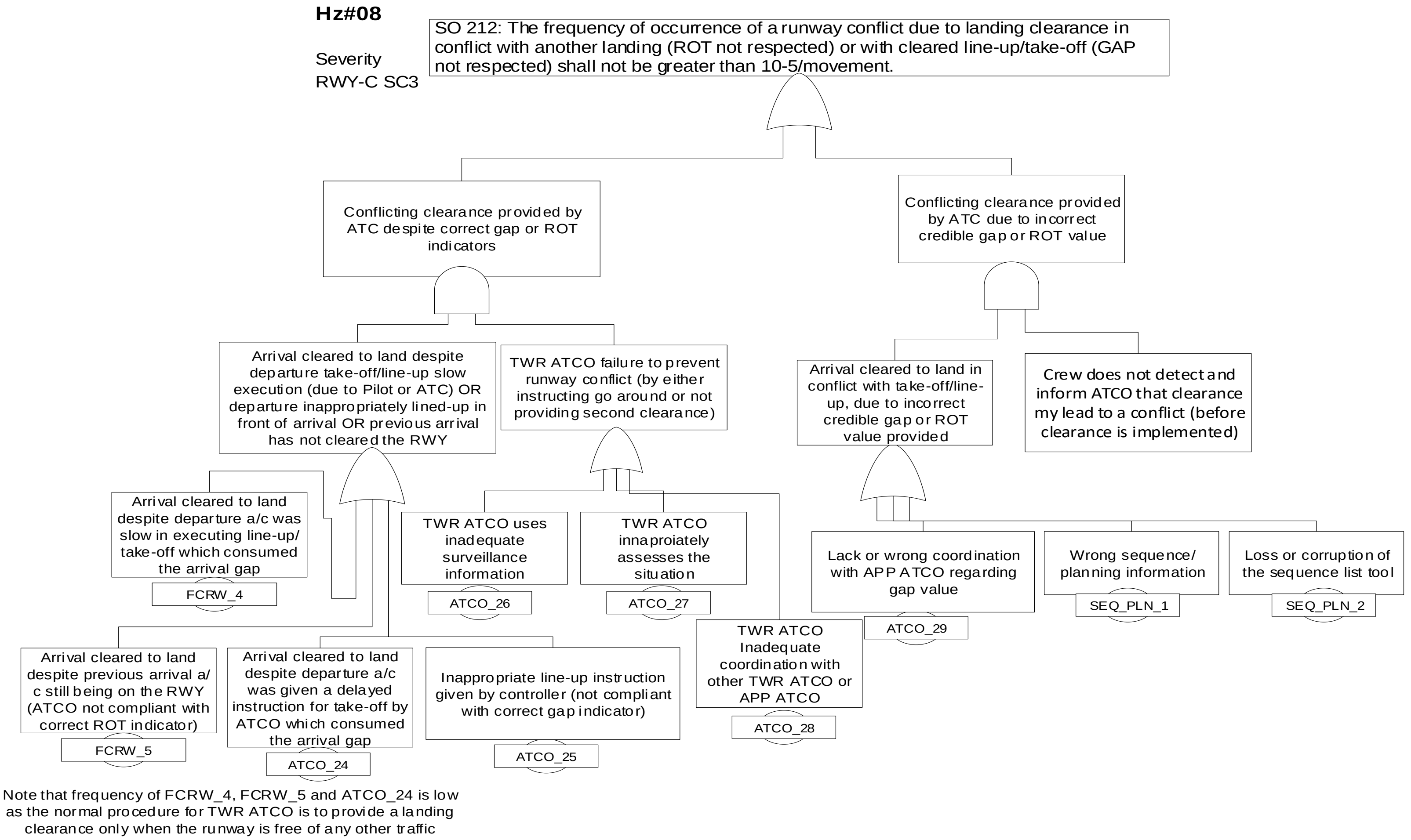


Figure 20 Hz#08 Fault Tree for the PJ02.01 Arrivals Concepts Solutions

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Conflicting clearance provided by ATC despite correct gap or ROT indicators			
Arrival cleared to land despite departure a/c was slow in executing line-up/take-off which consumed the arrival gap	FCRW_4	ATCO gives a line-up/take-off clearance, but because the pilot was slow in executing the line-up/take-off, the gap is consumed, ATCO doesn't check and clears the second a/c to land.	**SR1.089** in "normal conditions"
Arrival cleared to land despite previous arrival a/c still being on the RWY (ATCO not compliant with correct ROT indicator)	FCRW_5	ATCO is not compliant with the ROT indicator	As above
Arrival cleared to land despite departure a/c was given a delayed instruction for take-off by ATCO which consumed the arrival gap	ATCO_24	ATCO gives a correct line-up clearance and then is late to give the take-off clearance to the same a/c and by the time he gives the landing clearance he realises the gap is not enough.	As above
Inappropriate line-up instruction given by controller (not compliant with correct gap indicator)	ATCO_25	ATCO misjudges the gap time	As above
Conflicting clearance provided by ATC due to incorrect credible gap or ROT value			
Lack or wrong coordination with	ATCO_29	The arrival gap time is wrongly or not coordinated with the	This is not changed compared to current

APP ATCO regarding gap value		TWR ATCO which results in a runway conflict	operations. Additionally, the following mitigation applies: **SR1.072:** The separation delivery tool shall provide confirmation to ATCO that the gap spacing insertion is successful or not.
Wrong sequence/planning information	SEQ_PLN_1		**SR1.033, SR1.032, SR1.034, SR1.093** "normal conditions" and **SR1.200** "abnormal conditions" **SR1.300:** Controllers shall be trained to check the aircraft landing runway intent and that the aircraft order is correct and coherent with the arrival sequence list. They shall check if and that the aircraft order is displayed in the arrival sequence list and/or if the aircraft sequence number is displayed in the radar label in accordance with their intended sequence.
Loss or corruption of the sequence list tool	SEQ_PLN_2		Corruption of the sequence list: mitigated through the software assurance process which defines the acceptably safe level of confidence in the arrival sequence service prior to implementation. **SR1.317:** The software assurance level of the Separation Delivery tool and supporting tools shall be determined by the V4 safety assessment As for the loss of the arrival sequence service: **SR1.314:** If the Approach Arrival Sequence Service fails, the Separation Delivery tool shall continue

			displaying TDIs for aircraft already established and shall stop displaying TDIs for all other aircraft

4.1.5.1.12 Hz#07 (SO 211): One or multiple separation minima infringements induced by ATC through inadequate selection & management of a time-based separation mode

This hazard occurs during the execution phase due to an erroneous selection or management of the separation mode, in relation to the conditional activation of the time-based WT separation modes and ATC tools (TBS, TB-S-PWS, TB-WDS or TB-WD-PWS).

Basic causes for such failures have been captured in the Hz#07 Fault Tree (See Figure 21).

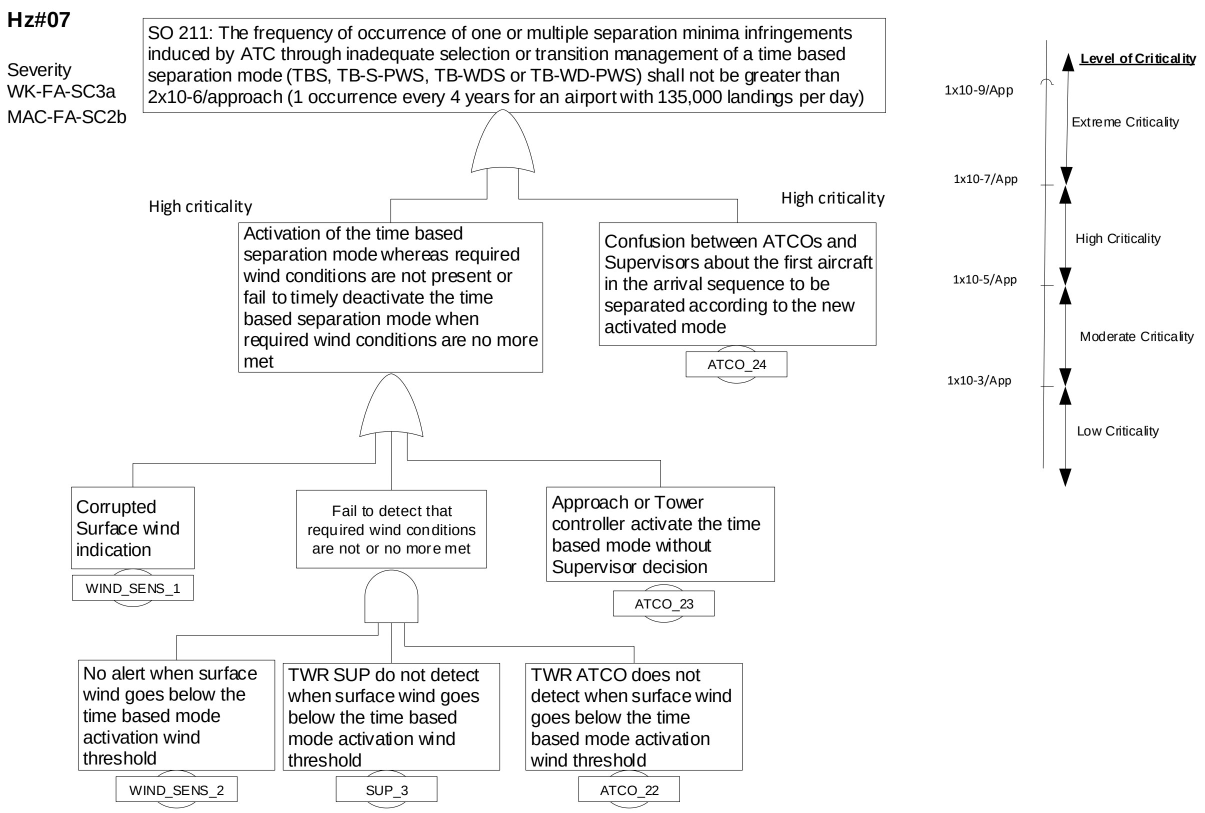


Figure 21: Hz#07 Fault Tree for the PJ02.01 Arrivals Concepts Solutions

The table below describes the basic causes of the Hazard Hz#07 Fault Tree and identifies the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Corrupted surface wind indication.	WIND_SENS_1	Surface wind sensor provides to ATC wrong surface wind information.	**SR1.315:** It shall be demonstrated that the data inputs including flight data, approach arrival sequence information and glideslope wind conditions to the Separation Delivery are sufficiently robust.

No alert when surface wind goes below the time based mode activation threshold wind.	WIND_SENS_2	ATC is not automatically informed when surface wind goes below the Time Based PWS activation wind threshold.	**SR1.024 and SR1.025** in "normal conditions" **SR1.207, SR1.208, SR1.209, SR1.210, SR1.211, SR1.212** in "abnormal conditions" **SR1.325**: Approach and Tower Supervisors shall be alerted when the wind monitoring function for the conditional application of the TB modes (glideslope headwind, total wind, cross wind) are lost or inoperative (encompassing loss of wind input)
Tower Supervisor does not detect that surface wind goes below the time based mode activation wind threshold.	SUP_3	TWR supervisor did not notice that required surface wind conditions are not or no more satisfied.	as above
Tower Controller does not detect that surface wind goes below time based mode activation wind threshold.	ATCO_22	TWR controllers did not notice that required surface wind conditions are no more satisfied.	as above
Approach or Tower controller activate the time based mode without Supervisor decision	ATCO_23	APP or TWR ATCO activates the time based mode in their CWP whereas required wind conditions are not satisfied.	**SR1.312**: The Separation Delivery tool implementation shall forbid the Approach and/or Tower Controller the possibility to activate the TB-WDS-A modes. **SR1.012 and SR1.013 in** "normal conditions"
Confusion between ATCOs and Supervisors about the first aircraft in the arrival sequence to be separated according to the new activated mode	ATCO_24		**SR1.120** from "normal operations"

Table 39: Derivation of Mitigation/Safety Requirements for Hazard Hz#07 for the PJ02.01 Arrivals Concepts Solutions

4.1.5.2 Common Cause Analysis for the Arrivals Concepts Solutions

The main common causes have been identified through an initial causal analysis of the successive WTA AIM barriers B3, B4, B5, B6 and B3a. They are related to the use of the separation indicators, as a lack of information, or incorrect information would affect all those ATM safety barriers.

To deal with the common causes, two dedicated operational hazards have been defined, and risk appropriately assessed and mitigated:

- **Hz#05**: One or multiple imminent infringements not detected and not recovered due to undetected corruption of separation indicator
- **Hz#06**: One or multiple imminent infringements due to lack of separation indicator for multiple or all aircraft.

4.1.5.3 Formalization of Mitigations for the Arrivals Concepts Solutions

This section derives the mitigations to reduce the likelihood that specific failures would propagate up to the Hazard (i.e. operational level) – these mitigations are then captured as additional Safety Requirements (Functional and Performance).

Considering the outcome of the causal analysis (see Section 4.1.5.1) and more particularly the Mitigations identified in each table accompanying the hazard fault trees.

The table below summarizes the safety requirements (functionality & performance) that have been derived in order to mitigate risk associated to the system generated hazards (i.e. mitigation which have not been already captured during the design analysis in Normal operations or in presence of Abnormal conditions).

SO/Hz	SRs	SR Description
SO 201 / Hz#01a	SR1.028 REQ-02.01-SPRINTEROP-ARR0.0300	The approach arrival sequence information shall be provided to the Separation Delivery tool.
	SR1.037 REQ-02.01-SPRINTEROP-ARR0.0110	The Separation Delivery tool shall provide to ATCOs a visualisation (FTD indicator) of the required minimum separation or spacing on final approach that needs to be delivered after considering all in-trail and if applicable not-in-trail constraints.
	SR1.048 REQ-02.01-SPRINTEROP-ARR0.0630	Criteria to determine the time for displaying indicators for each CWP shall be specified depending upon the local operation's needs.
	SR1.050 REQ-02.01-SPRINTEROP-ARR3.1000	If the ORD concept is implemented, the Final Approach Controller shall maintain the aircraft on or behind the ITD on the final approach and reduce to the final approach procedural airspeed until the transfer to the Tower controller.
	SR1.051 REQ-02.01-SPRINTEROP-	If the ORD concept is implemented, the Approach controller shall vector the follower aircraft so that it stays on or behind the

	ARR3.0170	corresponding ITD.
	SR1.085 REQ-02.01-SPRINTEROP-ARR0.0220	Aircraft identifier, ICAO aircraft type and wake category for all arrival aircraft, including subsequent updates to this information, shall be provided to the Separation Delivery tool.
	SR1.303 REQ-02.01-SPRINTEROP-ARR0.1010	Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors.
	SR1.309 REQ-02.01-SPRINTEROP-ARR0.1570	If an aircraft that needs to be inserted in the arrival sequence cannot be input into the Arrival Sequence Service, the Approach Controller shall inhibit the Target Distance Indicator corresponding to the follower aircraft whose position in the actual sequence is taken by the newly inserted aircraft and the Approach Controller shall observe DBS WT Category separation for the impacted pairs of aircraft
	SR1.117 REQ-02.01-SPRINTEROP-ARR0.1250	Approach and Tower Controllers shall be fully trained to apply the procedures for the new separation modes and to use of the Separation Delivery Tool and supporting systems (e.g. alerts) with indicators prior to deployment.
	SR1.314 REQ-02.01-SPRINTEROP-ARR0.1720	If the Approach Arrival Sequence Service fails, the Separation Delivery tool shall continue displaying TDIs for aircraft already established and shall stop displaying TDIs for all other aircraft
	SR1.315 REQ-02.01-SPRINTEROP-ARR0.0400	It shall be demonstrated that the data inputs including flight data, approach arrival sequence information and glideslope wind conditions to the Separation Delivery are sufficiently robust.
	SR1.316 REQ-02.01-SPRINTEROP-ARR0.1441	At the first contact with the Approach, the flight crew shall provide the Aircraft type or alternatively this information could be provided to the Approach Controller via data link and the Approach Controller shall cross check this information with the information displayed on the CWP
	SR1.321 REQ-02.01-SPRINTEROP-ARR0.0430	When a flight data input error (e.g. missing or wrong ICAO aircraft type or wake category) is detected, it shall be possible to update the corresponding information into the input for the separation delivery tool
	SR1.326 REQ-02.01-SPRINTEROP-ARR0.1730	In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point
	SR1.327 REQ-02.01-	In case of Separation Tool Failure, the Supervisors and Controllers shall

	SPRINTEROP-ARR0.1640	receive a message containing the source of the tool failure
	SR1.329 REQ-02.01-SPRINTEROP-ARR0.1020	Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.)
	SR1.330 REQ-02.01-SPRINTEROP-ARR0.1440	Approach control shall check the validity of Flight Plan information displayed on the CWP (ICAO aircraft type, wake category)
	SR1.331 REQ-02.01-SPRINTEROP-ARR0.1721	In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be instructed to break-off)
SO 202 / Hz#01b	SR1.056 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a high priority separation (WAKE, MRS) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner adequate to an alert (e.g. red colour)
	SR1.057 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a low priority spacing (ROT, gap, other spacing constraints) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner other than the one used for a high priority separation FTD (e.g. yellow colour)
	SR1.058 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the second and/or third most constraining ITD corresponding to a low/high priority spacing/separation is infringed the system shall display the corresponding FTDs in addition to the already displayed first most constraining FTD (FTD displayed according to the rules defined for the high priority separation and low priority spacing indicators)
	SR1.080 REQ-02.01-SPRINTEROP-ARR0.0130	In TB mode, the FTD computed by the tool to indicate the wake separation applicable at the delivery point shall take into consideration: • The time separation from the wake turbulence separation table (for WDS the separation tables might be more than one depending on the total/cross wind values); • The aircraft pair (from the arrival sequence list); • The glideslope headwind profile; • The follower time-to-fly profile obtained either from modelled time-to-fly profile in the considered headwind conditions

		• The time separation buffer considering uncertainties of final approach speed profiles of the a/c pair and of the glide slope wind prediction
	SR1.301 Example of REQ-02.01-SPRINTEROP-ARR0.0142 Example of REQ-02.01-SPRINTEROP-ARR0.0460	If the required wind input to calculate a time based wake separation (TBS or WDS) is not available for an interval longer than a specific duration (to be determined based on local wind evolution analysis), then: • The Separation Delivery Tool shall continue displaying TDIs for aircraft that are already established on the final approach path and for which the last available TDIs computation includes a safety buffer managing the acceptable failure rate of the wind measurement; • The Separation Delivery Tool shall display TDIs for non-established aircraft based on conservative wind inputs for TDIs computation
	SR1.093 REQ-02.01-SPRINTEROP-ARR0.0800	The HMI design shall allow Controllers to identify the aircraft associated with each displayed indicator.
	SR1.303 REQ-02.01-SPRINTEROP-ARR0.1010	Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors.
	SR1.310 REQ-02.01-SPRINTEROP-ARR0.1530	The Approach Controllers shall be alerted in case the aircraft instructed to turn onto the Target Distance Indicator on the runway extended centreline is not the one planned in the Arrival Sequencing Tool list.
	SR1.311 REQ-02.01-SPRINTEROP-ARR0.1560	In case of sequence error alert the Approach Controllers shall perform corrective action to re-establish consistency between the actual sequence order and the Arrival Sequencing Tool list.
	SR1.313 REQ-02.01-SPRINTEROP-ARR0.0450	If there is insufficient information to calculate a TDI then that TDI shall not be provided, together with a visual warning.
	SR1.123 REQ-02.01-SPRINTEROP-ARR0.1290	Regular trainings shall ensure ATCOs maintain sufficient competency to safely revert to and manage air traffic in DBS operations without Target Distance Indicators (i.e. implementation of the separation tool shall not adversely affect the controller's air traffic- vectoring skills- using DBS WT Category without Target Distance Indicators).
	SR1.326 REQ-02.01-	In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool

	SPRINTEROP-ARR0.1730	failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point
	SR1.327 REQ-02.01-SPRINTEROP-ARR0.1640	In case of Separation Tool Failure, the Supervisors and Controllers shall receive a message containing the source of the tool failure
	SR1.328 REQ-02.01-SPRINTEROP-ARR0.0791	When spacing ITD is infringed by the aircraft, the ATCOs shall be aware of the next most constraining separation factor ITD and FTD (e.g. Wake or MRS) on the APPROACH and TOWER positions.
	SR1.329 REQ-02.01-SPRINTEROP-ARR0.1020	Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.)
	SR1.331 REQ-02.01-SPRINTEROP-ARR0.1721	In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be instructed to break-off)
SO 203 / Hz#02a	SR1.110 REQ-02.01-SPRINTEROP-ARR0.1420	For all modes (where FTD and/or ITD are based on a pre-defined aircraft speed profile of the follower), Flight Crew shall be briefed and reminded (e.g. via information campaigns) on the importance to respect on the Final Approach path the ATC speed instructions until the start of the deceleration and/or the published procedural airspeed on final approach and to notify Controller in a timely manner in case of inability to conform to one of those.
	SR1.310 REQ-02.01-SPRINTEROP-ARR0.1530	The Approach Controllers shall be alerted in case the aircraft instructed to turn onto the Target Distance Indicator on the runway extended centreline is not the one planned in the Arrival Sequencing Tool list.
	SR1.311 REQ-02.01-SPRINTEROP-ARR0.1560	In case of sequence error alert the Approach Controllers shall perform corrective action to re-establish consistency between the actual sequence order and the Arrival Sequencing Tool list.
SO 204 / Hz#02b	SR1.037 REQ-02.01-SPRINTEROP-ARR0.0110	The Separation Delivery tool shall provide to ATCOs a visualisation (FTD indicator) of the required minimum separation or spacing on final approach that needs to be delivered after considering all in-trail and if applicable not-in-trail constraints.
	SR1.038 REQ-02.01-SPRINTEROP-ARR3.0120	If the ORD concept is considered, the Separation Delivery tool shall provide to ATCOs a visualisation (ITD indicator) of the required spacing on final approach to be delivered at the deceleration fix in order to deliver the required minimum separation / spacing at the delivery point.

	SR1.052 REQ-02.01-SPRINTEROP-ARR0.0710	The tool shall automatically display the FTD (if not already displayed) if the aircraft comes within a defined distance of the computed FTD. This distance shall be configurable within the tool.
	SR1.056 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a high priority separation (WAKE, MRS) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner adequate to an alert (e.g. red colour)
	SR1.057 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a low priority spacing (ROT, gap, other spacing constraints) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner other than the one used for a high priority separation FTD (e.g. yellow colour)
	SR1.058 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the second and/or third most constraining ITD corresponding to a low/high priority spacing/separation is infringed the system shall display the corresponding FTDs in addition to the already displayed first most constraining FTD (FTD displayed according to the rules defined for the high priority separation and low priority spacing indicators)
	SR1.063 REQ-02.01-SPRINTEROP-ARR0.1350	Procedures shall be defined regarding required actions if catching up or infringing the ITD or FTD.
	SR1.080 REQ-02.01-SPRINTEROP-ARR0.0130	In TB mode, the FTD computed by the tool to indicate the wake separation applicable at the delivery point shall take into consideration: • The time separation from the wake turbulence separation table (for WDS the separation tables might be more than one depending on the total/cross wind values); • The aircraft pair (from the arrival sequence list); • The glideslope headwind profile; • The follower time-to-fly profile obtained either from modelled time-to-fly profile in the considered headwind conditions • The time separation buffer considering uncertainties of final approach speed profiles of the a/c pair and of the glide slope wind prediction
	SR1.083 REQ-02.01-SPRINTEROP-ARR3.0150	The ITD computed by the tool for all separation and spacing constraints (wake separation in DB and TB modes, MRS, ROT and other spacing constraints) shall take in consideration: • The FTD for the considered aircraft pair • The glideslope headwind profile • The leader and follower time-to-fly profiles obtained either from modelled time-to-fly profile in the considered headwind conditions

		• The time separation buffer considering uncertainties of final approach speed profiles of the a/c pair and of the glide slope wind prediction
	SR1.328 REQ-02.01-SPRINTEROP-ARR0.0791	When spacing ITD is infringed by the aircraft, the ATCOs shall be aware of the next most constraining separation factor ITD and FTD (e.g. Wake or MRS) on the APPROACH and TOWER positions.
SO 205 / Hz#03a	SR1.052 REQ-02.01-SPRINTEROP-ARR0.0710	The tool shall automatically display the FTD (if not already displayed) if the aircraft comes within a defined distance of the computed FTD. This distance shall be configurable within the tool.
	SR1.053 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0792	For the TWR HMI, if the first most constraining ITD corresponding to a high priority separation indicator (e.g. WAKE or MRS) is infringed, then its already displayed corresponding FTD shall be accompanied by the distance countdown to the FTD of the corresponding aircraft such that the TWR controller is aware that a high priority ITD has been infringed Note this countdown to the FTD applies only to the high priority separation indicators (WAKE and MRS). The scope of this distance is to show the TWR ATCO when an ITD has been infringed keeping in mind that the ITD is not displayed by default for the TWR controller.
	SR1.054 Example of REQ-02.01-SPRINTEROP-ARR0.0792	For the TWR HMI, if the second most constraining ITD corresponding to a high priority separation is infringed, the system shall display the corresponding FTD accompanied by the distance countdown to the FTD, in addition to the already displayed first most constraining FTD such that the TWR controller is aware that a high priority ITD has been infringed (FTD displayed according to the rules defined for the high priority separation indicators)
	SR1.056 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a high priority separation (WAKE, MRS) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner adequate to an alert (e.g. red colour)
	SR1.057 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a low priority spacing (ROT, gap, other spacing constraints) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner other than the one used for a high priority separation FTD (e.g. yellow colour)
	SR1.058 Example of REQ-02.01-SPRINTEROP-	For the APP HMI, if the second and/or third most constraining ITD corresponding to a low/high priority spacing/separation is infringed the system shall display the corresponding FTDs in addition to the

	ARR0.0795	already displayed first most constraining FTD (FTD displayed according to the rules defined for the high priority separation and low priority spacing indicators)
	SR1.063 REQ-02.01-SPRINTEROP-ARR0.1350	Procedures shall be defined regarding required actions if catching up or infringing the ITD or FTD.
	SR1.090 REQ-02.01-SPRINTEROP-ARR0.0691	The Controllers shall be able to visually distinguish (via colour or symbol) if Target Distance Indicators are relative to WT, MRS or ROT (or other spacing constraint).
	SR1.103 REQ-02.01-SPRINTEROP-ARR0.0165	The Tower Controller shall monitor and ensure that there is no infringement of the FTD.
	SR1.214 REQ-02.01-SPRINTEROP-ARR0.1500	The Approach and/or Tower controller shall be alerted by the speed conformance alert function when the actual aircraft speed differs by more than a locally-defined threshold from the aircraft speed profile used for the TDIs computation.
	SR1.215 REQ-02.01-SPRINTEROP-ARR0.1700	In TB-modes, in case of speed conformance alert before the stabilisation fix, the Final Approach or Tower Controllers shall check whether the actual spacing behind the leader aircraft is below the distance-based WTC separation minima and if positive shall apply adequate corrective actions: airspeed instructions, path stretching instructions (if allowed after localiser interception), delegation of visual separation to Flight Crew and, if necessary, missed approach instruction, and shall manage the impact on subsequent aircraft in the arrival sequence.
	SR1.303 REQ-02.01-SPRINTEROP-ARR0.1010	Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors.
	SR1.117 REQ-02.01-SPRINTEROP-ARR0.1250	Approach and Tower Controllers shall be fully trained to apply the procedures for the new separation modes and to use of the Separation Delivery Tool and supporting systems (e.g. alerts) with indicators prior to deployment.
	SR1.118 REQ-02.01-SPRINTEROP-ARR0.1260	All Approach and Tower controllers and Supervisors shall be fully trained in the operating procedures for the new WT separation modes prior to deployment.
	SR1.124 REQ-02.01-SPRINTEROP-ARR2.0971	The Tower Controller shall ensure that the actual spacing behind the leader aircraft is not infringing the FTD and in case of imminent infringement he shall apply adequate corrective action like delegating visual separation to Flight Crew or instructing go-around.

SO 206 / Hz#03b	SR1.063 REQ-02.01-SPRINTEROP-ARR0.1350	Procedures shall be defined regarding required actions if catching up or infringing the ITD or FTD.
	SR1.302 REQ-02.01-SPRINTEROP-ARR2.1280	In case of WDS cross wind, when the leader and follower are established on the glideslope, the Approach and Tower controllers shall be able to give heading instructions (e.g. break-off) to the follower only upwind and not downwind.
	SR1.303 REQ-02.01-SPRINTEROP-ARR0.1010	Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors.
	SR1.306 REQ-02.01-SPRINTEROP-ARR0.0520	Approach and Tower Supervisors shall be made aware if any tool / monitoring / alerting features are lost or inoperative.
	SR1.123 REQ-02.01-SPRINTEROP-ARR0.1290	Regular trainings shall ensure ATCOs maintain sufficient competency to safely revert to and manage air traffic in DBS operations without Target Distance Indicators (i.e. implementation of the separation tool shall not adversely affect the controller's air traffic- vectoring skills- using DBS WT Category without Target Distance Indicators).
	SR1.326 REQ-02.01-SPRINTEROP-ARR0.1730	In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point
	SR1.327 REQ-02.01-SPRINTEROP-ARR0.1640	In case of Separation Tool Failure, the Supervisors and Controllers shall receive a message containing the source of the tool failure
	SR1.329 REQ-02.01-SPRINTEROP-ARR0.1020	Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.)
	SR1.331 REQ-02.01-SPRINTEROP-ARR0.1721	In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be instructed to break-off)

SO 207 / Hz#04a	SR1.110 REQ-02.01-SPRINTEROP-ARR0.1420	For all modes (where FTD and/or ITD are based on a pre-defined aircraft speed profile of the follower), Flight Crew shall be briefed and reminded (e.g. via information campaigns) on the importance to respect on the Final Approach path the ATC speed instructions until the start of the deceleration and/or the published procedural airspeed on final approach and to notify Controller in a timely manner in case of inability to conform to one of those.
	SR1.113 REQ-02.01-SPRINTEROP-ARR0.1430	With regards to WDS modes (total wind or cross wind) Flight Crew shall be briefed and reminded on the importance to respect the Final Approach path in terms of lateral deviation from the glide path and to notify Controller in a timely manner in case of inability to conform to it.
	SR1.214 REQ-02.01-SPRINTEROP-ARR0.1500	The Approach and/or Tower controller shall be alerted by the speed conformance alert function when the actual aircraft speed differs by more than a locally-defined threshold from the aircraft speed profile used for the TDIs computation.
	SR1.215 REQ-02.01-SPRINTEROP-ARR0.1700	In TB-modes, in case of speed conformance alert before the stabilisation fix, the Final Approach or Tower Controllers shall check whether the actual spacing behind the leader aircraft is below the distance-based WTC separation minima and if positive shall apply adequate corrective actions: airspeed instructions, path stretching instructions (if allowed after localiser interception), delegation of visual separation to Flight Crew and, if necessary, missed approach instruction, and shall manage the impact on subsequent aircraft in the arrival sequence.
	SR1.119 REQ-02.01-SPRINTEROP-ARR0.1270	ATCO training shall ensure that the operation in new WT separation modes will not lead to more un-stabilized approaches due to late/rush aircraft stabilisation as a result of tighter spacing and more frequent speed adjustments. However, a greater number of instructions might temporarily occur during the introduction of the new concept.
	SR1.124 REQ-02.01-SPRINTEROP-ARR2.0971	The Tower Controller shall ensure that the actual spacing behind the leader aircraft is not infringing the FTD and in case of imminent infringement he shall apply adequate corrective action like delegating visual separation to Flight Crew or instructing go-around.
SO 208 / Hz#04b	SR1.052 REQ-02.01-SPRINTEROP-ARR0.0710	The tool shall automatically display the FTD (if not already displayed) if the aircraft comes within a defined distance of the computed FTD. This distance shall be configurable within the tool.
	SR1.053 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0792	For the TWR HMI, if the first most constraining ITD corresponding to a high priority separation indicator (e.g. WAKE or MRS) is infringed, then its already displayed corresponding FTD shall be accompanied by the distance countdown to the FTD of the corresponding aircraft such that the TWR controller is aware that a high priority ITD has been infringed Note this countdown to the FTD applies only to the high priority separation indicators (WAKE and MRS). The scope of this distance is

		to show the TWR ATCO when an ITD has been infringed keeping in mind that the ITD is not displayed by default for the TWR controller.
	SR1.054 Example of REQ-02.01-SPRINTEROP-ARR0.0792	For the TWR HMI, if the second most constraining ITD corresponding to a high priority separation is infringed, the system shall display the corresponding FTD accompanied by the distance countdown to the FTD, in addition to the already displayed first most constraining FTD such that the TWR controller is aware that a high priority ITD has been infringed (FTD displayed according to the rules defined for the high priority separation indicators)
	SR1.056 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a high priority separation (WAKE, MRS) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner adequate to an alert (e.g. red colour)
	SR1.057 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a low priority spacing (ROT, gap, other spacing constraints) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner other than the one used for a high priority separation FTD (e.g. yellow colour)
	SR1.058 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the second and/or third most constraining ITD corresponding to a low/high priority spacing/separation is infringed the system shall display the corresponding FTDs in addition to the already displayed first most constraining FTD (FTD displayed according to the rules defined for the high priority separation and low priority spacing indicators)
	SR1.063 REQ-02.01-SPRINTEROP-ARR0.1350	Procedures shall be defined regarding required actions if catching up or infringing the ITD or FTD.
	SR1.214 REQ-02.01-SPRINTEROP-ARR0.1500	The Approach and/or Tower controller shall be alerted by the speed conformance alert function when the actual aircraft speed differs by more than a locally-defined threshold from the aircraft speed profile used for the TDIs computation.
	SR1.215 REQ-02.01-SPRINTEROP-ARR0.1700	In TB-modes, in case of speed conformance alert before the stabilisation fix, the Final Approach or Tower Controllers shall check whether the actual spacing behind the leader aircraft is below the distance-based WTC separation minima and if positive shall apply adequate corrective actions: airspeed instructions, path stretching instructions (if allowed after localiser interception), delegation of visual separation to Flight Crew and, if necessary, missed approach instruction, and shall manage the impact on subsequent aircraft in the arrival sequence.

SO 209 / Hz#05	SR1.028 REQ-02.01-SPRINTEROP-ARR0.0300	The approach arrival sequence information shall be provided to the Separation Delivery tool.
	SR1.300 REQ-02.01-SPRINTEROP-ARR0.0540	Controllers shall be trained to check the aircraft landing runway intent and that the aircraft order is correct and coherent with the arrival sequence list. They shall check if and that the aircraft order is displayed in the arrival sequence list and/or if the aircraft sequence number is displayed in the radar label in accordance with their intended sequence.
	SR1.200 Example of REQ-02.01-SPRINTEROP-ARR0.0852	The Intermediate and Final Approach controllers shall be the masters of the Final Approach arrival sequence and shall be able in a simple and timely way to update the sequence, insert or remove an aircraft and amend the sequence when there is a go-around in accordance with their strategy for the interception with no adverse impact on workload.
	SR1.201 REQ-02.01-SPRINTEROP-ARR0.0560	For every change in the arrival sequence (aircraft swapping positions, aircraft removed or missed approach, late change of the runway intent, etc.) the tool shall immediately re-compute all affected TDIs and reflect the change on the HMI accordingly.
	SR1.032 REQ-02.01-SPRINTEROP-ARR0.0550	If there is a change to the sequence order or runway intent, the Approach Controller should check that each indicator for each affected aircraft pair has been updated.
	SR1.033 REQ-02.01-SPRINTEROP-ARR0.0940	In case of a change of the arrival sequence order position of an aircraft, the Approach controller shall check that the arrival sequence order has been updated to reflect the change
	SR1.034 REQ-02.01-SPRINTEROP-ARR0.0941	The sequence manager shall ensure that for the change of the sequence order there is no overlap (or lack of awareness) between the actions taken by the Intermediate Approach Controller and the Final Approach Controller, by allowing only one change at a time.
	SR1.077 REQ-02.01-SPRINTEROP-ARR0.0060	In TBS mode, the separation delivery tool shall be provided with time separation rules.
	SR1.078 REQ-02.01-SPRINTEROP-ARR1.0070	S-PWS wake separation rules shall be provided to the Separation Delivery tool.
	SR1.079 Example of REQ-02.01-SPRINTEROP-ARR2.0030	In TB-modes where WDS is applied (WDS-Xw and WDS-Tw) the separation delivery tool shall be provided with time separation tables (for each cross-wind and respectively total wind value and each aircraft pair category) derived from: - the time required for a sufficient vortex decay

		- the time required for the vortex to be transported away from the path of the follower aircraft - the reference speed profile for the leader and follower aircraft
	SR1.080 REQ-02.01-SPRINTEROP-ARR0.0130	In TB mode, the FTD computed by the tool to indicate the wake separation applicable at the delivery point shall take into consideration: • The time separation from the wake turbulence separation table (for WDS the separation tables might be more than one depending on the total/cross wind values); • The aircraft pair (from the arrival sequence list); • The glideslope headwind profile; • The follower time-to-fly profile obtained either from modelled time-to-fly profile in the considered headwind conditions • The time separation buffer considering uncertainties of final approach speed profiles of the a/c pair and of the glide slope wind prediction
	SR1.085 REQ-02.01-SPRINTEROP-ARR0.0220	Aircraft identifier, ICAO aircraft type and wake category for all arrival aircraft, including subsequent updates to this information, shall be provided to the Separation Delivery tool.
	SR1.086 REQ-02.01-SPRINTEROP-ARR0.0280	The Separation Delivery tool shall be provided with the predicted headwind profile on the glideslope (ideally from ground to the published localiser interception altitude) to compute the ITD in all modes and the FTD in TB-modes. The used profiles shall ensure smooth temporal evolution of the ITD on the final approach.
	SR1.088 REQ-02.01-SPRINTEROP-ARR2.0141	In WDS modes (total wind/cross wind) the Separation Delivery tool shall use the relevant separation table for the FTD computation based on the measured total/cross wind
	SR1.093 REQ-02.01-SPRINTEROP-ARR0.0800	The HMI design shall allow Controllers to identify the aircraft associated with each displayed indicator.
	SR1.109	For all modes (where FTD and/or ITD are based on a pre-defined aircraft speed profile of the follower), the APP and TWR Controllers shall be made aware with respect to the impact on the TDIs correctness when actual aircraft speed profile is different from the pre-defined TAS profile used by the separation delivery tool.
	SR1.110 REQ-02.01-SPRINTEROP-ARR0.1420	For all modes (where FTD and/or ITD are based on a pre-defined aircraft speed profile of the follower), Flight Crew shall be briefed and reminded (e.g. via information campaigns) on the importance to respect on the Final Approach path the ATC speed instructions until the start of the deceleration and/or the published procedural airspeed on final approach and to notify Controller in a timely manner in case of inability to conform to one of those.

	SR1.208	In WDS total wind modes (A-TB-WDS-Tw), the Approach and Tower Controllers and Supervisors shall be alerted by the total wind monitoring function about a significant difference between actual reference total wind and the reference total wind used for the TB computation, i.e. when the predicted allowed time separation (based on the total wind prediction used for Target Distance Indicator computation) compared to the actual allowed time separation (based on the actual total wind measurement) exceeds a threshold to be determined locally.
	SR1.209	In WDS cross wind modes (A-TB-WDS-Xw), the Approach and Tower Controllers and Supervisors shall be alerted by the cross wind monitoring function about a significant difference between actual reference cross wind and the reference cross wind used for the TB computation, i.e. when the predicted allowed time separation (based on the cross wind prediction used for Target Distance Indicator computation) compared to the actual allowed time- separation (based on the actual cross wind measurement) exceeds a threshold to be determined locally.
	SR1.210	In WDS total wind modes (A-TB-WDS-Tw), in case of total wind monitoring alert, the Approach and Tower Controllers shall revert to the correspondent distance based or time based (e.g. TB-PWS) separation mode using the FTD and ITD indicators and when needed take corrective actions during the transition phase like instructing go-around.
	SR1.211 REQ-02.01-SPRINTEROP-ARR2.1680	In WDS crosswind modes (WDS-Xw), in case of cross wind monitoring alert, the Approach and Tower Controllers shall revert to the correspondent distance based or time based (e.g. TB-PWS) separation mode, using the FTD and ITD indicators and when needed take corrective actions during the transition phase like instructing go-around.
	SR1.212	In TBS and TB-PWS-A modes, in case there is a significant difference between actual glideslope headwind profile and the glideslope headwind profile used for the TDI computation, the Separation Delivery Tool shall re-compute the TDIs based on the correct headwind value and inform the ATCO about the re-computation.
	SR1.213 REQ-02.01-SPRINTEROP-ARR2.1690	The triggering values of the headwind, total wind and cross wind monitoring alerts shall be determined on the basis of the used buffers in the TDI computation
	SR1.214 REQ-02.01-SPRINTEROP-ARR0.1500	The Approach and/or Tower controller shall be alerted by the speed conformance alert function when the actual aircraft speed differs by more than a locally-defined threshold from the aircraft speed profile used for the TDIs computation.
	SR1.215 REQ-02.01-SPRINTEROP-	In TB-modes, in case of speed conformance alert before the stabilisation fix, the Final Approach or Tower Controllers shall check whether the actual spacing behind the leader aircraft is below the distance-based WTC separation minima and if positive shall apply

	ARR0.1700	adequate corrective actions: airspeed instructions, path stretching instructions (if allowed after localiser interception), delegation of visual separation to Flight Crew and, if necessary, missed approach instruction, and shall manage the impact on subsequent aircraft in the arrival sequence.
	SR1.217 REQ-02.01-SPRINTEROP-ARR0.1710	For all modes, in case of speed conformance alert the Final Approach and Tower Controllers shall be aware that ITD indicators are no longer accurate if the same speed is kept until the deceleration fix (ITD computation impacted by pre-defined glideslope airspeed profile of both follower and leader) thus shall manage compression without indicators as per today operations.
	SR1.218 REQ-02.01-SPRINTEROP-ARR0.1510	The triggering value used for the speed conformance alert shall be determined on the basis of the used buffers in the TDI computation. The region on the glideslope where the alert is active shall be defined locally (e.g. 8 NM from RWY threshold).
	SR1.304 REQ-02.01-SPRINTEROP-ARR0.0510	Wake category and aircraft type information shall be always available in the aircraft labels so that this information remains visible for Controllers
	SR1.306 REQ-02.01-SPRINTEROP-ARR0.0520	Approach and Tower Supervisors shall be made aware if any tool / monitoring / alerting features are lost or inoperative.
	SR1.315 REQ-02.01-SPRINTEROP-ARR0.0400	It shall be demonstrated that the data inputs including flight data, approach arrival sequence information and glideslope wind conditions to the Separation Delivery are sufficiently robust.
	SR1.316 REQ-02.01-SPRINTEROP-ARR0.1441	At the first contact with the Approach, the flight crew shall provide the Aircraft type or alternatively this information could be provided to the Approach Controller via data link and the Approach Controller shall cross check this information with the information displayed on the CWP
	SR1.317 REQ-02.01-SPRINTEROP-ARR0.0410	The software assurance level of the Separation Delivery tool and supporting tools shall be determined by the V4 safety assessment
	SR1.318 REQ-02.01-SPRINTEROP-ARR0.0390	Separation delivery tool verification shall be carried-out after modification of the separation time table configuration file (in TB-modes) or the distance separation table configuration file before the system returns in operational service
	SR1.319 REQ-02.01-SPRINTEROP-ARR0.0380	A quality assurance process shall be put in place to validate the separation time table configuration file (in TB- modes) or the distance separation table configuration file of the separation delivery tool

	SR1.320 REQ-02.01-SPRINTEROP-ARR0.0420	Separation delivery tool verification shall be carried-out after modification of the time-to-fly/airspeed profile configuration file (new A/C types or modification of existing A/C speed profiles) before the system returns in operational service
	SR1.321 REQ-02.01-SPRINTEROP-ARR0.0430	When a flight data input error (e.g. missing or wrong ICAO aircraft type or wake category) is detected, it shall be possible to update the corresponding information into the input for the separation delivery tool
	SR1.322 REQ-02.01-SPRINTEROP-ARR0.1330	In TB modes, relevant wind information shall be displayed on Approach / Tower Controller working positions for awareness purposes (e.g. to enable significant discrepancy check with the displayed TDI). Note the following assumption is conservatively taken: A015: Controllers cannot have detailed knowledge of separations for each pair of aircraft in all modes except for DBS therefore checking that Target Distance indications are consistent with the associated aircraft types and WT category is not realistic
	SR1.123 REQ-02.01-SPRINTEROP-ARR0.1290	Regular trainings shall ensure ATCOs maintain sufficient competency to safely revert to and manage air traffic in DBS operations without Target Distance Indicators (i.e. implementation of the separation tool shall not adversely affect the controller's air traffic- vectoring skills- using DBS WT Category without Target Distance Indicators).
	SR1.323 REQ-02.01-SPRINTEROP-ARR0.1310	Approach and Tower Controllers shall be provided with look-up tables for DBS minima to support DBS operations with no TDIs when necessary.
	SR1.324 REQ-02.01-SPRINTEROP-ARR0.0860	ATCOs shall continue to have a 'click and drag' distance measuring tool so they can accurately measure inter a/c spacing when required (e.g. for building confidence in the tool or during degraded modes)
	SR1.325 REQ-02.01-SPRINTEROP-ARR0.1770	Approach and Tower Supervisors shall be alerted when the wind monitoring function for the conditional application of the TB modes (glideslope headwind, total wind, cross wind) are lost or inoperative (encompassing loss of wind input)
	SR1.124 REQ-02.01-SPRINTEROP-ARR2.0971	The Tower Controller shall ensure that the actual spacing behind the leader aircraft is not infringing the FTD and in case of imminent infringement he shall apply adequate corrective action like delegating visual separation to Flight Crew or instructing go-around.
	SR1.330 REQ-02.01-SPRINTEROP-ARR0.1440	Approach control shall check the validity of Flight Plan information displayed on the CWP (ICAO aircraft type, wake category)
SO 210 /	SR1.028	The approach arrival sequence information shall be provided to the

Hz#06	REQ-02.01-SPRINTEROP-ARR0.0300	Separation Delivery tool.
	SR1.300 REQ-02.01-SPRINTEROP-ARR0.0540	Controllers shall be trained to check the aircraft landing runway intent and that the aircraft order is correct and coherent with the arrival sequence list. They shall check if and that the aircraft order is displayed in the arrival sequence list and/or if the aircraft sequence number is displayed in the radar label in accordance with their intended sequence.
	SR1.037 REQ-02.01-SPRINTEROP-ARR0.0110	The Separation Delivery tool shall provide to ATCOs a visualisation (FTD indicator) of the required minimum separation or spacing on final approach that needs to be delivered after considering all in-trail and if applicable not-in-trail constraints.
	SR1.048 REQ-02.01-SPRINTEROP-ARR0.0630	Criteria to determine the time for displaying indicators for each CWP shall be specified depending upon the local operation's needs.
	SR1.303 REQ-02.01-SPRINTEROP-ARR0.1010	Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors.
	SR1.304 REQ-02.01-SPRINTEROP-ARR0.0510	Wake category and aircraft type information shall be always available in the aircraft labels so that this information remains visible for Controllers
	SR1.305 REQ-02.01-SPRINTEROP-ARR0.1600	For all modes, in case of loss of glideslope headwind profile input to the separation tool, the alert for loss of glideslope headwind profile service shall be displayed to the Controllers and Supervisors.
	SR1.306 REQ-02.01-SPRINTEROP-ARR0.0520	Approach and Tower Supervisors shall be made aware if any tool / monitoring / alerting features are lost or inoperative.

	SR1.307 REQ-02.01-SPRINTEROP-ARR0.1650	In TB-modes, in the degraded situation where glideslope headwind profile input is missing: - The Controllers shall revert to the correspondent DB- mode (DBS or S-PWS) with use of FTDs only whilst ITDs shall no more be displayed (manual management of compression) or shall revert to an acceptably safe TB-mode with ITD and FTD computed using a conservative wind profile (until the glideslope headwind profile is available again); OR - The Separation Delivery Tool shall automatically revert to the correspondent DB-mode or to an acceptably safe TB-mode (FTD and ITD computed using a conservative wind profile). A notification of the automatic switch shall be provided to the ATCOs and Supervisors.
	SR1.308 REQ-02.01-SPRINTEROP-ARR0.1660	In DB- modes, in the degraded situation where glideslope headwind profile input is missing, the Approach Controller shall use only the FTD for the turn-on decision for merging on to final approach (whilst ITDs shall no more be displayed), vectoring the follower aircraft to intercept the final approach and further spacing management during interception whilst adding extra buffer to the FTD to manually account for compression or shall revert to an acceptably safe DB-mode with ITD and FTD computed using a conservative wind profile (until the glideslope headwind profile is available again)
	SR1.313 REQ-02.01-SPRINTEROP-ARR0.0450	If there is insufficient information to calculate a TDI then that TDI shall not be provided, together with a visual warning.
	SR1.314 REQ-02.01-SPRINTEROP-ARR0.1720	If the Approach Arrival Sequence Service fails, the Separation Delivery tool shall continue displaying TDIs for aircraft already established and shall stop displaying TDIs for all other aircraft
	SR1.123 REQ-02.01-SPRINTEROP-ARR0.1290	Regular trainings shall ensure ATCOs maintain sufficient competency to safely revert to and manage air traffic in DBS operations without Target Distance Indicators (i.e. implementation of the separation tool shall not adversely affect the controller's air traffic- vectoring skills- using DBS WT Category without Target Distance Indicators).
	SR1.323 REQ-02.01-SPRINTEROP-ARR0.1310	Approach and Tower Controllers shall be provided with look-up tables for DBS minima to support DBS operations with no TDIs when necessary.
	SR1.324 REQ-02.01-SPRINTEROP-ARR0.0860	ATCOs shall continue to have a 'click and drag' distance measuring tool so they can accurately measure inter a/c spacing when required (e.g. for building confidence in the tool or during degraded modes)
	SR1.325 REQ-02.01-SPRINTEROP-	Approach and Tower Supervisors shall be alerted when the wind monitoring function for the conditional application of the TB modes (glideslope headwind, total wind, cross wind) are lost or inoperative

	ARR0.1770	(encompassing loss of wind input)
	SR1.326 REQ-02.01-SPRINTEROP-ARR0.1730	In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point
	SR1.327 REQ-02.01-SPRINTEROP-ARR0.1640	In case of Separation Tool Failure, the Supervisors and Controllers shall receive a message containing the source of the tool failure
	SR1.329 REQ-02.01-SPRINTEROP-ARR0.1020	Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.)
	SR1.331 REQ-02.01-SPRINTEROP-ARR0.1721	In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be instructed to break-off)
SO 211 / Hz#07	SR1.012 REQ-02.01-SPRINTEROP-ARR2.1060	For TB- modes the Approach and Tower Supervisors shall collaboratively decide when the conditional (TB) mode should be activated or de activated based on meteorological data information and predefined activation criteria and on prior coordination with Controllers. Note: Activation of a WT separation mode encompasses both starting operations at the beginning of the day and transition to a different WT separation mode during the day.
	SR1.013 REQ-02.01-SPRINTEROP-ARR0.0980	The Tower Supervisor in coordination with the Approach Supervisor (and occasionally the Tower and Approach Controllers - in line with defined local procedures) shall determine the final approach separation mode and runway spacing constraints that are to be applied at any time by the separation delivery tool.
	SR1.024 REQ-02.01-SPRINTEROP-ARR0.1760	In case of conditional application in TB-modes, the Supervisors (Tower and Approach) and Controllers (Tower and Approach) shall be alerted automatically in advance when the predefined activation criteria will not be met anymore hence the imminent need to transition from one separation mode to another, in order to temporarily limit or regulate the flow of inbound traffic (e.g. through metering) prior to the switch of separation mode in order to manage the change and controllers workload

	SR1.208	In WDS total wind modes (A-TB-WDS-Tw), the Approach and Tower Controllers and Supervisors shall be alerted by the total wind monitoring function about a significant difference between actual reference total wind and the reference total wind used for the TB computation, i.e. when the predicted allowed time separation (based on the total wind prediction used for Target Distance Indicator computation) compared to the actual allowed time separation (based on the actual total wind measurement) exceeds a threshold to be determined locally.
	SR1.209	In WDS cross wind modes (A-TB-WDS-Xw), the Approach and Tower Controllers and Supervisors shall be alerted by the cross wind monitoring function about a significant difference between actual reference cross wind and the reference cross wind used for the TB computation, i.e. when the predicted allowed time separation (based on the cross wind prediction used for Target Distance Indicator computation) compared to the actual allowed time- separation (based on the actual cross wind measurement) exceeds a threshold to be determined locally.
	SR1.210	In WDS total wind modes (A-TB-WDS-Tw), in case of total wind monitoring alert, the Approach and Tower Controllers shall revert to the correspondent distance based or time based (e.g. TB-PWS) separation mode using the FTD and ITD indicators and when needed take corrective actions during the transition phase like instructing go-around.
	SR1.211 REQ-02.01-SPRINTEROP-ARR2.1680	In WDS crosswind modes (WDS-Xw), in case of cross wind monitoring alert, the Approach and Tower Controllers shall revert to the correspondent distance based or time based (e.g. TB-PWS) separation mode, using the FTD and ITD indicators and when needed take corrective actions during the transition phase like instructing go-around.
	SR1.212	In TBS and TB-PWS-A modes, in case there is a significant difference between actual glideslope headwind profile and the glideslope headwind profile used for the TDI computation, the Separation Delivery Tool shall re-compute the TDIs based on the correct headwind value and inform the ATCO about the re-computation.
	SR1.120 REQ-02.01-SPRINTEROP-ARR0.1040	All licenced Approach and Tower controllers (and Supervisors) shall be fully trained to switch between the time based and distance based modes of operation.
	SR1.312 REQ-02.01-SPRINTEROP-ARR2.1050	The Separation Delivery tool implementation shall forbid the Approach and/or Tower Controller the possibility to activate the TB-WDS-A modes.
	SR1.325 REQ-02.01-SPRINTEROP-	Approach and Tower Supervisors shall be alerted when the wind monitoring function for the conditional application of the TB modes (glideslope headwind, total wind, cross wind) are lost or inoperative

	ARR0.1770	(encompassing loss of wind input)
SO 212 / Hz#08	SR1.025 REQ-02.01-SPRINTEROP-ARR2.1190	If the Wind Forecast service detects WDS-A concept suspension, the information shall be transmitted to the Separation Delivery tool and a corresponding alert shall be displayed to the CWPs of the Controllers and Supervisors.
	SR1.300 REQ-02.01-SPRINTEROP-ARR0.0540	Controllers shall be trained to check the aircraft landing runway intent and that the aircraft order is correct and coherent with the arrival sequence list. They shall check if and that the aircraft order is displayed in the arrival sequence list and/or if the aircraft sequence number is displayed in the radar label in accordance with their intended sequence.
	SR1.200 Example of REQ-02.01-SPRINTEROP-ARR0.0852	The Intermediate and Final Approach controllers shall be the masters of the Final Approach arrival sequence and shall be able in a simple and timely way to update the sequence, insert or remove an aircraft and amend the sequence when there is a go-around in accordance with their strategy for the interception with no adverse impact on workload.
	SR1.032 REQ-02.01-SPRINTEROP-ARR0.0550	If there is a change to the sequence order or runway intent, the Approach Controller should check that each indicator for each affected aircraft pair has been updated.
	SR1.033 REQ-02.01-SPRINTEROP-ARR0.0940	In case of a change of the arrival sequence order position of an aircraft, the Approach controller shall check that the arrival sequence order has been updated to reflect the change
	SR1.034 REQ-02.01-SPRINTEROP-ARR0.0941	The sequence manager shall ensure that for the change of the sequence order there is no overlap (or lack of awareness) between the actions taken by the Intermediate Approach Controller and the Final Approach Controller, by allowing only one change at a time.
	SR1.072 REQ-02.01-SPRINTEROP-ARR0.0253	The separation delivery tool shall provide confirmation to ATCO that the gap spacing insertion is successful or not.
	SR1.089 REQ-02.01-SPRINTEROP-ARR0.0162	The tool in any mode shall display TDIs representing the greatest constraint out of all applicable in-trail or not in-trail separation constraints. The constraints can be the high priority separation (e.g. Wake and MRS) and the low priority runway spacing (ROT) and other spacing constraints (e.g. departure GAP, runway inspections, etc.).
	SR1.093 REQ-02.01-SPRINTEROP-ARR0.0800	The HMI design shall allow Controllers to identify the aircraft associated with each displayed indicator.

	SR1.314 REQ-02.01-SPRINTEROP-ARR0.1720	If the Approach Arrival Sequence Service fails, the Separation Delivery tool shall continue displaying TDIs for aircraft already established and shall stop displaying TDIs for all other aircraft
	SR1.317 REQ-02.01-SPRINTEROP-ARR0.0410	The software assurance level of the Separation Delivery tool and supporting tools shall be determined by the V4 safety assessment

Table 40: Additional functionality & performance safety requirements and assumptions to mitigate System generated Hazards for the PJ02.01 Arrivals Concepts Solutions

4.1.6 Achievability of the SAfety Criteria: Validation exercises results for the Arrivals Concepts Solutions

In Section 3.1.10 of the present document the safety-relevant validation objectives for each Safety Criteria have been defined for the safety assurance activities to be conducted according to the safety demonstration strategy.

This section outlines the results of the safety assurance activities in response to those 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 SPR-design level, Safety Objectives have been mapped to Safety Requirements for normal conditions (section 4.1.2.3), for abnormal conditions (section 4.1.4.2) and for failure aspects (section 4.1.5.3). 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 VAL PLN[26] for the relevant validation exercises. For detailed results please see the corresponding VALR[29].

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
RTS01 - Conducted by EUROCONTROL to assess the application of time based Weather Dependent Separations (WDS - AO-0310) with Optimised Runway Delivery (ORD - AO-0328) for arriving aircraft using the Paris CDG airport and approach environment	**OBJ-PJ02.01-V3-VALP-SA1:** To assess the impact of weather dependent separations on the final approach on operational safety compared to current wake vortex separation scheme	**CRT-PJ02.01-V3-VALP-SA1-001:** There is evidence that the level of operational safety is maintained and not negatively impacted under weather dependent separations on the final approach compared to the current operations applying wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	The controllers were seen to apply the safe standard practices when using the WDS with ORD tool in the simulation. Controllers reported that thanks to the reduced workload, stress levels, increased situation awareness compared to RECAT EU without ORD tool, they were able to allocate spare resources to other tasks, such as preventing runway incursions or detecting possible separation infringements. More specifically, controllers reported that when working in the Tower, the ORD/separation delivery tool increases their awareness of potential separation infringements enabling an easier and earlier identification. The above evidence suggests that the potential for human error with safety implication will as a minimum, not increase compared to using RECAT with no tool. Meanwhile a **Safety issue** subsists: the ITM ATCO situation awareness might be altered in the dual arrival environment (CDG North and South arrivals) because by focusing on the ITDs, the ITM position does not systematically check the

				altitude of the a/c corresponding to the other ITM, as they would in RECAT EU, with potential for separation loss. The impact of the sudden loss of one or multiple/all indicators (i.e. during degraded mode of operations) has been assessed in debriefings. Conclusion: - Multiple indicators: safety risk could be mitigated through an adaptation of the working methods, applying a higher separation than in RECAT EU and accepting a temporary increase in workload (situation judged as similar to manage as switching to LVP procedures in normal operations); - One indicator: applying RECAT-EU to the affected aircraft (making use of the distance vector) or instructing a go-around solves the issue.
		CRT-PJ02.01-V3-VALP-SA1-002: There is evidence that WDS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#R1	The number of minor under-separated aircraft (less than or equal to 0.5 NM but more than 0.1NM) on the final approach is lower with Solution compared to Reference scenario. Moreover, the under separation was at most 0.25NM with Solution, whilst several pairs were under-separated more than 0.25NM with

		large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.		Reference. No pairs were observed to be delivered with a major under-separation (more than 0.5NM) when applying WDS with ORD (note that in Reference 5% of the pairs were delivered with major under-separation for South operations and none for North, that being related to the fact that no TWR ATCO was involved on the South position (as such, very few Go-arounds have been initiated in order to prevent major under-separation). Additionally, the number of go-arounds related to separation was larger with Reference than with Solution. The analysis of the separation infringements before alignment did not reveal any cause imputable to the use of the ORD tool, neither related to transitioning between separation rules on the Base leg nor related to the Dual approach operations (conflicts North vs South). ATC can safely handle the mode switch provided they are notified in advance about the change in wind conditions and the imminent need to transition from one separation scheme to another. An advanced warning of the mode transition is required in order to temporarily limit or regulate the flow of inbound traffic (e.g. through metering) during the switch of

				separation scheme in order to manage the change and the controllers workload.
		CRT-PJ02.01-V3-VALP-SA1-003: The probability of Go around due to inadequate consideration of ROT constraint is not increased	A-SAC#R1	Only two Go-Arounds due to ROT constraint have been recorded in Reference, and none with the Solution – that complies with the success criteria, but is not a statistically representative evidence
RTS2 - Conducted by EUROCONTROL to assess the application of wake turbulence separations based on static aircraft characteristics for arriving aircraft (static PairWise Separations - PWS-A -AO-0310) with ORD (AO-0328)	**OBJ-PJ2.02-V3-VALP-SA2:** To assess the impact of static pairwise separations for arrivals with ORD on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of time based Static Pair Wise separations for arrivals PWS-A with ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	The controllers were seen to apply the safe standard practices when applying TB-PWS MRS 2.5NM with ORD tool in the simulation. No increase of potential human error was observed during the exercises.
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting	A-SAC#F1, A-SAC#F2,	No under spacings were observed in RTS02 for either the solution scenario TB PWS with the ORD or the reference scenario. There was no increase

		evidence that S-PWS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F3, A-SAC#F4	in separation non-conformances before alignment or on the base leg due to the use of TB PWS with ORD tool. Therefore no increase in separation infringements were observed in RTS02 with TB PWS and the ORD tool compared to the reference scenario. However, the validity of this conclusion is limited by the low relevance of the statistics involved due to the limited number of runs.
		CRT-PJ2.01-V3-VALP-SA2-003: that time based Static Pair Wise separations for arrivals PWS-A with ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario	A-SAC#R1	The number of ROT related Go-arounds is of same order of magnitude in TB PWS-A 2.5NM MRS ORD solution compared to the ICAO DBS reference.
RTS03a - Conducted by EUROCONTROL to assess the application of wake	**OBJ-PJ2.02-V3-VALP-SA3:** To assess the impact of the ORD on operational safety	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of time based Static Pair Wise	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5,	Safe standard controller working practices were observed with the tool in the 2A-2D-2A mixed mode runway procedures. No new potential causes for human error and no increase in the

turbulence separations based on static aircraft characteristics for arriving aircraft (static PairWise Separations - PWS-A -AO-0310) and wake turbulence separations based on static aircraft characteristics for departures (static PairWise Separations - PWS-D -AO-0323)	compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	separations for arrivals PWS-A with ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions. **CRT-PJ2.01-V3-VALP-SA3-001 :** To assess the impact of the ORD on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in single runway mixed mode operations under nominal conditions.	A-SAC#R1, A-SAC#R2, A-SAC#R3	potential severity of existing human errors were observed or reported to be introduced by the ORD tool or PWS procedures under nominal conditions. No new observations/remarks compared to previous simulations (e.g. RTS1) regarding the loss of separation indicators (ITD/FTD). Safe standard controller working practices were observed with the ORD tool in the alternating arrival departure sequence mixed mode runway procedures assessed. No new potential causes for human error and no increase in the potential severity of existing human errors were observed or reported to be introduced by the ORD tool under nominal conditions.
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals does not increase the number of minor under-	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4	The number of minor under-separated aircraft (less than or equal to 0.5NM) on the final approach in single runway mixed mode operations was not higher and was even reduced under Time Based PWS-A with ORD tool compared to the reference scenario. The number of major under-separated aircraft

		separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool. **CRT-PJ2.01-V3-VALP-SA3-003 :** To collect partial supporting evidence that the ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario		(more than 0.5NM) on the final approach in single runway mixed mode operations was reduced under Time Based PWS-A with ORD tool compared to the reference scenario. No separation infringements have occurred before alignment to runway centreline and when the aircraft are within 25 NM from the runway threshold (i.e. including base leg). However, more analysis is needed as the number of exercise runs and scenarios assessed was limited.
		CRT-PJ2.01-V3-VALP-SA2-003: that time based Static Pair Wise separations for arrivals PWS-A with ORD maintains the same probability of Go around due to inadequate	A-SAC#R1	*For RTS03a:* There was one go-around instructed by TWR controller in total in the TB PWS-A with ORD tool exercises compared to the no go-arounds in the reference scenario. However, more analysis is needed as the number of exercise runs and scenarios assessed was

		consideration of ROT constraint as per the reference scenario		limited. Number of go-arounds was not higher in the TB spacing with ORD tool exercises compared to DB spacings with no tool. In fact there were more go-rounds with in the DB spacings with no tool: 3 go-arounds were observed for the runs without the ORD tool, as opposed to no go-arounds being observed during the runs with the ORD tool. However, more analysis is needed to validate this finding due to the limited statistical analysis that can be performed based on the collected real time simulation data and to the limited number of scenarios and conditions tested
RTS03b - Conducted by EUROCONTROL to assess the application the operational feasibility of time based separations with the Optimised Runway Delivery (ORD - AO-0328) tool in a	**OBJ-PJ2.02-V3-VALP-SA3:** To assess the impact of the ORD tool with separation requirements based on the current wake vortex categories compared to no ORD on operational safety.	**CRT-PJ2.01-V3-VALP-SA3-001:** To assess the impact of TBS with the ORD tool on operational safety compared to distance based separation in segregated runways mode operations under nominal conditions.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	Safe controller working practice was observed during the simulation runs and no specific increase of the risk of potential for human error was observed. However, in the final debriefing controllers reported that while working with the ORD tool, a controller might become less aware about the aircraft distances on the final approach and consequently have a lower level of situational awareness. That issue could further lead to human error in degraded modes when no tool is

Performance Based Navigation environment				present.
		CRT-PJ2.01-V3-VALP-SA3-002: To collect partial supporting evidence that TBS with ORD tool for arrivals does not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#R1	Regarding under-spacing, for ATCO1, the reference run presents 4 under-spaced aircraft pairs, while none were observed during the corresponding solution runs. For ATCO2 and ATCO3, no under-spaced aircraft pairs were observed during the reference runs whereas one case of a small under-spacing is observed for one of the two solution runs (run #7 for ATCO2 and run #3 for ATCO3). For separation before alignment on the centre line no infringements were observed for ATCO2 and ATCo3 whereas for ATCO 1, 1 and 2 separation infringements were observed for the solution runs 5 and 11 respectively
		CRT-PJ2.01-V3-VALP-SA3-003: To collect partial supporting evidence that TBS with ORD maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the	A-SAC#R1	More go-arounds have been observed for the reference run compared to the solution runs: for the three ATCOs, between 2 and 3 go-arounds were performed during the reference run while none were observed for the corresponding solution runs except for one exercise where 2 were observed. In post exercise debriefings controllers reported that the go arounds were mainly due to the fact

		reference scenario		that the compression after the DF was not the same as in Copenhagen and this effect had a stronger impact in Reference with PBN than in the Solution scenario.
RTS04a – Please see Departures section				
RTS04b - Conducted by EUROCONTROL The first aim is to assess the 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	**OBJ-PJ2.02-V3-VALP-SA2:** To assess the impact of static pairwise separations for arrivals with ORD on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA2-001:** To assess the impact of arrivals PWS-A with the ORD in CSPR environment on operational safety compared to current operations applying wake vortex separation scheme without ORD tool in a non CSPR environment under nominal conditions.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	Both ININ and ITMN approach controllers were observed to apply safe standard practices during TB-PWS-A with ORD in CSPR for Arrivals operations. However, at CDG, the TWR ATCOs is already complex and the tower runway controller is already working at high capacity in the peak periods, having to manage crossings, departures on RWY27L and arrivals on RWY27R. Adding, to this environment, an un-steady flow of arrivals on RWY28L due to CSPR (partially segregated operations), was considered to be unacceptable from a safety point of view for the CDG TWR ATCOs.
		CRT-PJ2.01-V3-VALP-SA2-002: To collect partial supporting evidence that S-PWS with ORD tool for arrivals in a CSPR environment does	A-SAC#F1, A-SAC#F2, A-SAC#F3, A-SAC#F4	The number of under-separations (small and large) being at least not higher in the solution arrivals runs (TB PWS with the ORD tool under CSPR/DT) compared to the reference runs (RECAT EU with no tool support and no CSPR i.e. segregated runway operations).

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 using g the Paris CDG airport and approach environment.		not increase the number of minor under-separations and decreases the number of large under-separations (i.e. those with potential for severe wake encounters) compared to the current operations wake vortex separation scheme without ORD tool.		Additionally there was no increase observed in separation non-conformances before alignment or on the base leg due to the PWS-A with ORD in CSPR/DT.
		CRT-PJ2.01-V3-VALP-SA2-003: To collect partial supporting evidence that time based Static Pair Wise separations for arrivals PWS-A with ORD under CSPR maintains the same probability of Go around due to inadequate consideration of ROT constraint as per the reference scenario.	A-SAC#R1	No increase of ROT related go around was observed in Solution scenario (TB PWS with ORD in CSPR/DT environment) compared to Reference.
RTS5 – Please see Departures section				

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-SA1:** To assess the impact of weather dependent separations on the final approach on operational safety compared to current wake vortex separation scheme	**CRT-PJ2.01-V3-VALP-SA1-001:** There is evidence that the level of operational safety is maintained and not negatively impacted under weather dependent separations on the final approach compared to the current operations applying wake vortex separation scheme without ORD tool.	A-SAC#F2, A-SAC#F3, A-SAC#F4, A-SAC#F5, A-SAC#R1, A-SAC#R2, A-SAC#R3	Compared to ICAO DBS the results could be summarized as follows: • The percentage of infringements increased a 4% in solution scenarios. Due to several technical problems only two scenarios could be compared hence these results are not conclusive. More runs should be performed to guarantee that the level of infringements does not increase. • The number of go-around is higher in reference scenarios • The data of experienced workload obtained from the questionnaires show that the workload was very similar comparing solution and reference scenarios. Taking into account these results, safety did not get worse in solution scenarios, however more runs should be executed in future steps to guarantee it.
FTS09 – conducted by EUROCONTROL to support the CBA for the wake separation concepts. To assess	No Safety Validation Objective needed to be set for this FTS			

the performance impact of the different wake separation solutions on arrivals of the different concepts both when solutions are deployed in combination (e.g. PWS-A with ORD tool) and/or when solutions are deployed individually. The FTS takes as input the expected traffic sequence at IAF and different parameters (WV separation, MRS, ROT, etc.) to provide an estimate of the expected throughput and spacing between landing aircraft.	

Table 41 Safety Validation Results for the arrivals concepts

4.1.7 Realism of the SPR-level Design for the Arrivals Concepts Solutions

The development and safety analysis of the design would be seriously undermined if it were found in the subsequent Implementation phase that the Safety Requirements were either not 'testable' or impossible to satisfy (i.e. not achievable), and / or that some of the assumptions were in fact incorrect.

4.1.7.1 Achievability of Safety Requirements / Assumptions for the Arrivals Concepts Solutions

All the requirements in this SAR have been developed in different workshops at project level, involving the different partners interested in the arrival concepts solutions. The requirements have also been coordinated at project level such that to avoid duplications and/or contradictions with the OSED, HP and TS requirements.

The vast majority of the Safety Requirements have been demonstrated as capable of being satisfied in a typical implementation because they have been / will be exercised during validation exercises or because their achievability has been confirmed with Controllers, pilots and ground manufacturer during meetings, SAF/HP workshop or debriefing sessions. The information regarding the coverage and /or validation of the requirements in validation exercises is not provided in the current SAR. However, this is taken care of in the VALP[26] (which shows the link between the requirements and the validation objectives for each validation exercise), VALR[29] (which shows the detailed results of the exercises) and the OSED[22] (which shows for each requirement if it has been validated or not).

4.1.7.2 "Testability" of Safety Requirements for the Arrivals 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. This is particularly true for the development of the separation delivery and arrival sequencing tools (e.g. based on Software and/or hardware assurance level) but also for the data quality and assurance process of the separation tool configuration files.

4.1.8 Validation & Verification of the Safe Design at SPR Level for the Arrivals Concepts Solutions

A safety team encompassing controllers, pilots, ground suppliers, engineers, Safety and Human Performance specialists have supported this safety assessment of the Arrivals Concepts Solutions.

In addition to the activities conducted at OSED level, the first step was the validation of the SPR level model, then safety requirements have been derived in normal, abnormal and failure conditions to satisfy the Safety Objectives derived at OSED level which are identified in Section 3 of this document. In addition to the SAF/HP workshops, several meetings were organised to consolidate the list of safety requirements in particular to obtain consistent Safety and HP requirements.

Appendix A provides the consolidated list of Safety Objectives.

Appendix B provides the consolidated list of Safety Requirements.

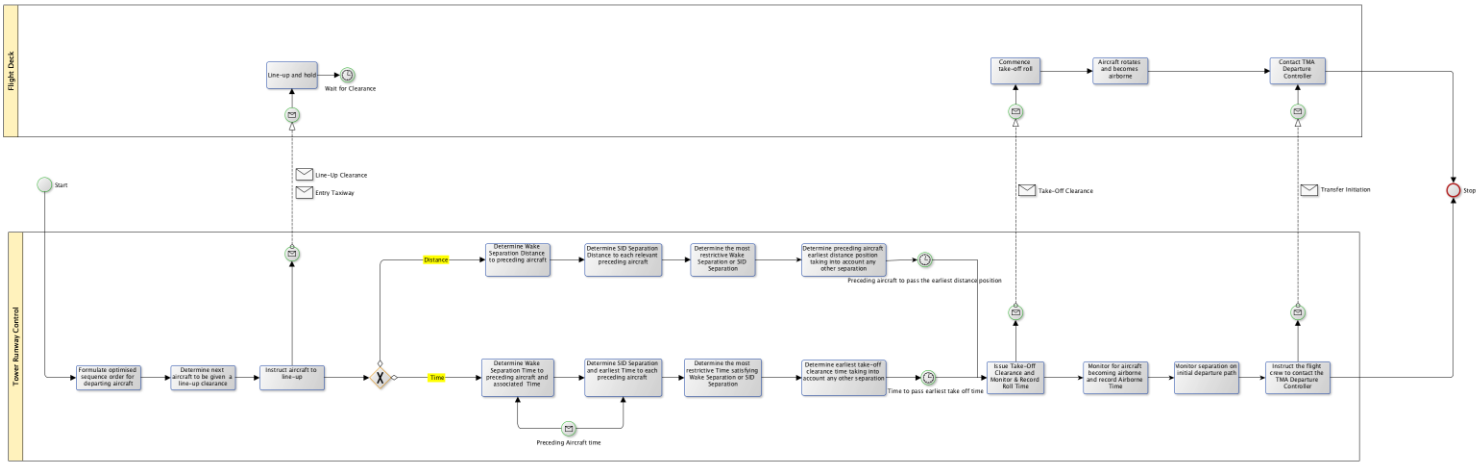
Appendix C provides the consolidated list of Safety Assumptions, Issues, Recommendations and Assessment Limitations.

4.2 Departures Concepts Solutions

4.2.1 The Departures Concepts Solutions Functional Model

4.2.1.1 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:



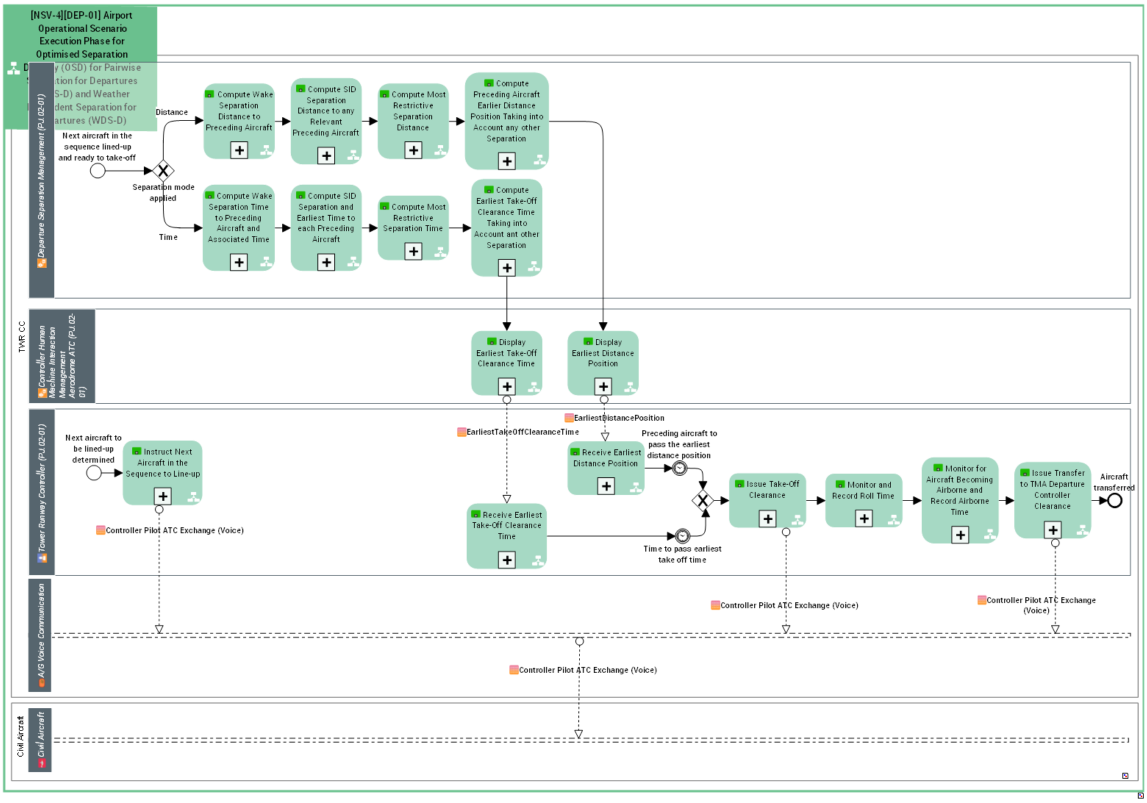
4.2.1.1.1 Safety functions

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.

4.2.2 The Departures Concepts Solutions SPR-level Model

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



4.2.2.1.1 Human Actors in the Model

Refer to Table 9 in the OSED Part 1

4.2.2.1.2 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[38]
	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 42 - Machine-based elements in the Model – Specific to WDS-D

4.2.2.1.3 Aircraft Elements

No change expected

4.2.2.1.4 Ground Elements

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

[38] 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.

4.2.2.1.5 External Entities

No Change expected

4.2.2.2 Derivation of the Safety Requirements (Functionality and Performance – success approach) for the Departures Concepts Solutions

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[39] 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)
	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.

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

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[40]
	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.
	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.

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

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[41]
	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.
	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.

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

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[42] 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[43] 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.
	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)

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

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

	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[44]
	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
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

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

	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 43 - Safety Objectives - Departures Concept- Success Approach

4.2.3 Analysis of the SPR-level Model – Normal Operations for the Departures Concepts Solutions

4.2.3.1 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 Part 1 Section 3.3.2.5.2

4.2.3.2 Scenarios for Abnormal Conditions for the Departures Concepts Solutions

Abnormal condition scenarios are as described in Table 14: Abnormal events experienced during RTS5 and Table 15: Other Abnormal/Non-nominal events.

4.2.3.3 Derivation of Safety Requirements (Functionality and Performance) for Abnormal Conditions for the Departures Concepts Solutions

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	N/A	No additional requirement – as per current

	separation between departing aircraft and an aircraft executing a go-around/missed approach		local procedures
SO#D14[45]	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.
		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[46]

[45] See Table 17

[46] 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

4.2.3.4 Thread Analysis of the SPR-level Model - Abnormal Conditions for the Departures Concepts Solutions

Not applicable for V3. Abnormal conditions should be assessed at a local level due to different procedures employed at individual airports along with local variations in conditions.

4.2.4 Design Analysis – Case of Internal System Failures for the Departures Concepts Solutions

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.

4.2.4.1 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 3.2.8.1 of this document.

4.2.4.1.1 Common Cause Analysis for the Departures Concepts Solutions

N/A

4.2.4.1.2 Formalisation of Mitigations

See paragraph 0

4.2.4.1.3 Hazard analysis

The following Bow-ties were produced as a result of the hazard analysis detailed in Table 17: High level description of Departure Concept Operational Hazards

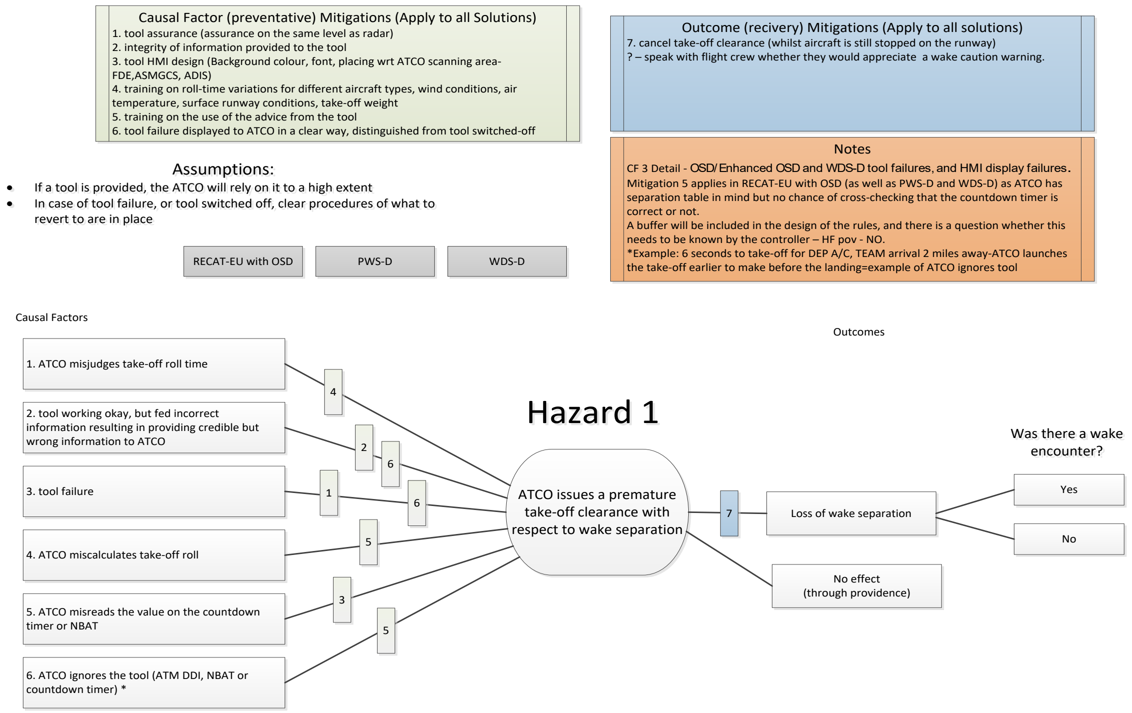


Figure 22: Bow-tie analysis Ho#D1

Hazard 2 was considered to be single sequence and, therefore, this can be referred to in Table 17: High level description of Departure Concept Operational Hazards

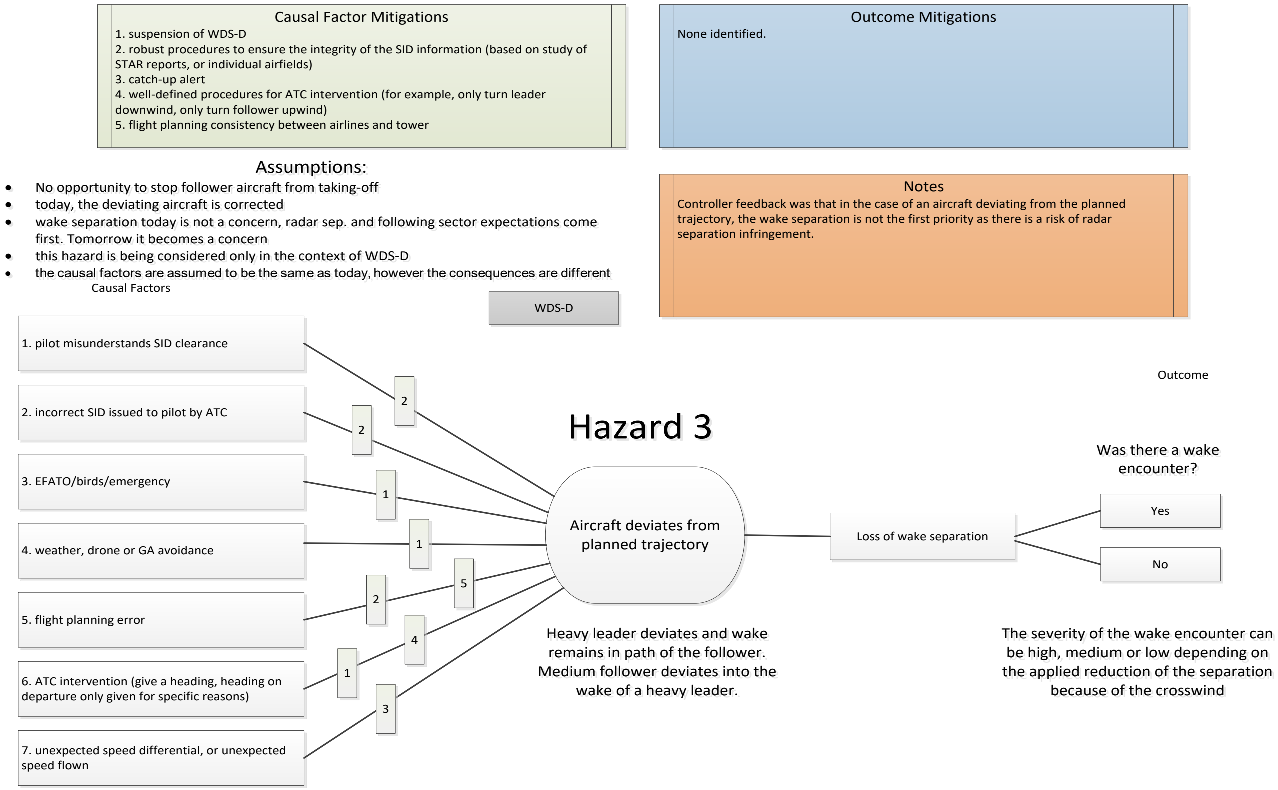


Figure 23: Bow-Tie analysis for Ho#D3

4.2.5 Achievability of the SAfety Criteria: Validation exercises results for the Departures Concepts Solutions

It is believed that the SACs applicable to the departures concept are achievable. This is confirmed by the results shown below which are reproduced from the VALR

<u>Impact on Operational Safety</u>

The following figure shows the ATCOs response to a question on the level of impact each solution scenario will have on operational safety (between strongly positive to strongly negative) compared to current operations.

All ATCOs scored a mark of four for the SOL1 scenario, indicating they think that the SOL1 scenario will have a positive impact on operational safety. The ATCOs commented how there could be a slight culture change in ATCO behaviour - waiting for the exact amount of time required to apply the correct wake separation, rather than rounding. One ATCO scored a neutral response (3) for the SOL2 scenario and two ATCOs scored a neutral response for the SOL3 scenario, indicating they don't envisage any impact on operational safety from these solution scenarios. No further comments were provided by these ATCOs on this question.

This result indicates the ATCOs believe the level of operational safety will at least be maintained or improved with the use of all three solution scenarios.

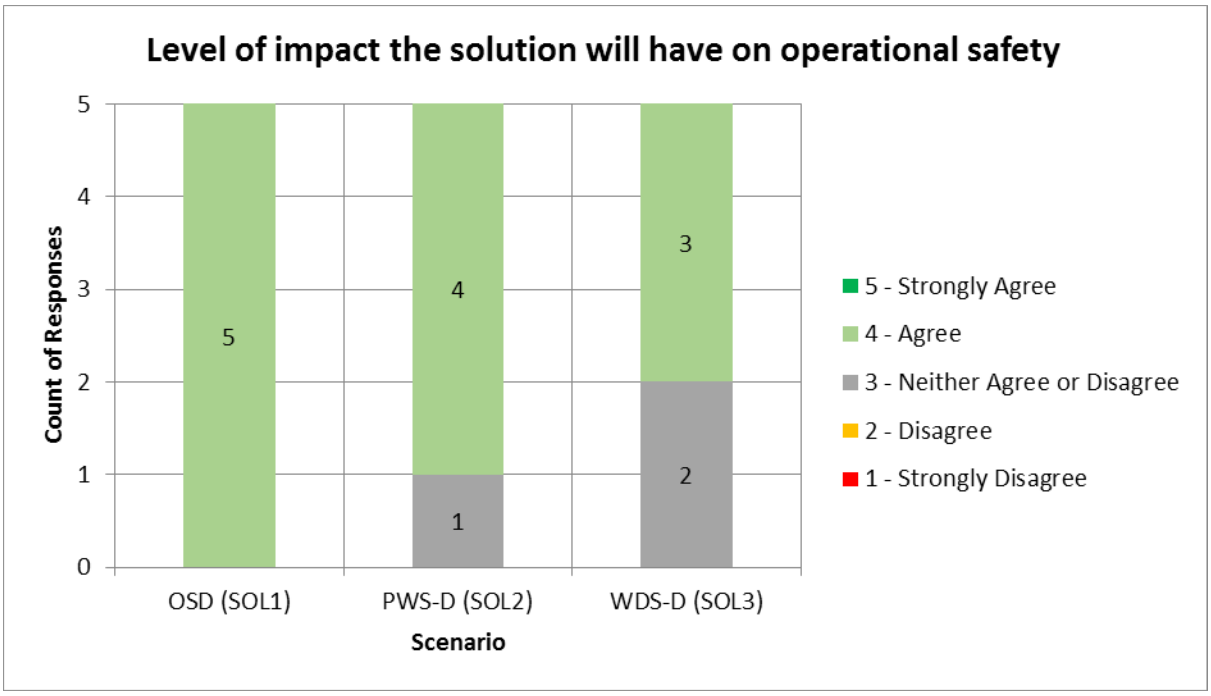


Figure 24: Level of impact each solution scenario will have on operational safety compared to current operations

Results relating to the potential for human error in all scenarios are reported in the next section.

SID Under-Separation

The actual separation achieved between departure pairs (measured between the departure airborne times) was compared against the time-based SID separation rules representative of the controller practice for achieving the required distance separation. The proportion of under-separated SID pairs compared against the approximate time-based SID separation rules was calculated. The change in the proportion of under-separated SID pairs between each of the solution scenario runs and the matched reference scenario runs was calculated.

This calculation was done when the preceding aircraft in a pair was directly ahead of the follower aircraft (shown in the left chart in the following figure) and when the preceding aircraft in a pair was one aircraft ahead of the follower aircraft, with another departure in between the pair (shown in the right chart in the following figure).

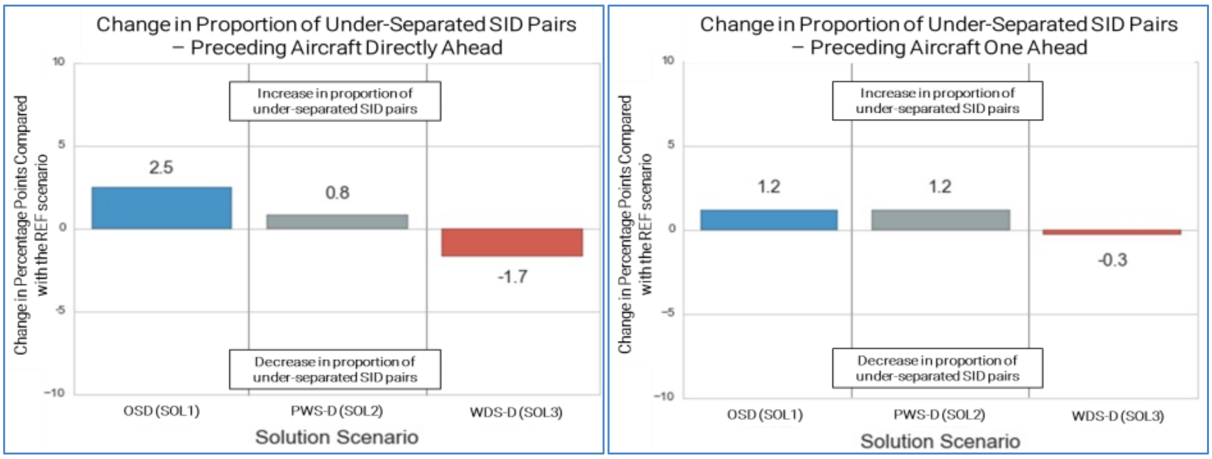


Figure 25: Change in the proportion of under-separated SID pairs in the Solution Scenario Runs compared to the Reference Scenario Runs – Preceding aircraft directly ahead (Left chart) and Preceding aircraft one ahead (Right Chart).

The results show minor changes in the proportion of under-separated SID pairs in the solution scenario runs compared to the matched reference scenario runs. The SOL1 and SOL2 scenario runs both show a minor increase whilst the SOL3 scenario runs show a minor decrease against the matched REF scenario runs, for both the preceding aircraft directly ahead and the preceding aircraft one ahead of the follower.

A comparison of the change in the proportion of under-separated SID pairs when the preceding aircraft was two ahead of the follower aircraft was also made. The results are in-line with those shown in the previous figure. Due to a low number of under-separated SID pairs, the change in the proportion of under-separated SID pairs has not been reported.

These changes in SID under-separation were observed to be minor in comparison to the overall levels of SID under-separation, meaning the likely cause in the differences is due to statistical noise. The levels of SID under-separation in all scenario runs (including the reference scenario runs) were higher than expected. This was partly due to aircraft initiating their take-off roll quicker than they do in operations, leading to less SID separation being delivered than intended and anticipated by the Tower Runway Controller.

No difference on the impact of applying the SID separation was expected between the matched SOL2 and SOL3 scenario runs. This is because both scenarios used the same tools and the same wake separation scheme of PWS-D, with only a few pairs being eligible to apply the WDS-D reduced wake separations in the SOL3 scenario runs. This would mean it would be more likely for the SOL3 scenario runs to show an increase in proportion of under-separated SID pairs compared to the REF scenario runs, rather than the SOL2 scenario runs. However, this is not seen in the results.

The ATCOs highlighted an issue with measuring SID under-separation using this method. They said that the SID separations are defined as a time separation between airborne times, in order to achieve a distance separation before the ATCO hands the follower aircraft over to the TMA Departure Controller. As there are many factors the ATCO has to consider to achieve the required distance separation, the aircraft pair may be under-separated according to their SID time separation requirement but still achieve the required distance separation before hand-over. For a number of runs in the different scenarios, a TMA Departure Controller observed the separations between the aircraft pairs delivered by the Tower Runway Controller and observed that there were no issues with the SID separation delivered during these runs.

Due to the small changes in proportion of under-separated SID pairs and the limitations of measuring SID under-separation using this method, the overall conclusion is that the solution scenarios show no substantial impact in the consistency of SID separation delivery.

Wake Under-Separation

To measure the wake under-separation, the actual separation achieved between departure pairs (measured between the departure airborne times) was compared against the required wake separation time according to the wake separation rules that were applied during each run. The proportion of under-separated wake pairs was calculated and split into minor under-separation (less than or equal to 10 seconds) and large under-separation (greater than 10 seconds). A change in proportion of minor under-separated wake pairs between each of the solution scenario runs and the matched reference scenario runs is shown in the following figure.

The results show a (7, 15 and 4 percentage points) reduction in the proportion of minor under-separated wake pairs in the SOL1, SOL2 and SOL3 scenario runs compared to the matched REF scenario runs, respectively.

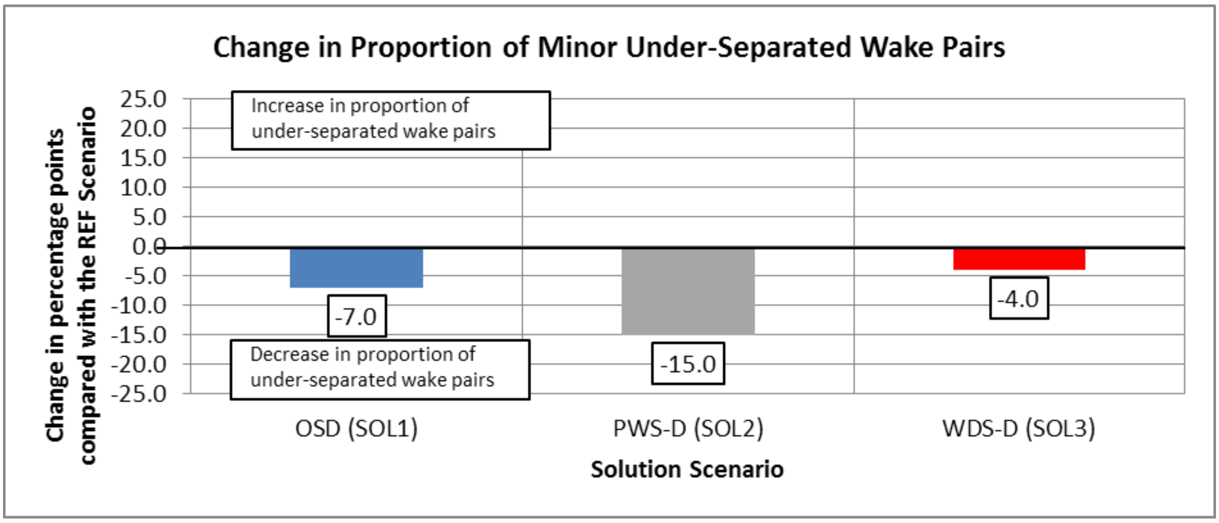


Figure 26: Change in Proportion of Minor Under-Separated Wake Pairs in the Solution Scenario Runs compared to the Matched Reference Scenario Runs

There were four large under-separated wake pairs across all scenario runs during RTS5 as detailed in the following table. All large under-separated wake pairs occurred during strong headwind runs where the aircraft roll times were significantly shorter due to the strong headwind. The likely cause, mentioned several times by the ATCOs, was the ACPO reaction time to the clearance to take-off being much quicker than the flight crews in operations, resulting in the combined reaction time and roll time for the aircraft in the simulation environment being significantly shorter than they expected. There were no large under-separated wake pairs in the SOL3 scenario runs. This result shows there is no impact in the proportion of large under-separated wake pairs in the solution scenarios compared to the reference scenario.

Run	Scenario	RECAT-EU Pair	Aircraft Type Pair	Actual Separation	Required Separation	Under-Separation
D2R3	REF	A_B	A388_B77W	84	100	16
D3R2	SOL1	A_B	A388_B788	85	100	15
D3R3	SOL2	A_B	A388_B77W	75	90	15
D2R1	SOL2	B_D	B744_A319	89	100	11

Table 44: List of Large Under-Separated Wake Pairs.

Aborted Take-offs, Go-arounds & Constrained TEAM Arrivals

During the matched runs there were no occurrences of aborted take-offs or go-arounds for any of the scenarios. All TEAM arrivals during 09R runs were observed to be safely delivered, with no impact caused by the solution scenarios.

Summary

Overall, the safety results show the ATCOs believe the solution scenarios will have either no impact or a positive impact on operational safety compared to current operations. The proportion of under-separated SID pairs showed minor changes in the solution scenarios compared to the reference scenario. The proportion of minor under-separated wake pairs showed a reduction in the SOL1, SOL2 and SOL3 scenarios compared to the reference scenario. There were few instances of large under-separated wake pairs with very little difference in proportions between all scenarios.

4.2.6 Realism of the SPR-level Design for the Departures Concepts Solutions

4.2.6.1 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.

4.2.6.2 "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 4.2.6.1, 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.

4.2.7 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 B2 specific to departures.

Appendix C1 lists assumptions, issues and recommendations specific to departures.

4.3 Wake Decay Enhancing

4.3.1 Achievability of the SAfety Criteria: Validation exercises results for the Wake Decay Enhancing Concept

Table 45 summarizes the results for the Safety KPA dedicated to the SESAR solution success criteria identified in the VALP[26] for the live trial LT10. Detailed descriptions of the live trial LT10 data collection and assessment can be found in Appendix J of the VALR[29].

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage	Validation results & Level of safety evidence
LT10 Live trial conducted by DLR, Austro Control and Leonardo at runway 16 of Vienna airport to assess the functionality of the wake decay enhancing devices (AO-0325) in order to reduce the lifetime of the long-lived wake vortices.	**OBJ-PJ02.01-V3-VALP-SA8:** To assess the impact on the wake decay enhancing concept on safety.	**CRT-PJ2.01-V3-VALP-SA8-001:** There is evidence that the level of safety is increased with the wake decay enhancing concept by reducing the lifetime of the longest-lived and thus potentially most hazardous wake vortices during the flight phase with most encounters.	**SAC#1, SAC#2**	The analysis of the lidar measurements provides evidence that the level of safety is increased with the wake decay enhancing concept by reducing the lifetime of the longest-lived and thus potentially most hazardous wake vortices during the flight phase with most encounters by about 30%.

Table 45: Achievability of the SAfety Criteria for the Wake Decay Enhancing Concept.

SAC#1 "The lifetime of the longest-lived wake vortices for a given aircraft type and similar environmental conditions within a safety corridor at the runway ends shall decrease or at least not increase by the introduction of decay enhancing devices":

During live trial LT10 6888 approaches on runway 16 of Vienna International Airport were conducted from which 5039 were measured by three lidars and 209 were processed. For headwinds below 2 m/s (the headwind range where most wake vortex encounters occur) the lifetime of the long-lived vortices in a safety corridor extending ±50 m from the extended runway centreline is reduced by 30% for all measured landings comprising medium, heavy, and super weight class aircraft. This result considers 239 measurements with plates and 191 measurements without plates. As a representative for heavy aircraft, landings of B763 aircraft (46 measurements with plates and 37 measurements without plates) have been assessed separately leading to a 29% vortex lifetime reduction. For 113 medium weight category A320 aircraft (57 measurements with plates and 56 measurements without plates) the vortex lifetime could be reduced by 32%.

SAC#2 "The decay enhancing devices shall comply with the requirements set forth by ICAO regarding obstacle clearance and frangibility":

A plate line consists of 8 plates separated by 20 m where each plate features dimensions of 4.5 m height and 9 m length. The plate line closer to the runway was installed behind the localizer at a distance of about 400 m to the threshold, thus obeying obstacle clearance requirements. Frangibility was demonstrated with a plate prototype according to the Autodrome Design Manual, Part 6 Frangibility of ICAO (see VALR). A safety assessment was conducted by the EASA Safety- & Compliance Management of Vienna Int. Airport confirming compliance with ICAO regulations. Finally, the installation of the plates and the instrumentation was approved by the authorities (Bundesministerium für Verkehr, Innovation und Technologie).

5 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 PJ02 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
PJ02.01	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

Table 46: Acronyms and terminology

6 References

Safety

[1] SESAR, Safety Reference Material, Edition 4.0, April 2016

[2] SESAR, Guidance to Apply the Safety Reference Material, Edition 3.0, April 2016

[3] SESAR Safety Assessment Plan Template

[4] SESAR, Final Guidance Material to Execute Proof of Concept, Edition 00.04.00, August 2015

[5] SESAR, Resilience Engineering Guidance, May 2016

[6] SESAR 1 P06.08.01, Input to D46, TBS, ORD, S-PWS and WDS for Arrivals – Safety Assessment Report, Edition.00.01.00, 30/11/2016

[7] EUROCONTROL Wake Turbulence Re-Categorisation and Pair-Wise Separation Minima on Approach and Departure (RECAT-PWS-EU) Safety Case Edition 1.2 14/04/2016

[8] SESAR Time-based PWS for Arrivals - Safety Assessment Report (SAR), input to D46, Edition 01.01 dated 01/10/2015

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[10] SESAR P6.8.1, W06-8-01 D2 WDS – Data mining / analysis final report Edition 0.1, 11/03/2016

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[14] CREDOS Human Factors Case Repot D4-10, Version 1.0, June 2009

[15] F. Holzäpfel, A. Stephan, T. Heel, S. Körner, "Enhanced Wake Vortex Decay in Ground Proximity Triggered by Plate Lines", Aircraft Engineering and Aerospace Technology, Vol. 88, Issue 2, 2016, pp. 206-214, http://dx.doi.org/10.1108/AEAT-02-2015-0045

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[18] ICAO Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM), Doc 4444, Fifteenth Edition, 2007

[19] CREDOS Preliminary Safety Case Report D4-12, Version 1.0, 10th November 2009

[20] EUROCONTROL Wake Turbulence Re-Categorisation and Pair-Wise Separation Minima on Approach and Departure (RECAT-EU-PWS) Safety Case, Edition 1.2, 25th May 2016

[21] Validation Targets (2019), 23 January 2019, Edition 00.00.01

PJ.02-01 Data Pack

[22]D1.1.01 – PJ02-01 OSED-SPR-INTEROP (Final) Part I – 01.00.00

[23]D1.1.01 – PJ02-01 OSED-SPR-INTEROP (Final) Part IV – 01.00.00

[24]D1.1.01 – PJ02-01 OSED-SPR-INTEROP (Final) Part V – 01.00.00

[25]D1.1.02 – PJ02-01 TS/IRS (Final) – 01.00.00

[26]D1.1.03 – PJ02-01 VALP (Final) Part I – 00.01.00

[27]D1.1.03 – PJ02-01 VALP (Final) Part II – 00.01.00

[28]D1.1.03 – PJ02-01 VALP (Final) Part IV – 00.01.00

[29]D1.1.04 – PJ02-01 VALR (Final) – 01.00.00

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 Arrivals Concepts Solutions

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

Consolidated list of Safety Objectives – Success Case for the Arrivals Concepts Solutions:

ID	Safety Objective (success approach)
SO 001	ATC shall be able to apply consistent and accurate DBS, TBS, PWS-A or WDS-A wake turbulence separation rules on final approach (encompassing interception) and landing, through operating under Distance Based modes (DBS, DB-PWS-A) and Time Based modes (TBS, T-PWS-A, A-WDS-Tw and A-WDS-Xw), with the possibility to safely switch between a TB-mode and the corresponding DB-mode.
SO 002	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 003	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 004	In case of conditional application of 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-A modes or respectively TB-PWS-A and A-TB-WD-PWS modes are not met anymore
SO 005	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 006	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 (e.g. departure gaps)

SO 007	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 008	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.
SO 009	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
SO 010	ATC (and potentially Flight Crew/Aircraft) shall consider the potential for WDS separation infringement due to lateral deviation from final approach path (e.g. dog leg when WDS crosswind is operated)
SO 011	The runway spacing or other spacing constraint (e.g. departure gaps) shall be input to and accounted for the Separation Delivery Tool (in support of SO 006)
SO 012	TWR ATC shall request the insertion of departure gaps from APP ATC, and shall coordinate with APP the modification and cancellation of these gaps as operationally needed

A.1.2 Consolidated List of Safety Objectives for the Arrivals Concepts Solutions – Abnormal Operations

ID	Description	Abnormal Scenario
SO 101	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 wind in TB-modes only; for the ITD – glideslope wind in all modes (TB and DB).	5
SO 102	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	2
SO 103	ATC shall maintain an updated arrival sequence order following a late change of aircraft runway intent or a go-around	1 and 3
SO 104	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	6
SO 105	The Target Distance Indicators shall be correctly updated in case of late (not planned) change of landing runway	8

SO 106	ATC shall be able to handle scenario specific spacing requests while using the separation delivery tool	9

A.1.3 Consolidated List of Safety Objectives (Integrity) for the Arrivals Concepts Solutions

Consolidated list of Safety Objectives – Failure Case for the Arrivals Concepts Solutions:

ID	Safety Objective
SO 201 **Hz#01a** **(WK-FA SC-3b** **MAC-FA-SC3)**	The frequency of occurrence of the inadequate separation management of a pair of aircraft instructed by ATC to merge on the Final Approach interception (which is nevertheless recovered by ATC i.e. SMI[47]≤0.5NM), shall not be greater than 2x10-3 /approach *(2x10-3/approach means 2 occurrences every 3 days for an airport with 135,000 landings per year)* ***Explanation:*** *Computation of the Safety Objective:* *SO =* $\frac{MTFoO}{N*IM} = \frac{1E-02}{5*1}$ *= 2E-03 occurrences per approach* *Computation of the no of occurrences per day: 2E-03*135000/365 = 0.74* *Which comes to 2 occurrences every 3 days*
SO 202 **Hz#01b** **(WK-FA-SC3a** **MAC-FA-SC2b)**	The frequency of occurrence of separation not being recovered following imminent infringement of A/C pair instructed by ATC to merge on the Final Approach interception (SMI>0.5NM) shall not be greater than 4x10-5/ approach *(4x10-5/approach means 6 occurrence per year for an airport with 135,000 landings per year)*
SO 203 **Hz#02a** **(WK-FA SC-3b** **MAC-FA-SC3)**	The frequency of occurrence of the inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach interception profile without ATC instruction given (which is nevertheless recovered by ATC i.e. SMI≤0.5NM), shall not be greater than 2x10-3 /approach *(2x10-3/approach means 2 occurrences every 3 days for an airport with 135,000 landings per year)*

[47] SMI stands for Separation Minima Infringement (WT or MRS)

SO 204 **Hz#02b** **(WK-FA-SC3a** **MAC-FA-SC2b)**	The frequency of occurrence of separation not being recovered following imminent infringement due to aircraft deviation from Final Approach interception profile without ATC instruction given (SMI>0.5NM) shall not be greater than 4x10-5/approach *(4x10-5/approach means 6 occurrence per year for an airport with 135,000 landings per year)*
SO 205 **Hz#03a** **(WK-FA SC-3b** **MAC-FA-SC3)**	The frequency of occurrence of the inadequate separation management of an aircraft pair naturally catching-up as instructed by ATC on the Final Approach (which is nevertheless recovered by ATC i.e. SMI≤0.5NM) shall not be greater than 2x10-3 /approach *(2x10-3/approach means 2 occurrences every 3 days for an airport with 135,000 landings per year)*
SO 206 **Hz#03b** **(WK-FA-SC3a** **MAC-FA-SC2b)**	The frequency of occurrence of separation not being recovered following imminent infringement by an aircraft pair instructed by ATC on the Final Approach (SMI>0.5NM) shall not be greater than 4x10-5/approach *(4x10-5/approach means 6 occurrences per year for an airport with 135,000 landings per year)*
SO 207 **Hz#04a** **(WK-FA SC-3b** **MAC-FA-SC3)**	The frequency of occurrence of the inadequate separation management of a spacing conflict due to aircraft deviation from Final Approach profile without ATC instruction given (which is nevertheless recovered by ATC i.e. SMI≤0.5NM) shall not be greater than 2x10-3 /approach *(2x10-3/approach means 2 occurrences every 3 days for an airport with 135,000 landings per year)*
SO 208 **Hz#04b** **(WK-FA-SC3a** **MAC-FA-SC2b)**	The frequency of occurrence of separation not being recovered following imminent infringement due to aircraft deviation from Final Approach profile without ATC instruction given (SMI>0.5NM) shall not be greater than 4x10-5/approach *(4x10-5/approach means 6 occurrences per year for an airport with 135,000 landings per year)*
SO 209 **Hz#05** **(WK-FA-SC3a** **MAC-FA-SC2b;** **IM=20)**	The frequency of occurrence of one or multiple separation minima infringements due to undetected corruption of separation indicator (SMI>0.5NM) shall not be greater than 2x10-6/approach *(2x10-6/approach means 1 occurrences every 4 years for an airport with 135,000 landings per year)* *Explanation:* *Computation of the no of occurrences per year: 2E-6*135000/365 = 7.4E-04* *Which comes to 1 occurrence every 1350 days which represents 1 occurrence every 3.7 years (rounded to 1 occurrence every 4 years)*

SO 210 **Hz#06** **(WK-FA-SC3a** **MAC-FA-SC2b; IM=10)**	The frequency of occurrence of one or multiple imminent infringements due to lack/loss of separation indicator for multiple or all aircraft (which are nevertheless recovered by ATC i.e. SMI≤0.5NM) shall not be greater than 2x10-4 /approach *(2x10-4/approach means 1 occurrence every 15 days for an airport with 135,000 landings per year)*
SO 211 **Hz#07** **(WK-FA-SC3a** **MAC-FA-SC2b; IM=20)**	The frequency of occurrence of one or multiple separation minima infringements induced by ATC through inadequate selection or management of a separation mode shall not be greater than 2x10-6/approach *(2x10-6/approach means 1 occurrences every 4 years for an airport with 135,000 landings per year)*
SO 212 **Hz#08** **(RWY-C SC3)**	The frequency of occurrence of a runway conflict due to conflicting ATC clearances shall not be greater than 10-7/movement. (10-7/movement means 2,6x10-4/day) It should be noted that **2,6x10-4/day** is **too stringent** for this type of operational hazard. This value will be updated once the Severity Classification Scheme for the Runway Collision Model is updated.

A.2 Departures Concepts Solutions

A.2.1 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.2.2 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 covers the following Concepts Solutions:

- Consolidated Lists of Requirements for Arrivals Concepts Solution in Section B.1
- Consolidated Lists of Requirements for Departures Concepts Solutions in Section B.2

B.1 Arrivals Concepts Solutions

B.1.1 Safety Requirements (Functionality and Performance) for the Arrivals Concepts Solutions

In the next tables the traceability of the Safety Requirements (functionality & performance) is ensured versus the Safety Objectives for the Arrivals Concepts Solutions.

Safety Requirements in Normal Operational Conditions for the Arrivals Concepts Solutions

SRs	General Description	Derived from
SR1.001 REQ-02.01-SPRINTEROP-ARR0.0050	The Intermediate Approach, Final Approach and Tower Controllers shall be provided with a Separation Delivery Tool displaying Target Distance Indicators (TDI) to enable consistent and accurate application of TBS, PWS-A, DBS and/or WDS-A wake turbulence separation rules on final approach and landing.	SO 005 SO 008
SR1.002 REQ-02.01-SPRINTEROP-ARR0.0100	The tool shall operate under Distance Based modes (DB- modes: DBS, S-PWS) and Time Based modes (TB- modes:TB S-PWS, TB-WDS-Tw, TB-WDS-Xw, TB-WD-PWS-TW, TB-WD-PWS-XW), with the possibility to switch between DB- modes and corresponding TB- modes.	SO 001
SR1.003 REQ-02.01-SPRINTEROP-ARR0.0131	For the time based separation modes (TB-modes i.e. TBS, TB-PWS-A, TB-WDS-A or A-TB-WD-PWS), for which FTD (Final Target Distance standing for the separation indication) is computed based on a time separation, the risk of under-separation induced by the uncertainty in glideslope headwind prediction and in the actual final approach speed profile shall be mitigated.	SO 003
SR1.004 REQ-02.01-SPRINTEROP-ARR0.0132	For the Time based separation modes the risk of under-separation induced by the uncertainty in glideslope headwind prediction and in the actual final approach speed profile shall be mitigated by one or a combination of the following means: • Adding a time separation buffer in the design of the FTD indicators displayed to Controllers. These buffers may vary depending on the considered applicable separation minima and wind conditions • The conditional application of any TB- mode (e.g. WDS shall be locally pre-determined and used as a wind-based criterion for the activation of that mode • For the TB- mode, taking a buffer in the design of TBS minima (e.g. higher headwind conditions when selecting reference baseline minima)	SO 003

	• The selection of most appropriate mean(s) shall be based on the local operational conditions, local wind behaviour, wind profile and aircraft speed profile prediction system accuracy	
SR1.005 REQ-02.01-SPRINTEROP-ARR3.0151	For all separation modes, for which an ITD (Initial Target Distance standing for the compression indication) is used, the risk of under-separation after Deceleration Fix induced by the uncertainty in glideslope headwind prediction and in the actual final approach speed profile shall be mitigated.	SO 003
SR1.006 REQ-02.01-SPRINTEROP-ARR3.0152	For all separation modes, for which an ITD is used, the risk of under-separation after Deceleration Fix induced by the uncertainty in glideslope headwind prediction and in the actual final approach speed profile shall be mitigated by adding a time separation buffer in the design of the ITD indicators displayed to Controllers. These buffers may vary depending on the considered applicable separation minima and wind conditions.	SO 003
SR1.007 REQ-02.01-SPRINTEROP-ARR0.1030	The Approach or Tower Controller shall be able to safely perform their separation duties during transition between separation modes.	SO 001 SO 004
SR1.008 REQ-02.01-SPRINTEROP-ARR0.1080	The frequency of separation mode switches shall be done in a way that would avoid controller confusion and unnecessary workload.	SO 001 SO 004
SR1.009 REQ-02.01-SPRINTEROP-ARR0.1120	The mode of operation shall be clearly displayed to the controllers (Tower and Approach) and Supervisors (Tower and Approach) at all times.	SO 001 SO 004
SR1.010 REQ-02.01-SPRINTEROP-ARR0.1390	Consideration shall be given to the impact of mode changes on external systems and processes such as AMAN and flow management.	SO 001
SR1.011 REQ-02.01-SPRINTEROP-ARR0.0530	The system architecture shall ensure all applicable Controller Working Positions (e.g. per runway) operate in the same mode(s).	SO 001
SR1.012 REQ-02.01-SPRINTEROP-ARR2.1060	For TB- modes the Approach and Tower Supervisors shall collaboratively decide when the conditional (TB) mode should be activated or de activated based on meteorological data information and predefined activation criteria and on prior coordination with Controllers. Note: Activation of a WT separation mode encompasses both starting operations at the beginning of the day and transition to a different WT separation mode during the day.	SO 002 SO 211

SR1.013 REQ-02.01-SPRINTEROP-ARR0.0980	The Tower Supervisor in coordination with the Approach Supervisor (and occasionally the Tower and Approach Controllers - in line with defined local procedures) shall determine the final approach separation mode and runway spacing constraints that are to be applied at any time by the separation delivery tool.	SO 002 SO 011 SO 211
SR1.014 REQ-02.01-SPRINTEROP-ARR0.1070	Supervisor must reconsider the mode of operation if they receive WTE reports from Pilots over a short period of time via Controllers. Rationale: Several WTE reports in a short space of time may mean the incorrect mode of operation is activated hence Supervisors should reassess the decision.	SO 004
SR1.015 REQ-02.01-SPRINTEROP-ARR0.1222	The Approach and Tower Supervisors shall inform the respective Controller when the conditional (TB) mode will be activated or de activated by indicating the first aircraft in the arrival sequence to be separated according to the new mode. (e.g. at least 2 min before interception- to be locally defined)	SO 002
SR1.016 REQ-02.01-SPRINTEROP-ARR0.1090	In case the reversion from a TB mode is triggered automatically by the Separation Delivery Tool (e.g. due to the wind falling below the applicable minima), the Separation Delivery Tool shall indicate to the ATCO the aircraft to be separated according to the new separation mode. A notification shall indicate to the Controller and the Supervisor the change and preferably the reason behind it.	SO 004
SR1.017 REQ-02.01-SPRINTEROP-ARR0.1223	The ATCOs and the Supervisors shall always have a clear indication in the CWP from which aircraft in the sequence the new mode of operations or the reversion to standard mode are applied.	SO 002 SO 004
SR1.018 REQ-02.01-SPRINTEROP-ARR2.1130	The WDS-TW mode shall be activated only when the runway surface and glide-slope reference total wind (as used in the separation minima design) is equal or greater than the WDS-Tw threshold	SO 003
SR1.019 REQ-02.01-SPRINTEROP-ARR2.1140	The WDS-Xw mode shall be activated only when the runway surface and glide-slope reference cross wind (as used in the separation minima design) is equal or greater than the WDS-Xw threshold	SO 003
SR1.020 REQ-02.01-SPRINTEROP-ARR2.1170	The Wind Forecast Service shall be provided to the users to plan or execute WDS-A (Xw or Tw) concept operations. The service shall include standard meteorological information and WDS-A (Xw or respectively Tw) concept specific information with respect to wind nowcast and forecast, wind speed, direction and trends, in particular the crosswind component (glide-slope and surface cross winds) or respectively the total wind (glide-slope and surface total winds) with respect to each runway direction.	SO 002 SO 004

SR1.021 REQ-02.01-SPRINTEROP-ARR2.1150	The WDS-Tw and WDS-Xw activation thresholds shall be determined to mitigate the risk of wake vortex encounter due to the uncertainties on the wind prediction data and on the lateral aircraft deviation from RWY extended centreline.	SO 003
SR1.022 REQ-02.01-SPRINTEROP-ARR0.0670	Local implementation shall define the latest time that a stable TDI is required by the Controller for spacing, so that the FTD and ITD indicators may be re-calculated due to changing glideslope wind conditions	SO 005
SR1.023 REQ-02.01-SPRINTEROP-ARR2.1160	In order to enable the modes activation/deactivation, the Tower Supervisor and the Approach supervisor shall be provided with a meteorological situation picture that includes the nowcast and forecast data regarding the wind speed and direction at different locations and altitudes covering the area encompassing the final approach phase of arrival flights. Such information shall in particular display the relevant wind component for the application of WDS-A concept reduced wake separations.	SO 002 SO 004
SR1.024 REQ-02.01-SPRINTEROP-ARR0.1760	In case of conditional application in TB-modes, the Supervisors (Tower and Approach) and Controllers (Tower and Approach) shall be alerted automatically in advance when the predefined activation criteria will not be met anymore hence the imminent need to transition from one separation mode to another, in order to temporarily limit or regulate the flow of inbound traffic (e.g. through metering) prior to the switch of separation mode in order to manage the change and controllers workload	SO 004 SO 211
SR1.025 REQ-02.01-SPRINTEROP-ARR2.1190	If the Wind Forecast service detects WDS-A concept suspension, the information shall be transmitted to the Separation Delivery tool and a corresponding alert shall be displayed to the CWPs of the Controllers and Supervisors.	SO 004 SO 212
SR1.026 REQ-02.01-SPRINTEROP-ARR0.1100	Upon reversion to (activation of) a new separation mode, the separation delivery tool shall display the adequate FTD (separation indication) and ITD (compression indications) to the Approach ATCO for all aircraft starting with the first aircraft in the arrival sequence to be separated according to the new mode.	SO 004
SR1.027 REQ-02.01-SPRINTEROP-ARR0.1110	The Approach and Tower Runway ATCO shall continue to use the TDIs that are already displayed (as per the previous separation mode) for the aircraft in the arrival sequence preceding the first one to be separated according to the new mode.	SO 002 SO 004
SR1.028 REQ-02.01-SPRINTEROP-ARR0.0300	The approach arrival sequence information shall be provided to the Separation Delivery tool.	SO 005 SO 201 SO 209 SO 210

SR1.029 REQ-02.01-SPRINTEROP-ARR0.0910	The separation delivery tool shall be given the arrival runway intent including eventual updates for each aircraft such that it is considered for the computation of the Target Distance Indicators	SO 005
SR1.030 REQ-02.01-SPRINTEROP-ARR0.0920	The runway final approach sequence order shall be displayed on the HMI so that it is visible to the Approach, Tower and Supervisor positions.	SO 005
SR1.031 REQ-02.01-SPRINTEROP-ARR0.0570	If there is a change to the separation / spacing constraint (e.g. Gap) the TDI for the affected aircraft pair shall be re-computed.	SO 006 SO 012
SR1.032 REQ-02.01-SPRINTEROP-ARR0.0550	If there is a change to the sequence order or runway intent, the Approach Controller should check that each indicator for each affected aircraft pair has been updated.	SO 005 SO 209 SO 212
SR1.033 REQ-02.01-SPRINTEROP-ARR0.0940	In case of a change of the arrival sequence order position of an aircraft, the Approach controller shall check that the arrival sequence order has been updated to reflect the change	SO 005 SO 209 SO 212
SR1.034 REQ-02.01-SPRINTEROP-ARR0.0941	The sequence manager shall ensure that for the change of the sequence order there is no overlap (or lack of awareness) between the actions taken by the Intermediate Approach Controller and the Final Approach Controller, by allowing only one change at a time.	SO 005 SO 209 SO 212
SR1.035 REQ-02.01-SPRINTEROP-ARR0.0139	TDIs shall be displayed on the extended runway centreline behind each lead aircraft established on final approach and shall be linked to the actual lead aircraft position along the runway axis.	SO 006
SR1.036 REQ-02.01-SPRINTEROP-ARR0.0133	TDI position shall provide the accurate information about the required separation/spacing for each aircraft pair	SO 006
SR1.037 REQ-02.01-SPRINTEROP-ARR0.0110	The Separation Delivery tool shall provide to ATCOs a visualisation (FTD indicator) of the required minimum separation or spacing on final approach that needs to be delivered after considering all in-trail and if applicable not-in-trail constraints.	SO 005 SO 008 SO 201 SO 204 SO 210
SR1.038 REQ-02.01-SPRINTEROP-ARR3.0120	If the ORD concept is considered, the Separation Delivery tool shall provide to ATCOs a visualisation (ITD indicator) of the required spacing on final approach to be delivered at the deceleration fix in order to deliver the required minimum separation / spacing at the delivery point.	SO 005 SO 008 SO 204

SR1.039 REQ-02.01-SPRINTEROP-ARR0.0890	The separation delivery tool shall support ATCOs in the delivery of wake separations that are allowed only when leader and follower aircraft are aligned on the centreline.	SO 005 SO 008
SR1.040 REQ-02.01-SPRINTEROP-ARR0.0190	There shall be surveillance coverage down to the separation delivery point to allow the separation tool to display Target Distance Indicators on the runway extended centreline including the last part of the final approach.	SO 005 SO 008
SR1.041 REQ-02.01-SPRINTEROP-ARR0.0730	The TDIs corresponding to the high priority MRS separation constraint shall remain visible on the radar display until the leader aircraft reaches the separation delivery point.	SO 008
SR1.042 REQ-02.01-SPRINTEROP-ARR0.0740	The TDIs corresponding to the high priority Wake separation constraint shall remain visible on the radar display until the leader aircraft reaches the separation delivery point.	SO 008
SR1.043 REQ-02.01-SPRINTEROP-ARR0.0750	The TDIs corresponding to the low priority Runway Occupancy Time constraint shall remain visible on the radar display until the leader aircraft reaches the separation delivery point.	SO 008
SR1.044 REQ-02.01-SPRINTEROP-ARR0.0760	The TDIs corresponding to the low priority Gap spacing constraint shall remain visible on the radar display until the follower aircraft reaches the separation delivery point.	SO 008 SO 012
SR1.045 REQ-02.01-SPRINTEROP-ARR0.0690	TDI display shall be robust to ensure they do not keep switching on and off as aircraft perform normal manoeuvres	SO 005 SO 008
SR1.046 REQ-02.01-SPRINTEROP-ARR0.0490	The follower TDI shall be linked to the actual aircraft position of the leader: - If the leader is aligned with the runway axis, then the follower TDIs are to be displayed behind the actual leader position; - If the leader is not yet aligned with the runway axis and the perpendicular projected position on the runway extended centreline is behind its own ITD then the follower TDIs are to be displayed behind the perpendicular projected position on the runway extended centreline; - If the leader is not yet aligned with the runway axis and the perpendicular projected position on the runway extended centreline is ahead its own ITD, then the follower TDIs are to be displayed behind the position of ITD ahead. In case several aircraft have not yet intercepted the glide, this leads to a train of ITDs, each one being attached to the previous one and all	SO 005

	moving at the speed of the last aircraft on the extended runway centreline.	
SR1.047 REQ-02.01-SPRINTEROP-ARR0.0480	The TDIs shall be displayed to the Intermediate and Final Approach Controllers sufficiently early in order to allow correct interception	SO 005
SR1.048 REQ-02.01-SPRINTEROP-ARR0.0630	Criteria to determine the time for displaying indicators for each CWP shall be specified depending upon the local operation's needs.	SO 005 SO 201 SO 210
SR1.049 REQ-02.01-SPRINTEROP-ARR0.0470	The Separation Delivery tool and associated procedures shall support the Controller decision to turn onto final approach.	SO 005
SR1.050 REQ-02.01-SPRINTEROP-ARR3.1000	If the ORD concept is implemented, the Final Approach Controller shall maintain the aircraft on or behind the ITD on the final approach and reduce to the final approach procedural airspeed until the transfer to the Tower controller.	SO 005 SO 008 SO 201
SR1.051 REQ-02.01-SPRINTEROP-ARR3.0170	If the ORD concept is implemented, the Approach controller shall vector the follower aircraft so that it stays on or behind the corresponding ITD.	SO 005 SO 008 SO 201
SR1.052 REQ-02.01-SPRINTEROP-ARR0.0710	The tool shall automatically display the FTD (if not already displayed) if the aircraft comes within a defined distance of the computed FTD. This distance shall be configurable within the tool.	SO 005 SO 008 SO 204 SO 205 SO 208
SR1.053 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0792	For the TWR HMI, if the first most constraining ITD corresponding to a high priority separation indicator (e.g. WAKE or MRS) is infringed, then its already displayed corresponding FTD shall be accompanied by the distance countdown to the FTD of the corresponding aircraft such that the TWR controller is aware that a high priority ITD has been infringed Note this countdown to the FTD applies only to the high priority separation indicators (WAKE and MRS). The scope of this distance is to show the TWR ATCO when an ITD has been infringed keeping in mind that the ITD is not displayed by default for the TWR controller.	SO 008 SO 205 SO 208
SR1.054 Example of REQ-02.01-SPRINTEROP-	For the TWR HMI, if the second most constraining ITD corresponding to a high priority separation is infringed, the system shall display the corresponding FTD accompanied by the distance countdown to the FTD, in addition to the already displayed first most constraining FTD	SO 008 SO 205 SO 208

ARR0.0792	such that the TWR controller is aware that a high priority ITD has been infringed (FTD displayed according to the rules defined for the high priority separation indicators)	
SR1.055 Example of REQ-02.01-SPRINTEROP-ARR0.0793	For the TWR HMI, if the high priority ITD is no longer infringed: - In case the FTD corresponding to this high priority ITD is the first most constraining FTD the corresponding countdown distance to the FTD shall be hidden by the system and - In case the FTD corresponding to this high priority ITD is the second most constraining FTD, the FTD shall be hidden together with the countdown to the FTD	SO 008
SR1.056 Example of REQ-02.01-SPRINTEROP-ARR3.1520 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a high priority separation (WAKE, MRS) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner adequate to an alert (e.g. red colour)	SO 005 SO 008 SO 202 SO 205 SO 204 SO 208
SR1.057 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the most constraining ITD corresponding to a low priority spacing (ROT, gap, other spacing constraints) indicator is infringed or the aircraft comes within a defined distance of the computed FTD, then its corresponding FTD shall be displayed in a manner other than the one used for a high priority separation FTD (e.g. yellow colour)	SO 202 SO 205 SO 204 SO 208
SR1.058 Example of REQ-02.01-SPRINTEROP-ARR0.0795	For the APP HMI, if the second and/or third most constraining ITD corresponding to a low/high priority spacing/separation is infringed the system shall display the corresponding FTDs in addition to the already displayed first most constraining FTD (FTD displayed according to the rules defined for the high priority separation and low priority spacing indicators)	SO 005 SO 008 SO 202 SO 205 SO 204 SO 208
SR1.059 Example of REQ-02.01-SPRINTEROP-ARR0.0796	For the APP HMI, if the second and/or third most constraining ITD is no longer infringed, the corresponding FTDs shall be hidden by the system	SO 005 SO 008
SR1.060 REQ-02.01-SPRINTEROP-ARR0.0850	The HMI design shall allow ATCO to hide/unhide indicators for a specific aircraft pair, and current and forthcoming alerts/warnings for that aircraft as a follower (e.g. infringement, catch-up, speed,..)	SO 005 SO 008

SR1.061 REQ-02.01-SPRINTEROP-ARR0.0900	Following the ATCO action to suppress the TDIs for specific aircraft the tool shall • remove any information on the spacing/separation (ITD and FTD) • remove its ongoing or not display the forthcoming Separation Delivery Tool alerts (e.g. Catchup/Speed/SeqNumber/Infringement)	SO 005 SO 008
SR1.062 REQ-02.01-SPRINTEROP-ARR0.0720	The Approach controller shall be able to remove the FTD from the radar display, but not when the FTD has been automatically displayed by the System.	SO 005 SO 008
SR1.063 REQ-02.01-SPRINTEROP-ARR0.1350	Procedures shall be defined regarding required actions if catching up or infringing the ITD or FTD.	SO 005 SO 008 SO 204 SO 205 SO 206 SO 208
SR1.064 REQ-02.01-SPRINTEROP-ARR0.0870	The Approach controller shall maintain applicable surveillance separation minima at any point during approach. This includes the case of a leader aircraft established on the final approach axis and a follower not yet established	SO 005 SO 008
SR1.065 REQ-02.01-SPRINTEROP-ARR0.1340	The current operational procedures for transitioning from intermediate separations (3NM) to final approach separations (e.g. 2.5NM MRS) shall continue to apply.	SO 005
SR1.066 REQ-02.01-SPRINTEROP-ARR3.0500	Once the follower aircraft has been positioned w.r.t ITD and before the leader reaches its deceleration point, the Controller shall apply speed instructions in accordance to the reference glide slope air speed used for ITD calculation.	SO 005 SO 008
SR1.067 REQ-02.01-SPRINTEROP-ARR0.0080	In DB- modes the separation delivery tool shall be provided with a range of wake turbulence distance-based separation rules based on ICAO Aircraft Type (e.g. ICAO, RECAT-EU, RECAT-EU-PWS) depending upon the airport needs.	SO 006
SR1.068 REQ-02.01-SPRINTEROP-ARR0.0230	All applicable Minimum Radar Separation (MRS) rules shall be provided to the Separation Delivery tool.	SO 006
SR1.069 REQ-02.01-SPRINTEROP-ARR0.0251	The separation delivery tool shall provide ATCOs the possibility to manage gap spacing between consecutive arrival flights.	SO 006

SR1.070 REQ-02.01-SPRINTEROP-ARR0.0240	All applicable runway-related spacing rules other than those related to runway configuration shall be provided to the Separation Delivery tool.	SO 006
SR1.072 REQ-02.01-SPRINTEROP-ARR0.0253	The separation delivery tool shall provide confirmation to ATCO that the gap spacing insertion is successful or not.	SO 006 SO 012 SO 212
SR1.073 REQ-02.01-SPRINTEROP-ARR0.0254	The ATCOs shall be able to insert automatic gap spacing based on pre-defined scenarios in the sequence manager	SO 006 SO 012
SR1.074 REQ-02.01-SPRINTEROP-ARR0.0255	The tool shall provide ATCOs the ability to update and cancel any gap spacing previously inserted.	SO 006 SO 012
SR1.075 REQ-02.01-SPRINTEROP-ARR0.0310	An expected aircraft speed or time-to-fly profile model on the final approach glide-slope shall be provided to the Separation Delivery tool for the FTD calculation.	SO 006
SR1.076 REQ-02.01-SPRINTEROP-ARR1.0320	An expected aircraft speed or time-to-fly profile model on the final approach glide-slope shall be provided to the Separation Delivery tool for the ITD calculation.	SO 006
SR1.077 REQ-02.01-SPRINTEROP-ARR0.0060	In TBS mode, the separation delivery tool shall be provided with time separation rules.	SO 006 SO 209
SR1.078 REQ-02.01-SPRINTEROP-ARR1.0070	S-PWS wake separation rules shall be provided to the Separation Delivery tool.	SO 006 SO 209
SR1.079 Example of REQ-02.01-SPRINTEROP-ARR2.0030	In TB-modes where WDS is applied (WDS-Xw and WDS-Tw) the separation delivery tool shall be provided with time separation tables (for each cross-wind and respectively total wind value and each aircraft pair category) derived from: - the time required for a sufficient vortex decay - the time required for the vortex to be transported away from the path of the follower aircraft - the reference speed profile for the leader and follower aircraft	SO 006 SO 209

SR1.080 REQ-02.01-SPRINTEROP-ARR0.0130	In TB mode, the FTD computed by the tool to indicate the wake separation applicable at the delivery point shall take into consideration: • The time separation from the wake turbulence separation table (for WDS the separation tables might be more than one depending on the total/cross wind values); • The aircraft pair (from the arrival sequence list); • The glideslope headwind profile; • The follower time-to-fly profile obtained either from modelled time-to-fly profile in the considered headwind conditions • The time separation buffer considering uncertainties of final approach speed profiles of the a/c pair and of the glide slope wind prediction	SO 006 SO 202 SO 204 SO 209
SR1.081 REQ-02.01-SPRINTEROP-ARR0.0161	The spacing constraint computation shall take into consideration the same inputs as for the ITD and FTD plus: • The time separation value representing the spacing constraint (ROT, GAP, scenario specific spacing, etc.)	SO 006
SR1.082 REQ-02.01-SPRINTEROP-ARR0.0321	Aircraft time-to-fly profiles used in the FTD and ITD calculations shall be based on a time-to-fly model representative of nominal aircraft speed behaviour on final approach, in the local environment.	SO 006
SR1.083 REQ-02.01-SPRINTEROP-ARR3.0150	The ITD computed by the tool for all separation and spacing constraints (wake separation in DB and TB modes, MRS, ROT and other spacing constraints) shall take in consideration: • The FTD for the considered aircraft pair • The glideslope headwind profile • The leader and follower time-to-fly profiles obtained either from modelled time-to-fly profile in the considered headwind conditions • The time separation buffer considering uncertainties of final approach speed profiles of the a/c pair and of the glide slope wind prediction	SO 006 SO 204
SR1.084 REQ-02.01-SPRINTEROP-ARR3.0163	If the ITD calculation is smaller than the FTD (e.g. pull away scenario) then it shall be changed to the same value as the FTD.	SO 006
SR1.085 REQ-02.01-SPRINTEROP-ARR0.0220	Aircraft identifier, ICAO aircraft type and wake category for all arrival aircraft, including subsequent updates to this information, shall be provided to the Separation Delivery tool.	SO 006 SO 201 SO 209
SR1.086 REQ-02.01-SPRINTEROP-ARR0.0280	The Separation Delivery tool shall be provided with the predicted headwind profile on the glideslope (ideally from ground to the published localiser interception altitude) to compute the ITD in all modes and the FTD in TB-modes. The used profiles shall ensure smooth temporal evolution of the ITD on the final approach.	SO 006 SO 209

SR1.087 REQ-02.01-SPRINTEROP-ARR0.0290	If in a local implementation the tool is required to consider the actual runway surface wind conditions, then the runway surface wind conditions shall be provided to the Separation Delivery tool.	SO 006
SR1.088 REQ-02.01-SPRINTEROP-ARR2.0141	In WDS modes (total wind/cross wind) the Separation Delivery tool shall use the relevant separation table for the FTD computation based on the measured total/cross wind	SO 006 SO 209
SR1.089 REQ-02.01-SPRINTEROP-ARR0.0162	The tool in any mode shall display TDIs representing the greatest constraint out of all applicable in-trail or not in-trail separation constraints. The constraints can be the high priority separation (e.g. Wake and MRS) and the low priority runway spacing (ROT) and other spacing constraints (e.g. departure GAP, runway inspections, etc.).	SO 006 SO 011 SO 212
SR1.090 REQ-02.01-SPRINTEROP-ARR0.0691	The Controllers shall be able to visually distinguish (via colour or symbol) if Target Distance Indicators are relative to WT, MRS or ROT (or other spacing constraint).	SO 006 SO 205
SR1.091 REQ-02.01-SPRINTEROP-ARR0.0580	The display option for the indicator shall be configurable depending on the type of separation / spacing.	SO 006
SR1.092 REQ-02.01-SPRINTEROP-ARR0.0681	The design of the TDIs shall be made in order to ensure they are easy to read and interpret, being in line with the design philosophy (shape, colour etc.) of the other ATC tools used in the local environment.	SO 006
SR1.093 REQ-02.01-SPRINTEROP-ARR0.0800	The HMI design shall allow Controllers to identify the aircraft associated with each displayed indicator.	SO 006 SO 202 SO 209 SO 212
SR1.094 REQ-02.01-SPRINTEROP-ARR0.1410	The Flight Crew shall be made aware of the locally applied separation mode and minima via appropriate means (e.g. from ATIS, AIP, NOTAM, information campaigns).	SO 007
SR1.095 REQ-02.01-SPRINTEROP-ARR0.1421	Information campaigns shall familiarise the flight crew/ airspace users with all novel concepts associated to the implementation of reduced separations.	SO 007
SR1.096 REQ-02.01-SPRINTEROP-ARR0.1400	An overview of the key principles of the TBS, S-PWS, WDS and / or ORD concept of operations (ConOps) shall be published in AIP.	SO 007

SR1.097 REQ-02.01-SPRINTEROP-ARR0.0970	If ORD is not implemented, the Final Approach Controller shall maintain the aircraft behind the FTD with sufficient buffer due to the effect of compression caused by different leader and follower groundspeed profiles, and shall reduce aircraft's speed to the final approach procedural airspeed.	SO 005 SO 008
SR1.098 REQ-02.01-SPRINTEROP-ARR0.0167	If both the FTD and ITD are available, the ITD indication ("compressions indicator") shall be the main indicator to be used by the final approach controller.	SO 005 SO 006 SO 008
SR1.099 REQ-02.01-SPRINTEROP-ARR0.0651	In case the ITD is the main display on the final approach, the ATCOs shall be able to display the FTD , depending upon the local operation's needs.	SO 005 SO 006 SO 008
SR1.100 REQ-02.01-SPRINTEROP-ARR0.0590	TDIs shall be displayed on all applicable ATCO and SUP CWPs (Tower Runway, Final Approach and Intermediate Approach), according to the local implementation rules.	SO 006
SR1.101 REQ-02.01-SPRINTEROP-ARR0.0700	Approach and Tower shall have access to consistent information (on their CWP HMI) relating to separation delivery to be able to communicate effectively with each other.	SO 006
SR1.102 REQ-02.01-SPRINTEROP-ARR0.0770	The displayed indicator distance and shape shall be consistent between all applicable CWPs.	SO 006
SR1.103 REQ-02.01-SPRINTEROP-ARR0.0165	The Tower Controller shall monitor and ensure that there is no infringement of the FTD.	SO 008 SO 205
SR1.104 REQ-02.01-SPRINTEROP-ARR0.0650	The Approach controller shall have the possibility to globally select the display of the FTD, however the FTD shall automatically be displayed when some alerts are active (e.g. risk of imminent FTD infringement).	SO 006
SR1.105 REQ-02.01-SPRINTEROP-ARR0.0164	The FTD indicator shall be the main TDI to be used by the Tower Controller.	SO 006 SO 008
SR1.106 REQ-02.01-SPRINTEROP-ARR3.0660	The Tower controller shall have the possibility to globally select the display of the ITD (in addition to FTD which shall always be displayed).	SO 006

SR1.107 REQ-02.01-SPRINTEROP-ARR3.0160	Before the Leader reaches its Deceleration Fix (DF), the ITD shall be "static" (i.e. the separation distance between the Leader position and the displayed ITD shall be static, the ITD shall hence move at the leader speed). It shall be computed accounting for the compression/ pull-away effect for the aircraft pair expected from the leader DF until the separation delivery point. After the Leader passes the DF, the ITD shall move towards the FTD, accurately account for compression/pull-away effect for the aircraft pair expected from the actual leader position until the separation delivery point.	SO 006
SR1.108 REQ-02.01-SPRINTEROP-ARR0.0140	Before the Leader reaches the separation delivery point, the FTD shall be "static" (i.e. the separation distance between the Leader position and the displayed FTD shall be static, the FTD shall hence move at the Leader speed). It shall be computed accounting for the expected time-to-fly of the Follower aircraft until the separation delivery point. After the Leader passes the separation delivery point and until the Follower reaches the separation delivery point, the FTD shall be disconnected from the Leader (e.g. move at the expected Follower speed to reach zero when the Follower is expected to reach the delivery point).	SO 006
SR1.109	For all modes (where FTD and/or ITD are based on a pre-defined aircraft speed profile of the follower), the APP and TWR Controllers shall be made aware with respect to the impact on the TDIs correctness when actual aircraft speed profile is different from the pre-defined TAS profile used by the separation delivery tool.	SO 009 SO 209
SR1.110 REQ-02.01-SPRINTEROP-ARR0.1420	For all modes (where FTD and/or ITD are based on a pre-defined aircraft speed profile of the follower), Flight Crew shall be briefed and reminded (e.g. via information campaigns) on the importance to respect on the Final Approach path the ATC speed instructions until the start of the deceleration and/or the published procedural airspeed on final approach and to notify Controller in a timely manner in case of inability to conform to one of those.	SO 009 SO 209 SO 203 SO 207
SR1.111 REQ-02.01-SPRINTEROP-ARR0.0200	All applicable runway configuration spacing rules shall be provided to the Separation Delivery tool.	SO 006
SR1.112 REQ-02.01-SPRINTEROP-ARR0.0270	The tool shall allow the runway occupancy time (ROT) constraints to be configurable for each aircraft based on multiple parameters.	SO 006
SR1.113 REQ-02.01-SPRINTEROP-ARR0.1430	With regards to WDS modes (total wind or cross wind) Flight Crew shall be briefed and reminded on the importance to respect the Final Approach path in terms of lateral deviation from the glide path and to notify Controller in a timely manner in case of inability to conform to it.	SO 010 SO 207

SR1.114 REQ-02.01-SPRINTEROP-ARR0.0166	Clear guidelines with regard to the list of possible actions to be made in the case of an FTD infringement (in the APP and in the TWR) shall be described per position for the local implementation.	SO 005 SO 008
SR1.115 REQ-02.01-SPRINTEROP-ARR0.0441	In case of a change of runway configuration, the Approach and/or Tower supervisors shall coordinate prior to inserting the new arrival runway into the tool.	SO 006
SR1.116 REQ-02.01-SPRINTEROP-ARR0.0440	In case of a change of runway configuration, the Approach and/or Tower supervisors shall be able to input to the separation tool the new arrival runway to be considered for Target Distance Indicators computation. ISSUE 2: In case of a late landing runway change, it should be verified if the arrival sequencing tool can be timely reconfigured in order to display the Approach Arrival Sequence for the switched runway and update the TDIs accordingly.	SO 006
SR1.117 REQ-02.01-SPRINTEROP-ARR0.1250	Approach and Tower Controllers shall be fully trained to apply the procedures for the new separation modes and to use of the Separation Delivery Tool and supporting systems (e.g. alerts) with indicators prior to deployment.	SO 005 SO 008 SO 201 SO 205
SR1.118 REQ-02.01-SPRINTEROP-ARR0.1260	All Approach and Tower controllers and Supervisors shall be fully trained in the operating procedures for the new WT separation modes prior to deployment.	SO 005 SO 008 SO 205
SR1.119 REQ-02.01-SPRINTEROP-ARR0.1270	ATCO training shall ensure that the operation in new WT separation modes will not lead to more un-stabilized approaches due to late/rush aircraft stabilisation as a result of tighter spacing and more frequent speed adjustments. However, a greater number of instructions might temporarily occur during the introduction of the new concept.	SO 207
SR1.120 REQ-02.01-SPRINTEROP-ARR0.1040	All licenced Approach and Tower controllers (and Supervisors) shall be fully trained to switch between the time based and distance based modes of operation.	SO 001 SO 211
SR1.121 REQ-02.01-SPRINTEROP-ARR0.0370	Local implementation shall ensure that roles and responsibilities are clearly defined regarding the management of data inputs into the Separation Delivery tool including runway policy, runway spacing constraints, visibility conditions and runway conditions.	SO 006 SO 011
SR1.122 REQ-02.01-SPRINTEROP-ARR0.0180	The Surveillance system shall provide the Separation Delivery Tool with aircraft position and altitude for all arrival aircraft.	SO 006

SR1.123 REQ-02.01-SPRINTEROP-ARR0.1290	Regular trainings shall ensure ATCOs maintain sufficient competency to safely revert to and manage air traffic in DBS operations without Target Distance Indicators (i.e. implementation of the separation tool shall not adversely affect the controller's air traffic- vectoring skills- using DBS WT Category without Target Distance Indicators).	SO 001 SO 209 SO 210 SO 202 SO 206
SR1.124 REQ-02.01-SPRINTEROP-ARR2.0971	The Tower Controller shall ensure that the actual spacing behind the leader aircraft is not infringing the FTD and in case of imminent infringement he shall apply adequate corrective action like delegating visual separation to Flight Crew or instructing go-around.	SO 008 SO 209 SO 205 SO 207
SR1.125 REQ-02.01-SPRINTEROP-ARR0.0990	The Approach and Tower Runway Controllers shall remain responsible for monitoring for separation infringements and for timely intervention actions to resolve or prevent them.	SO 008
SR1.126 REQ-02.01-SPRINTEROP-ARR0.1021	The transition tasks (activation and deactivation of TB modes) shall be defined for all actors involved, for both a spontaneous transition (e.g. sudden change of wind conditions, etc.) as well as for a planned transition, where a collaborative approach for the ATCO and SUPs in APP and TWR shall apply.	SO 001
SR1.127 REQ-02.01-SPRINTEROP-ARR0.1031	Mode transitions (planned) should take place outside peak hours.	SO 001
SR1.128 REQ-02.01-SPRINTEROP-ARR2.1222	Timely reversion from conditional mode to standard mode of operations shall be triggered by the Supervisor or automatically by the system depending on the local implementation. The possibility for the ATCOs spontaneous reversal (e.g. in case of sudden loss of indicators) shall be locally defined.	SO 001
SR1.129 REQ-02.01-SPRINTEROP-ARR0.1351	In a dual approach arrival environment, ATCOs shall have supporting alert, for identifying vertical and horizontal infringements for the crossing aircraft (e.g. North runways to South runways)	SO 005 SO 008

Safety Requirements in Abnormal Operational Conditions for the Arrivals Concepts Solutions

SRs	General Description	Derived from
SR1.200 Example of REQ-02.01-SPRINTEROP-ARR0.0852	The Intermediate and Final Approach controllers shall be the masters of the Final Approach arrival sequence and shall be able in a simple and timely way to update the sequence, insert or remove an aircraft and amend the sequence when there is a go-around in accordance with their strategy for the interception with no adverse impact on workload.	SO 103 SO 209 SO 212
SR1.201 REQ-02.01-SPRINTEROP-ARR0.0560	For every change in the arrival sequence (aircraft swapping positions, aircraft removed or missed approach, late change of the runway intent, etc.) the tool shall immediately re-compute all affected TDIs and reflect the change on the HMI accordingly.	SO 103 SO 209
SR1.202 REQ-02.01-SPRINTEROP-ARR0.0561	For a late change of the runway intent, the tool shall immediately re-compute all affected TDIs and reflect the change on the HMI accordingly (i.e. the TDIs corresponding to the affected aircraft disappear from the extended runway centreline of the old runway and is displayed on the extended runway centreline of the new runway).	SO 105
SR1.203 REQ-02.01-SPRINTEROP-ARR0.0950	When the aircraft is already inserted into the sequence with a runway intent and there is a change of aircraft landing runway intent, the Approach controller shall check that Target Distance Indicators reflect the change of aircraft landing runway intent	SO 105
SR1.204 REQ-02.01-SPRINTEROP-ARR0.0851	Local procedures shall define the procedures related to the use of the TDIs and the specific instances in which they can be removed.	SO 103
SR1.205 REQ-02.01-SPRINTEROP-ARR0.0960	The Target Distance Indicators associated to a leader aircraft executing a go-around shall be removed from the sequence and new Target Distance Indicators shall be computed for the following a/c, considering the new arrival pairs created due to this go-around. The aircraft could be removed from the sequence manually by the ATCO or automatically.	SO 103
SR1.206 REQ-02.01-SPRINTEROP-ARR0.0250	Scenario specific spacing gaps between aircraft pairs shall be provided to the Separation Delivery tool.	SO 106
SR1.208	In WDS total wind modes (A-TB-WDS-Tw), the Approach and Tower Controllers and Supervisors shall be alerted by the total wind monitoring function about a significant difference between actual reference total wind and the reference total wind used for the TB computation, i.e. when the predicted allowed time separation	SO 101 SO 209 SO 211

	(based on the total wind prediction used for Target Distance Indicator computation) compared to the actual allowed time separation (based on the actual total wind measurement) exceeds a threshold to be determined locally.	
SR1.209	In WDS cross wind modes (A-TB-WDS-Xw), the Approach and Tower Controllers and Supervisors shall be alerted by the cross wind monitoring function about a significant difference between actual reference cross wind and the reference cross wind used for the TB computation, i.e. when the predicted allowed time separation (based on the cross wind prediction used for Target Distance Indicator computation) compared to the actual allowed time-separation (based on the actual cross wind measurement) exceeds a threshold to be determined locally.	SO 101 SO 209 SO 211
SR1.210	In WDS total wind modes (A-TB-WDS-Tw), in case of total wind monitoring alert, the Approach and Tower Controllers shall revert to the correspondent distance based or time based (e.g. TB-PWS) separation mode using the FTD and ITD indicators and when needed take corrective actions during the transition phase like instructing go-around.	SO 101 SO 209 SO 211
SR1.211 REQ-02.01-SPRINTEROP-ARR2.1680	In WDS crosswind modes (WDS-Xw), in case of cross wind monitoring alert, the Approach and Tower Controllers shall revert to the correspondent distance based or time based (e.g. TB-PWS) separation mode, using the FTD and ITD indicators and when needed take corrective actions during the transition phase like instructing go-around.	SO 101 SO 209 SO 211
SR1.212	In TBS and TB-PWS-A modes, in case there is a significant difference between actual glideslope headwind profile and the glideslope headwind profile used for the TDI computation, the Separation Delivery Tool shall re-compute the TDIs based on the correct headwind value and inform the ATCO about the re-computation.	SO 101 SO 209 SO 211
SR1.213 REQ-02.01-SPRINTEROP-ARR2.1690	The triggering values of the headwind, total wind and cross wind monitoring alerts shall be determined on the basis of the used buffers in the TDI computation	SO 101 SO 209
SR1.214 REQ-02.01-SPRINTEROP-ARR0.1500	The Approach and/or Tower controller shall be alerted by the speed conformance alert function when the actual aircraft speed differs by more than a locally-defined threshold from the aircraft speed profile used for the TDIs computation.	SO 102 SO 209 SO 205 SO 208 SO 207
SR1.215 REQ-02.01-SPRINTEROP-ARR0.1700	In TB-modes, in case of speed conformance alert before the stabilisation fix, the Final Approach or Tower Controllers shall check whether the actual spacing behind the leader aircraft is below the distance-based WTC separation minima and if positive shall apply adequate corrective actions: airspeed instructions, path stretching	SO 102 SO 209 SO 205 SO 208 SO 207

	instructions (if allowed after localiser interception), delegation of visual separation to Flight Crew and, if necessary, missed approach instruction, and shall manage the impact on subsequent aircraft in the arrival sequence.	
SR1.216 REQ-02.01-SPRINTEROP-ARR0.1370	Pilots shall notify ATC of an inability to fly the standard approach procedure, and of any non-conformant final approach procedural airspeed issues, in a timely manner.	SO 104
SR1.217 REQ-02.01-SPRINTEROP-ARR0.1710	For all modes, in case of speed conformance alert the Final Approach and Tower Controllers shall be aware that ITD indicators are no longer accurate if the same speed is kept until the deceleration fix (ITD computation impacted by pre-defined glideslope airspeed profile of both follower and leader) thus shall manage compression without indicators as per today operations.	SO 102 SO 209
SR1.218 REQ-02.01-SPRINTEROP-ARR0.1510	The triggering value used for the speed conformance alert shall be determined on the basis of the used buffers in the TDI computation. The region on the glideslope where the alert is active shall be defined locally (e.g. 8 NM from RWY threshold).	SO 102 SO 209
SR1.219 REQ-02.01-SPRINTEROP-ARR0.1360	The Approach Controller shall take into account any notified inability to fly the standard approach procedure and any non-conformant final approach procedural airspeed issues when setting up the spacing on final approach.	SO 104
SR1.220 REQ-02.01-SPRINTEROP-ARR0.1380	Procedures shall be locally defined for the handling of scenario specific spacing requests and runway changes.	SO 106

Safety Requirements Mitigation to System Generated Hazards for the Arrivals Concepts Solutions

SRs	General Description	Derived from
SR1.300 REQ-02.01-SPRINTEROP-ARR0.0540	Controllers shall be trained to check the aircraft landing runway intent and that the aircraft order is correct and coherent with the arrival sequence list. They shall check if and that the aircraft order is displayed in the arrival sequence list and/or if the aircraft sequence number is displayed in the radar label in accordance with their intended sequence.	SO 209 SO 210 SO 212
SR1.301 Example of REQ-02.01-SPRINTEROP-ARR0.0142 Example of REQ-02.01-SPRINTEROP-ARR0.0460	If the required wind input to calculate a time based wake separation (TBS or WDS) is not available for an interval longer than a specific duration (to be determined based on local wind evolution analysis), then: • The Separation Delivery Tool shall continue displaying TDIs for aircraft that are already established on the final approach path and for which the last available TDIs computation includes a safety buffer managing the acceptable failure rate of the wind measurement; • The Separation Delivery Tool shall display TDIs for non-established aircraft based on conservative wind inputs for TDIs computation	SO 202
SR1.302 REQ-02.01-SPRINTEROP-ARR2.1280	In case of WDS cross wind, when the leader and follower are established on the glideslope, the Approach and Tower controllers shall be able to give heading instructions (e.g. break-off) to the follower only upwind and not downwind.	SO 206
SR1.303 REQ-02.01-SPRINTEROP-ARR0.1010	Local operational procedures shall be developed for handling traffic situations with missing Target Distance Indicators in different WT separation modes for both controllers and supervisors.	SO 210 SO 206 SO 205 SO 201 SO 202
SR1.304 REQ-02.01-SPRINTEROP-ARR0.0510	Wake category and aircraft type information shall be always available in the aircraft labels so that this information remains visible for Controllers	SO 209 SO 210
SR1.305 REQ-02.01-SPRINTEROP-ARR0.1600	For all modes, in case of loss of glideslope headwind profile input to the separation tool, the alert for loss of glideslope headwind profile service shall be displayed to the Controllers and Supervisors.	SO 210
SR1.306 REQ-02.01-SPRINTEROP-	Approach and Tower Supervisors shall be made aware if any tool / monitoring / alerting features are lost or inoperative.	SO 210 SO 206 SO 209

ARR0.0520		
SR1.307 REQ-02.01-SPRINTEROP-ARR0.1650	In TB-modes, in the degraded situation where glideslope headwind profile input is missing: - The Controllers shall revert to the correspondent DB- mode (DBS or S-PWS) with use of FTDs only whilst ITDs shall no more be displayed (manual management of compression) or shall revert to an acceptably safe TB-mode with ITD and FTD computed using a conservative wind profile (until the glideslope headwind profile is available again); OR - The Separation Delivery Tool shall automatically revert to the correspondent DB-mode or to an acceptably safe TB-mode (FTD and ITD computed using a conservative wind profile). A notification of the automatic switch shall be provided to the ATCOs and Supervisors.	SO 210
SR1.308 REQ-02.01-SPRINTEROP-ARR0.1660	In DB- modes, in the degraded situation where glideslope headwind profile input is missing, the Approach Controller shall use only the FTD for the turn-on decision for merging on to final approach (whilst ITDs shall no more be displayed), vectoring the follower aircraft to intercept the final approach and further spacing management during interception whilst adding extra buffer to the FTD to manually account for compression or shall revert to an acceptably safe DB-mode with ITD and FTD computed using a conservative wind profile (until the glideslope headwind profile is available again)	SO 210
SR1.309 REQ-02.01-SPRINTEROP-ARR0.1570	If an aircraft that needs to be inserted in the arrival sequence cannot be input into the Arrival Sequence Service, the Approach Controller shall inhibit the Target Distance Indicator corresponding to the follower aircraft whose position in the actual sequence is taken by the newly inserted aircraft and the Approach Controller shall observe DBS WT Category separation for the impacted pairs of aircraft	SO 201
SR1.310 REQ-02.01-SPRINTEROP-ARR0.1530	The Approach Controllers shall be alerted in case the aircraft instructed to turn onto the Target Distance Indicator on the runway extended centreline is not the one planned in the Arrival Sequencing Tool list.	SO 202 SO 203
SR1.311 REQ-02.01-SPRINTEROP-ARR0.1560	In case of sequence error alert the Approach Controllers shall perform corrective action to re-establish consistency between the actual sequence order and the Arrival Sequencing Tool list.	SO 202 SO 203
SR1.312 REQ-02.01-SPRINTEROP-ARR2.1050	The Separation Delivery tool implementation shall forbid the Approach and/or Tower Controller the possibility to activate the TB-WDS-A modes.	SO 211

SR1.313 REQ-02.01-SPRINTEROP-ARR0.0450	If there is insufficient information to calculate a TDI then that TDI shall not be provided, together with a visual warning.	SO 202 SO 210
SR1.314 REQ-02.01-SPRINTEROP-ARR0.1720	If the Approach Arrival Sequence Service fails, the Separation Delivery tool shall continue displaying TDIs for aircraft already established and shall stop displaying TDIs for all other aircraft	SO 201 SO 210 SO 212
SR1.315 REQ-02.01-SPRINTEROP-ARR0.0400	It shall be demonstrated that the data inputs including flight data, approach arrival sequence information and glideslope wind conditions to the Separation Delivery are sufficiently robust.	SO 201 SO 209
SR1.316 REQ-02.01-SPRINTEROP-ARR0.1441	At the first contact with the Approach, the flight crew shall provide the Aircraft type or alternatively this information could be provided to the Approach Controller via data link and the Approach Controller shall cross check this information with the information displayed on the CWP	SO 201 SO 209
SR1.317 REQ-02.01-SPRINTEROP-ARR0.0410	The software assurance level of the Separation Delivery tool and supporting tools shall be determined by the V4 safety assessment	SO 209 SO 212
SR1.318 REQ-02.01-SPRINTEROP-ARR0.0390	Separation delivery tool verification shall be carried-out after modification of the separation time table configuration file (in TB-modes) or the distance separation table configuration file before the system returns in operational service	SO 209
SR1.319 REQ-02.01-SPRINTEROP-ARR0.0380	A quality assurance process shall be put in place to validate the separation time table configuration file (in TB- modes) or the distance separation table configuration file of the separation delivery tool	SO 209
SR1.320 REQ-02.01-SPRINTEROP-ARR0.0420	Separation delivery tool verification shall be carried-out after modification of the time-to-fly/airspeed profile configuration file (new A/C types or modification of existing A/C speed profiles) before the system returns in operational service	SO 209
SR1.321 REQ-02.01-SPRINTEROP-ARR0.0430	When a flight data input error (e.g. missing or wrong ICAO aircraft type or wake category) is detected, it shall be possible to update the corresponding information into the input for the separation delivery tool	SO 209 SO 201
SR1.322 REQ-02.01-SPRINTEROP-	In TB modes, relevant wind information shall be displayed on Approach / Tower Controller working positions for awareness purposes (e.g. to enable significant discrepancy check with the displayed TDI).	SO 209

ARR0.1330	Note the following assumption is conservatively taken: A015: Controllers cannot have detailed knowledge of separations for each pair of aircraft in all modes except for DBS therefore checking that Target Distance indications are consistent with the associated aircraft types and WT category is not realistic	
SR1.323 REQ-02.01-SPRINTEROP-ARR0.1310	Approach and Tower Controllers shall be provided with look-up tables for DBS minima to support DBS operations with no TDIs when necessary.	SO 209 SO 210
SR1.324 REQ-02.01-SPRINTEROP-ARR0.0860	ATCOs shall continue to have a 'click and drag' distance measuring tool so they can accurately measure inter a/c spacing when required (e.g. for building confidence in the tool or during degraded modes)	SO 209 SO 210
SR1.325 REQ-02.01-SPRINTEROP-ARR0.1770	Approach and Tower Supervisors shall be alerted when the wind monitoring function for the conditional application of the TB modes (glideslope headwind, total wind, cross wind) are lost or inoperative (encompassing loss of wind input)	SO 209 SO 210 SO 211
SR1.326 REQ-02.01-SPRINTEROP-ARR0.1730	In case of separation tool failure with loss of TDI computation (TDIs preserved for aircraft already established) a specific separation tool failure alert shall be provided and the Controllers shall revert to DBS without indicators for aircraft without TDIs. Only for aircraft already established, TDIs that continue to be displayed can be used up to the separation delivery point	SO 201 SO 202 SO 210 SO 206
SR1.327 REQ-02.01-SPRINTEROP-ARR0.1640	In case of Separation Tool Failure, the Supervisors and Controllers shall receive a message containing the source of the tool failure	SO 201 SO 202 SO 206 SO 210
SR1.328 REQ-02.01-SPRINTEROP-ARR0.0791	When spacing ITD is infringed by the aircraft, the ATCOs shall be aware of the next most constraining separation factor ITD and FTD (e.g. Wake or MRS) on the APPROACH and TOWER positions.	SO 202 SO 204
SR1.329 REQ-02.01-SPRINTEROP-ARR0.1020	Controllers and Supervisors shall regularly receive training on reversal procedures (TB to DB modes) and contingency measures in case of abnormal and degraded modes of operation (e.g. loss of one TDI, loss of all TDIs etc.)	SO 201 SO 202 SO 206 SO 210
SR1.330 REQ-02.01-SPRINTEROP-ARR0.1440	Approach control shall check the validity of Flight Plan information displayed on the CWP (ICAO aircraft type, wake category)	SO 201 SO 209

SR1.331 REQ-02.01-SPRINTEROP-ARR0.1721	In case of separation tool failure with loss of all TDIs (aircraft already established and aircraft going to intercept), the Controllers shall revert to DBS without indicators for all aircraft (one or several aircraft might be instructed to break-off)	SO 201 SO 202 SO 206 SO 210

B.2 Departures Concepts Solutions

B.2.1 Safety Requirements (Functionality and Performance) for the Departures Concepts Solutions

See Table 43 - Safety Objectives - Departures Concept- Success Approach

Safety Requirements in Abnormal Operational Conditions for the Departures Concepts Solutions

See Derivation of Safety Requirements (Functionality and Performance) for Abnormal Conditions for the Departures Concepts Solutions

Safety Requirements Mitigation to System Generated Hazards for the Departures Concepts Solutions

See 3.2.8.1.1 Requirements (as a result of the hazard analysis)

Safety Requirements (Integrity) for the Departures Concepts Solutions

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

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 Arrivals Concepts Solutions

C.1.1 Assumptions Log for the Arrivals Concepts Solutions

The following Assumptions were necessarily raised during the safety assessment of the Arrivals Concepts Solutions:

Assumption ref	Safety Assumption	Validation
A015	Controllers cannot have detailed knowledge of separations for each pair of aircraft in all modes except for DBS, therefore checking that Target Distance indications are consistent with the associated aircraft types and WT category is not realistic.	Validated. Associated to Hz#05.

Table 47: Assumptions Log for the PJ02.01 Arrivals Concepts Solutions

C.1.2 Safety Issues Log for the Arrivals Concepts Solutions

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

Issue ref [origin]	Safety Issue	Status
ISSUE 01	The wind used for the WDS concept remains to be defined. The corresponding separation reductions shall be defined accordingly (and will depend on the wind definition). A forecast of that wind shall be available with the time window required for separation computation.	Closed. The A-WDS concept is described in Appendix I
ISSUE 02 SO 105	In case of a late landing runway change, it should be verified if the arrival sequencing tool can be timely reconfigured in order to display the Approach Arrival Sequence for the switched runway and update the TDIs accordingly.	Open.
ISSUE 03 See Hz#01a, ARR_SEQ_5	Whether the Approach or Tower Controllers shall be able to inhibit a Target Distance Indicator for a particular aircraft (both FTD and ITD) remains to be further validated. In case Controllers are allowed to inhibit both FTD and ITD for a particular aircraft, a means to recall the lack of TDI needs to be specified in order to mitigate the risk of a wrong association by ATCO of the aircraft with the FTD/ITD of another aircraft (e.g. change colour (fade) when inhibited).	Closed. Requirements have been put in place to mitigate this issue.
ISSUE 04 SAF/HP workshop,	The changes introduced by the new WT separation modes and ATC tools should not negatively impact Flight Crew workload by significantly increasing the number of speed instructions.	Closed. Requirements have been put in place to

Issue ref [origin]	Safety Issue	Status
(Hz#01a, FCRW_1)		mitigate this issue.

Table 48: Safety Issues Log for the PJ02.01 Arrivals Concepts Solutions

C.1.3 Recommendations Log for the Arrivals Concepts Solutions

The following Recommendations were necessarily raised during the safety assessment of the Arrivals Concepts Solutions:

Rec ref [origin]	Safety Recommendation	Status
REC001 See SAC#1 for any mode, in relation to LIM#003	For any local implementation of a specific WT separation concept it is recommended that an analysis be conducted which, for the given local traffic mix and wind conditions, estimates the net effect on the frequency of wake turbulence encounters at each level of severity in comparison to an accepted baseline. This analysis may then be reviewed by local stakeholders and regulatory bodies.	To be addressed in local implementation.
REC002 See SAC#1 for any mode, in relation to LIM#004	For any local implementation and based on the local procedure design and potential encounter geometries, the impact on the wake turbulence encounter probability and severity during the intermediate approach and localiser intercept phases should be considered.	To be addressed in local implementation.

Table 49: Recommendations Log for the PJ02.01 Arrivals Concepts Solutions

C.1.4 Operational Limitations Log for the Arrivals Concepts Solutions

The following Operational Limitations were necessarily raised during the safety assessment of the Arrivals Concepts Solutions:

Lim ref	Limitation	Status
LIM#001	Dependent Parallel Approach operations are not addressed in this Safety Assessment	In line with OSED
LIM#002	Only runway segregated mode is addressed in this Safety Assessment	In line with OSED
LIM#003	The P6.81 WT risk analysis and safety assessment work have not addressed the net effect on the frequency of wake turbulence encounters at each level of severity in comparison to an accepted baseline (focusing only on ensuring that for each aircraft pair the WT encounter severity shall not be higher than the severity of reference aircraft type pair in reasonable worst-case conditions).	To be addressed in local implementation (See REC001)

Lim ref	Limitation	Status
LIM#004	The design criteria for each specific WT separation scheme consider only the final approach wake turbulence encounter risk	To be addressed in local implementation (See REC002)
LIM#005	Regarding the conditional application of Time-based modes, in line with the OSED, only the activation and deactivation conditions of each WT separation mode and the switching between each TB-mode and the corresponding DB-mode are covered within this specification and related safety assessment, but not other transitions between modes.	To be considered in further steps.
~~LIM#006~~	~~The assessment of whether the Approach Controllers (Intermediate and Final) and the Tower Controller can safely deliver aircraft during and after the transition between WT separation modes has not been covered by the validation exercises (both planned transition and unplanned reversion to correspondent DBS mode with indicators or to DBS mode without indicators need to be validated)~~	To be considered in further steps. Has been considered within THALIN 3.
LIM#007	The assessment of whether the Approach or the Tower Controller can safely revert to DBS separation without indicator for a particular aircraft has not been covered by the validation exercises.	To be considered in further steps.
LIM#008	Further investigation is required into understanding how well separation is maintained as aircraft are intercepting the localiser. This could be studied in a future RTS after separation rule transition procedures have been defined (i.e. ICAO to new WT separation, or 3Nm MRS to 2.5Nm MRS, as aircraft merge onto the final approach); Additionally, specific validation needs to be performed in each local implementation because: the assessment of whether Approach Controllers can maintain radar separation during the intermediate approach and localiser intercept phases is strongly dependant on the local environment & interception conditions (altitude, distance to threshold, orientation of the arrival flows, wind conditions, etc.).	To be addressed in further steps & in local implementation.
LIM#009	The demonstration that the number of go-arounds (ATC initiated) due to the operation in the new WT separation modes and ATC tools does not increase significantly has not been successfully performed. Further refinement of the tool and procedures about when to initiate a go-around are required in order to ensure that the go-around rate (ATC induced) does not significantly increase with the new WT separation modes.	To be addressed in further steps.

Table 50: Operational Limitations Log for the PJ02.01 Arrivals Concepts Solutions

C.2 Departures Concepts Solutions

C.2.1 Assumptions Log for the Departures Concepts Solutions

None identified during V3

C.2.2 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 51: Safety Issues Log for the PJ02.01 Departures Concepts Solutions

C.2.3 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.2.4 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 PJ02 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 Concepts Solutions

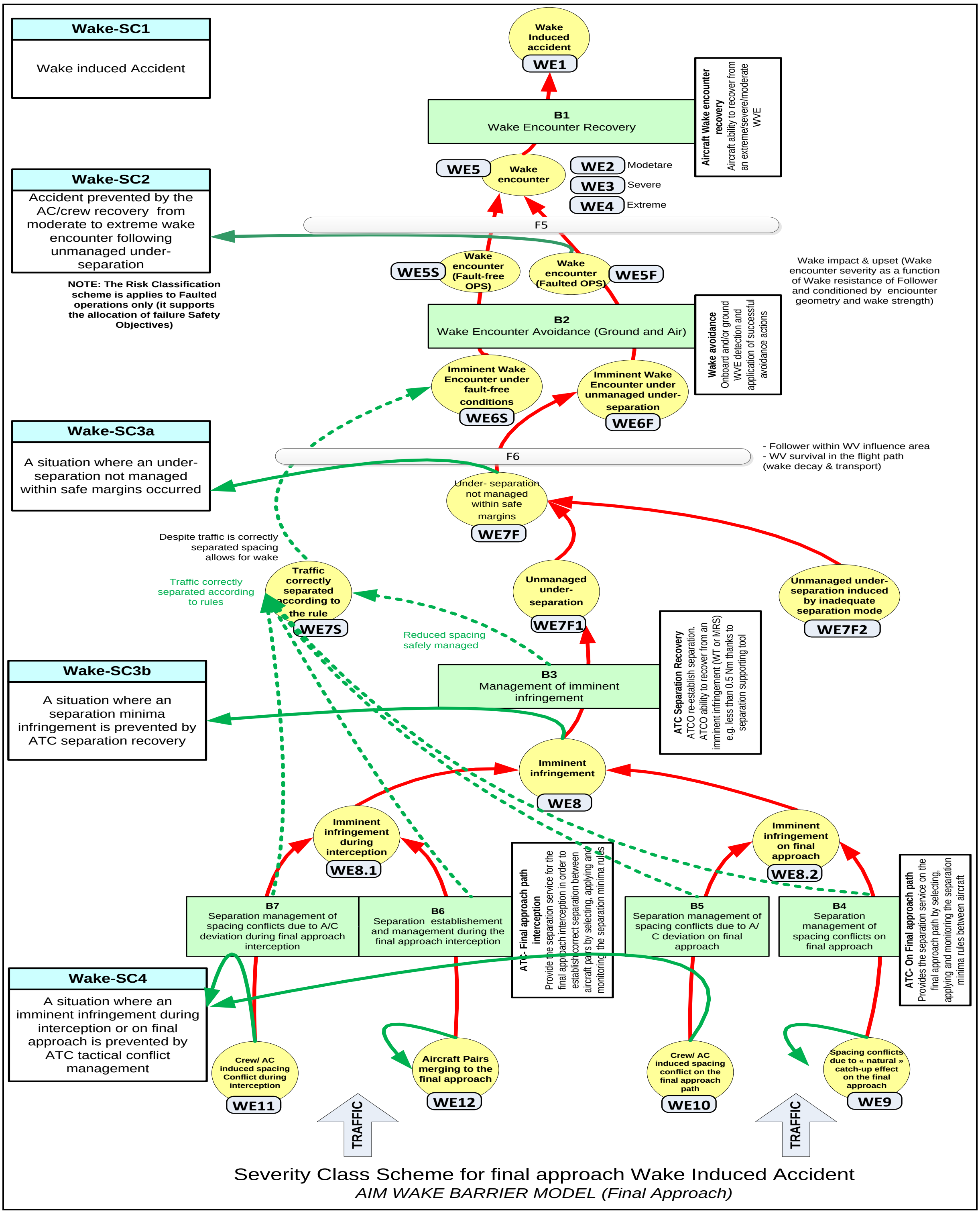

Figure 27: Simplified AIM Model for WT Induced Accident on Final Approach for the PJ02.01 Arrivals Concepts Solutions

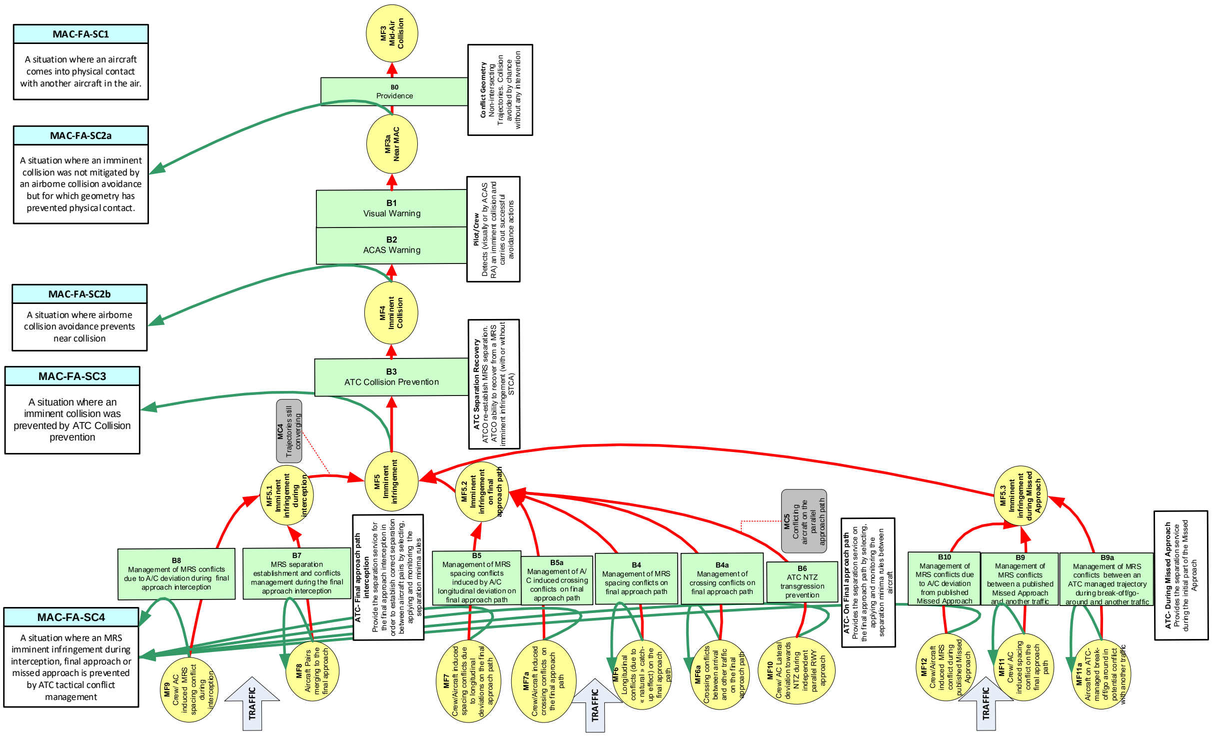

Figure 28: Simplified AIM Model for MAC on Final Approach for the PJ02.01 Arrivals Concepts Solutions

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

TBD – simplified version not yet available.

D.3 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)

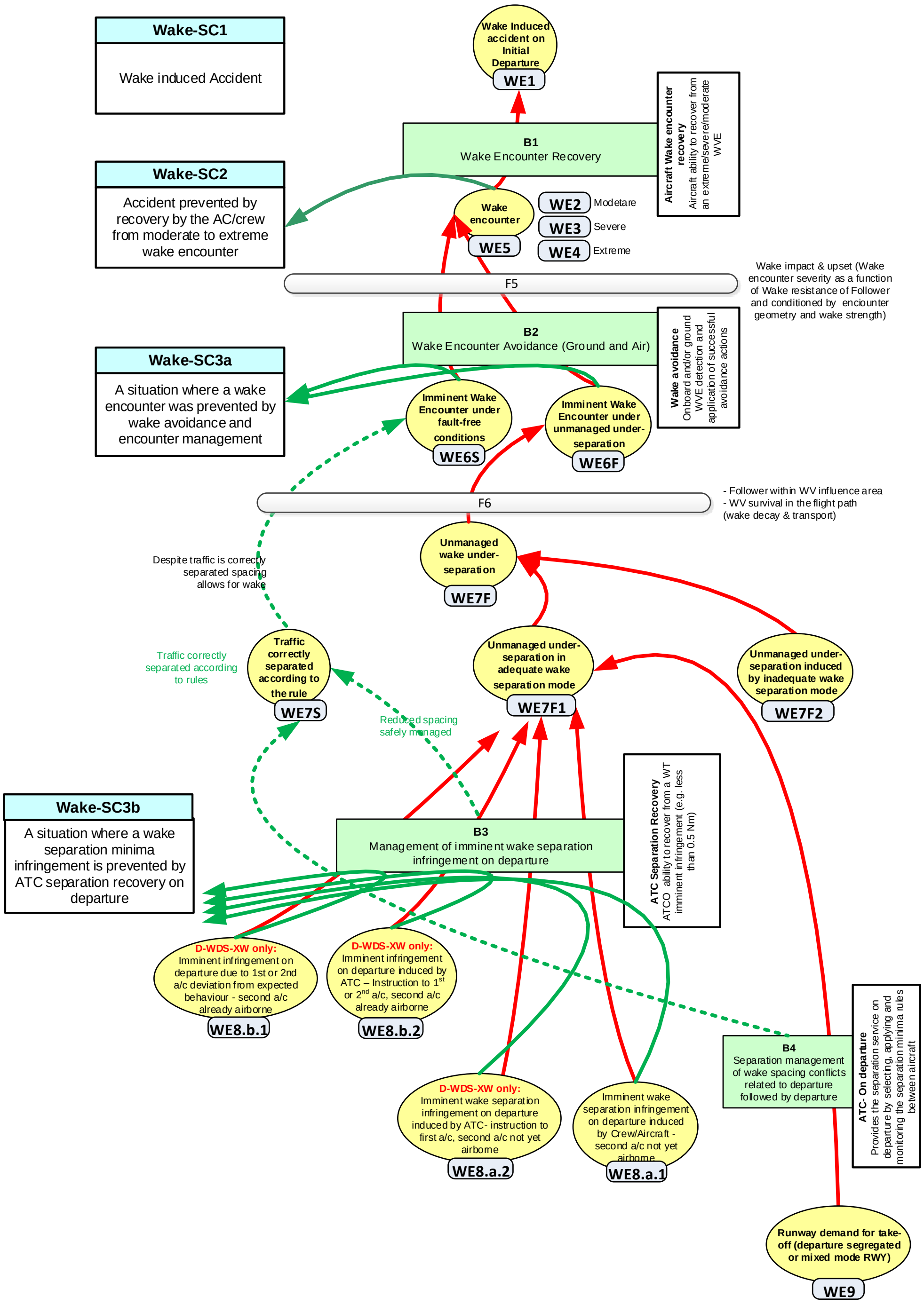

Figure 29: Simplified AIM model for WT Induced Accident on Initial Departure for the PJ02.01 Departure Concepts Solutions

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						

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#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) ➢ 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)	**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
	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 - late change in the interception arrival sequence	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 is spaced closely to the indication, then the separation support tool is inducing a Separation Minima Infringement, which can possibly lead to Severe WVE Multiple corrupted indications might affect the ability to detect errors during the turn on because it may distract	➢ 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) ➢ 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	**TB_Hz#01b:** Fail to recover separation	**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
			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.	following inadequate management of a spacing conflict during the Final Approach interception (following ATC instruction)	
			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-based PWS 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 (SR1.123)	**TB_Hz#01:** Spacing conflict following ATC instruction during the final approach interception	**Wake-SC4**
	Time-based PWS indications provided behind an incorrect	- Aircraft ID swap - late change in the interception arrival	If the provided Time-based PWS indication is incorrect because it is associated to an incorrect lead aircraft,	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced at least with APP ATCO	**TB_Hz#01a:** 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
	aircraft	sequence -AMAN failure	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	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	following ATC instruction 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.	**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 - 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	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 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	**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
				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 -Intercept Glide from above	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 front of the indicator when established).	➢ 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 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	**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
				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**
				➢ 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	**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	**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
				considered sufficient to recover the situation.	given	
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**
	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		

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
				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 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.	➢ 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**
				➢ 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**

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 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 - late change in the interception arrival sequence - AMAN failure	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 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	➢ 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)	**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
			detected).	➢ 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**
	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) • 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.	**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
				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 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	**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
				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 spacing minima delivery from final approach path acquisition until landing based on Time-based PWS indicators.	Time-based PWS 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 Time-based PWS indication for several aircraft	Before indications disappear for one or several aircraft during the approach, it 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	➢ APP and/or TWR ATCO easily detect the problem: • 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	**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
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			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	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)		
	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 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	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 enhanced with ATCO procedure in order to easily revert back to DBS operations without indicators (SR 525)	**TB_Hz#03:** Spacing conflict following ATC instruction during the final approach	**Wake-SC4**
			If the provided indications are actually	➢ Management of imminent infringement during final approach (B3a). This barrier	**TB_Hz#03a:** Inadequate separation management	**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
		sequence	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.	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	of a spacing conflict 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.	**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 - ATCO confusion between separation and spacing	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 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	➢ 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) • 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)	**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
			infringement	➢ 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 • 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	**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
				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. ➢ 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#65: Flight Crew/Aircraft shall fly the final approach path whilst respecting the aircraft speed profile	Aircraft does not respect the speed profile during the approach in Time-based PWS mode (without any specific ATC	-Airspeed computer problem -A/C flap configuration	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-	➢ During the approach: • APP and/or TWR ATCO applies a separation buffer to the displayed indication to prevent	**TB_Hz#04:** Spacing conflict due to aircraft deviation from final approach profile without	**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
(unless instructed otherwise by ATC or airborne needs to initiate go around)	instructions)	-Wrong VAPP computation -Pilot error/misunderstanding -A/C deviates from the glide	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.	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.	ATC instruction given	
			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 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	➢ Management of imminent infringement during final approach (B3a). This barrier needs to be enhanced by at least APP ATCO and Pilot procedures as follows: • 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)	**TB_Hz#04a: I**nadequate separation management of a spacing conflict due to aircraft deviation from final approach 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
			the separation indicator, then it might induce a Separation Minima Infringement, and possibly a WVE.	➢ 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#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 turbulence) on approach	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 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	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 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 detect the problem: • APP and/or TWR ATCO applies DBS (without indication) for the aircraft (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	**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
		late change in the interception arrival sequence		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**
	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	If the Approach or Tower controller does not respect the DBS 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 final approach (B3a). This barrier needs to be enhanced by APP ATCO 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	**DB_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
				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		
				➢ 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 • 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).	**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
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) • 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	**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
				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 on generic conditions (traffic mix, weather…) or locally considering specificities of local traffic and weather conditions	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**
			<u>For aircraft on the final approach:</u> 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	**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
				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		
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		
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	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	Same as results provided above for SO#15				

TBS Success SO	Failure mode	Example of causes	Operational effect	Mitigations detecting and protecting against propagation of the failure mode effects	Operational hazard	Severity
DBS to Time-based PWS mode	be applied					

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 path acquisition until landing based on Time-based PWS indicators.	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**
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.
TB_Hz#02b	Fail to recover separation following inadequate separation management of a spacing conflict due to	Hz#02b	Separation not being recovered following imminent infringement due to aircraft deviation from Final Approach interception profile without ATC

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**
DB_Hz#02b	aircraft deviation from final approach interception profile without ATC instruction given.		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.
New		Hz#06	One or multiple imminent infringements due to lack/loss of separation indicator for multiple or all aircraft.

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**
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 PJ02.01 SAF & HP Workshop

A PJ02.01 SAF & HP workshop took place at EUROCONTROL Bretigny the 30th of October 2018. The list of participants was as follows:

Organisation	Name	Email	Position
Vienna Airport	Haris Usanovic	Haris.Usanovic@austrocontrol.at	TWR & APP ATCO
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	Valerio Cappellazzo	Valerio.Cappellazzo@eurocontrol.int	Concept design expert
	Ivan De Visscher	ivan.devisscher@wapt.be	Wake expert

F.1 Arrivals

F.1.1 Applicable to the Interception Phase

Possible Hz	Causes	Mitigations	Comments
1. Unanticipated pilot/aircraft behaviour during interception (cause for Hz#01a orHz#02a)	(a) Pilot slow in following instruction or inadequate response to ATC (not recovered through monitoring) (b) Overshoot (c) Lateral, vertical or speed deviation initiated by crew/aircraft (e.g. deviation from published speed) (d) Wrong a/c turns on the indicator (pick-up instruction for other aircraft) Note: a) is a cause for Hz#01a: Inadequate separation management during interception b), c) and d) are causes for Hz#02a: Inadequate separation management of a spacing conflict due to aircraft deviation from Final	**<u>Preventive Mitigations:</u>** **<u>Protective Mitigations</u>** (a, b, c, d) Continue with the currently applicable rules for allowance to descend from 3NM to 2.5NM upon turning on to intercept (spacing buffer leaving room for separation recovery during interception) (a) Detect inadequate response to ATC through monitoring of the instruction execution & correct (a, b, c, d) ATC Recovery from imminent infringement by adequate action (vectoring, level instructions or go-around) - see line 11	Heathrow: Pilot compliance with speed instruction has been a problem at the beginning of the TBS implementation. Airlines have been briefed about the safety importance of the speed compliance with the new concept. Current HP REQ: Information campaigns for flight crew. E.g. aircraft instructed 160 kt then transferred to TWR, afterwards leader a/c reduces to 150 kt before DF with risk of separation infringement by the follower. That requires APP ATCO to quickly coordinate with TWR requiring to increase speed back to 160 kt

Possible Hz	Causes	Mitigations	Comments
	Approach interception profile without ATC instruction given		
HUMAN PERFORMANCE	1. TDIs reduce ATCOs overall SA→ risk to focus too much on getting the a/c to the target so their focus of attention may become narrower • Not detecting the deviation on time • Not detecting downwind or base leg infringements • Need of having alerts/ alarms at this stage for identifying a, b, c or any other possible causes for this hazard?		

Possible Hz	Causes	Mitigations	Comments
2. Wrong ATC instruction during interception despite correct separation indicator (cause for Hz#01a or Hz#02a)	(a) Inadequate procedures/instructions for separation establishment/management (b) ATCO – pilot misunderstanding	**Preventive Mitigations:** (a) Target distance indicators displayed far enough in advance on RWY extended centreline (a) INI_APP contribution (prepare traffic for ITM_APP) **Protective Mitigations** Resolve situation by vectoring, level instructions or go-around	
HUMAN PERFORMANCE	1. Equitable distribution of work for INI and ITM? • Communication load • a/c on frequency Type/ number of instructions		

Possible Hz	Causes	Mitigations	Comments

Possible Hz	Causes	Mitigations	Comments
3. Separation indicator not displayed or not timely available for one aircraft pair during turn-on (cause of Hz#01a)	(a) ORD tool failure (one pair affected only) (b) No input from Sequencing tool (one pair) (c) Aircraft not in arrival sequence tool (d) Flight Planning info missing/not recognized (a/c type or WT CAT)	**Preventive Mitigations** **Protective Mitigations** ATCO detects the missing indicator and: (c) corrects the arrival sequence (a), (b), (d) ATCO applies Baseline DBS separation minima (ATCO needs to keep awareness of the aircraft type/WTC)	
HUMAN PERFORMANCE	1. Would it be easy/ enough to identify the a/c pair based on the sequence alert? 2. How would you keep the awareness for this a/c pair with regard to the DBS application?		

Possible Hz	Causes	Mitigations	Comments
4. Lack/loss of indicators for multiple or all aircraft Cause for Hz#06	(a) Loss of ORD Tool (b) Loss of sequencer tool (c) Loss of flight planning information (d) RWY Separation mode not updated (the information about the mode of operation -segregated or mixed mode- is not sent to the	**Preventive Mitigations:** **Protective Mitigations** ATCO detects the missing indicators and reverts to Baseline DBS (a supporting DBS table is required, especially in TB PWS with multiple categories) Aircraft established on Final approach stabilized with 160kts IAS and behind ITD are allowed to continue the approach All other aircraft – either not established on	

<table>
<tr><th>Possible Hz</th><th>Causes</th><th>Mitigations</th><th>Comments</th></tr>
<tr><td></td><td>arrival sequencer)</td><td>Final or not at stabilized IAS 160kts or not behind ITD
 Initiate Go-around or break off
 Establish ICAO DBS asap</td><td></td></tr>
<tr><td>HUMAN PERFORMANCE</td><td colspan="3">1. What is the role of the supervisor in case this hazard applies? For spontaneous transitions, the ATCO independently reverts to DBS, as the collaboration with the SUP might not be timely enough.
2. Would you trust the TDIs if they suddenly reappear?
• E.g. in Vienna there is a Central Control Service that gives permission to proceed after degraded modes.
• How is it in CDG?
3. Are alerts necessary for all these possible causes so that you quickly understand the situation and act accordingly? Where possible, there shall be an indication of the error that has occurred. HP REQ: To be clearly specified at local level what alerts and alarms are available and what procedures apply in case of such errors.
4. In this case is the separation table a “must have” ? What other support info you would need handy? What other support info you would need handy? HP REQ: ATCOs shall have the conventional separation table available (on display if required) in case they need to revert from TBS to DBS.
5. In case the possibility to “toggle on and off” the indicators exists and is applicable, what indications would you need to make sure they were intentionally removed or you are actually dealing with a degraded mode. The ATCOs would like to know whether the TDIs disappeared as a result of an error or if they are intentionally removed for DBS reversal.</td></tr>
</table>

F.1.2 Applicable to the Interception and Final Approach Phases

Possible Hz	Causes	Mitigations	Comments
5. Corruption of one or multiple separation indicators Cause for Hz#05	(a) Incorrect a/c type or WT CAT (b) Flight plan info corruption (c) Corruption of separation tool (d) Sep tool config failure (i.e. incorrect airspeed profile, incorrect sep table) (e) Corruption of arr seq or arr seq not (correctly) updated (f) Corrupted RWY operation mode (g) Inadequate/missing surveillance data (h) Missing update or detected loss of the G/S headwind profile	**Preventive Mitigations** Adequate SW assurance **Protective Mitigations** (a, b) Incorrect a/c type might be detected via Pilot reporting **(to derive SAF REQ for systematic a/c type reporting)** (c to g): Only in case of gross error ATCO might detect the corruption of the indicator/s. Upon detection: Discard the corrupted indicator(s) and instruct aircraft such as to enable Baseline DBS separation minima (if not feasible, instruct break-off/go around If undetected, no protective mitigation available **For (h) only:** ATCO reverts to Baseline DBS with no indicators without coordination with SUP due to not enough time to coordinate (a supporting DBS table is required, especially in TB PWS with multiple categories). *SR1.307 "In TB-modes, in the degraded situation where glideslope headwind profile input is missing:*	LHR: in case of loss of wind input, ORD tool reverts to DBS plus conservative conditions for computing compression In case of tool loss, ATCOs apply DBS plus 1NM conservative for compression

Possible Hz	Causes	Mitigations	Comments
		- The Controllers shall be displayed with the loss of glideslope headwind alert and shall revert to the correspondent DB- mode (DBS or S-PWS) with use of FTD but without ITD (manual management of compression) or keep using the TB-mode with ITD and FTD computed using a conservative wind profile until the glideslope headwind profile is available again; ***OR*** *- The Separation Delivery Tool shall automatically revert to the correspondent DB-mode or an acceptably safe TB-mode (FTD and ITD computed using a conservative wind profile). A notification of the automatic switch shall be provided to the ATCOs and Supervisors"*	
HUMAN PERFORMANCE			

Possible Hz	Causes	Mitigations	Comments
6. Incorrect G/S wind profile used for computation Cause for Hz#05	(a) Meteo error/incorrect reference wind prediction (b) Incorrect reference wind monitoring	**<u>Preventive Mitigations:</u>** (b) Reference wind monitoring alert Upon detection via this alert, APP/TWR SUP or ATCOs revert from TB-mode to corresponding DB-mode (similar to lack of glideslope wind profile input; see SR688)	

Possible Hz	Causes	Mitigations	Comments
		<u>Protective Mitigations</u> Partially for both DB and TB modes: Buffer for ITD and FTD take margins on the wind computation. In DB-mode: ATCO will realise that the tool is using incorrect wind reference because successive aircraft separated correctly using the chevrons will have the tendency to infringe the correct FTD as the leader decelerates, triggering a go-around by the TWR controller. In TB-mode: It is difficult for the ATCO to realise that the tool is using incorrect wind reference. The a/c will be separated according to a wrong FTD, i.e. wake separation infringement. TO DERIVE INTEGRITY/RELIABILITY SO OR SR Mitigation for sudden wind variation: *SR300: "For all DB modes with ORD (i.e. displaying ITDs) and TB modes, the Approach and Tower Controllers and Supervisors shall be alerted by the glideslope headwind monitoring function about a significant difference between actual glideslope headwind profile and the glideslope headwind*	

Possible Hz	Causes	Mitigations	Comments
		profile used for the TDI computation, i.e. when the predicted time-to-fly (based on the headwind profile prediction used for Target Distance Indicator computation) compared to the actual time-to-fly (based on the actual headwind measurement) exceeds a threshold to be determined locally"	
HUMAN PERFORMANCE	1. What additional wind information would you require as compared to today`s operations? What about the supervisor?		

Possible Hz	Causes	Mitigations	Comments
7. Incorrect separation indicator in relation to speed non-conformance of the leader aircraft Cause for Hz#05	(a) ATCO failure to detect a/c abnormal speed (b) Speed conformance alert failure	**<u>Preventive Mitigations:</u>** (a) Speed conformance monitoring alert (10NM to DF) (b) The tool computes some buffer for coping with speed non-conformance **<u>Protective Mitigations</u>** Go-around to Follower (because TDI might be wrong)	
HUMAN PERFORMANCE	1. A failure of LORD related alerts would make you uncomfortable working with the LORD, prompting that other indications might be incorrect?		

F.1.3 Applicable to the Final Approach Phase

Possible Hz	Causes	Mitigations	Comments
8. Inadequate use of separation indicators by the APP ATCO Cause for Hz#03a	(a) ATCO confusion between separation and spacing (b) ATCO does not adjust a/c speed to solve a conflict due to catch-up effect (c) Inadequate ATCO competency/currency with the use of indicators	**Preventive Mitigations:** (a to c) Catch-up alert (a to c) Adequate ATCO training for the use of indicators **Protective Mitigations** Go-around (note that ITD and FTD are computed with buffers, which gives some room to ATCO to prevent the loss of separation if the problem is detected)	
HUMAN PERFORMANCE			

Possible Hz	Causes	Mitigations	Comments
9. Aircraft deviates from the final approach speed profile expected by ATC Cause of Hz#04a	(a) Pilot picks up instruction for other a/c (b) Pilot deviates from expected/instructed speed profile (c) Aircraft failure (d) Un-stabilized approach	**Preventive Mitigations:** (a, b) Publish procedural air speed on Final Approach (a, b) Add briefing to airlines, provide monthly reports on speed compliance (e.g. as in EGLL), follow-up with WebEx/calls. **Protective Mitigations** Supported by catch-up warning; Re-clear a/c to fly a different speed if possible OR	

Possible Hz	Causes	Mitigations	Comments
		Go-around;	
HUMAN PERFORMANCE			

Possible Hz	Causes	Mitigations	Comments
10.Lack/loss of indicator for one aircraft on Final App Cause of Hz#01a and Hz#03a	(a) ORD tool failure (b) Sequencer tool failure (c) Aircraft not in the arrival sequence tool (d) Flight planning information (A/C Type or WT CAT) missing or not recognized for a given aircraft	**Preventive Mitigations:** **Protective Mitigations** ATCO detects the missing indicator and: Aircraft established on Final approach stabilized with 160kts IAS and behind ITD is allowed to continue the approach, otherwise initiate Go around Proposed saf req: Consider this non-nominal situation in Training and in the procedures (operating manual) Proposed saf req: Consider this non-nominal situation in Training and in the procedures (operating manual) To validate *SRx41 (REQ-02.01-SPRINTEROP-OPS3.0004): "The tool shall provide ATCOs the ability to selectively supress TDIs for specific aircraft (Rationale: For example in case of*	

Possible Hz	Causes	Mitigations	Comments
		delegating responsibility for wake separation to flight deck)"	
HUMAN PERFORMANCE	1. Would you feel comfortable working with the TDIs for the following a/c pairs? 2. Would you just increase separations for this a/c pair (DBS) and then continue with TBS? 3. Would you consult the Supervisor → new procedure?		

Possible Hz	Causes	Mitigations	Comments
Protective mitigation for above hazards			
11. Fail to recover from imminent infringement by adequate action Cause for: Hz#01b, Hz#02b, Hz#03b, Hz#04b	(a) ATCO failure to detect need for recovery action (e.g. Go around, break off etc- depends on the triggering event) (b) ATCO failure to instruct timely the separation recovery action before the imminent infringement is evolving to a large under-separation (c) Pilot failure to timely execute the separation recovery instruction	**Preventive Mitigations** FTD (in TB concepts) and ITD (in both DB and TB concepts) are computed with buffers to attempt to prevent separation infringement, regardless of the value of the FTD. Outside a pre-defined region (4NM at Heathrow): STCA will trigger. Indication of IAS and GS to APP ATCO (current mitigation). **Protective Mitigations** With respect to WTE risk: Follower within WV influence area, WV survival in the flight path (F6) Wake impact & upset (F5) Wake encounter recovery (B1) The use of ORD is expected to mitigate that risk increase by contributing to the reduction	

Possible Hz	Causes	Mitigations	Comments
		of separation infringements thanks to the increased separation delivery accuracy.	
HUMAN PERFORMANCE			

Possible Hz	Causes	Mitigations	Comments
	Abnormal conditions		
12. Unplanned blocked Runway Abnormal condition	Debris on RWY	**Protective Mitigations** Instruct Go around & break off to all aircraft established or in the process of interception - Instruct go around (alternative left, straight, right – if those alternatives are possible at the airport, for horizontal separation) - Instruct level off at different intermediary altitudes (for vertical separation) - Transfer to Departures.	
HUMAN PERFORMANCE			

Possible Hz	Causes	Mitigations	Comments
Applicable to Mode Management (Selection, Transition)			

Possible Hz	Causes	Mitigations	Comments
13. Incorrect selection or transition management of separation mode when a/c established on final (only with conditional application e.g. in WDS) Hz#07	(a) Corrupted surface wind indication (b) Fail to detect that wind cond are not or no more met (c) ATCO activate TB mode without SUP decision (d) Confusion between ATCO-SUP about first aircraft to be separated according to the new activated mode	**<u>Preventive Mitigations:</u>** SW assurance Reliable wind measurements (double source) **<u>Protective Mitigations</u>**	
HUMAN PERFORMANCE	1. Examples from today`s operations (e.g. when they switch to LVP)? 2. What does the SUP coordination imply? 3. How do the supervisors communicate (more need of silent communication?)? 4. What is the role of the ATCO in the transition? 5. When do the supervisors need to consult ATCOs? 6. How would the tool display this information? (both ATCO and SUP) 7. What type of alerts would they need? (both ATCO and SUP) – wind related/ mode related etc. 8. Any other potential risks remained unidentified? 9. Any additional information needed for ATCOs? (e.g. the first aircraft in the arrival sequence to be separated according to the new mode (e.g. at least 2 min before interception) 10. Unaware whether you operate in DBS or WDS/TBS –PWS: would a simple indication of the mode of operation be enough? 11. Supervisor WKLD? → significant changes? 12. Equitable distribution of work during transition for APP – TWR (ATCO and SUP)/ communication load?		

F.2 Mixed Mode

Possible Hz	Causes	Mitigations	Comments
1. Instruct aircraft line-up in conflict with arrival aircraft	(c)	**<u>Preventive Mitigations:</u>** A wrong Sequence planning information is systematically detected by ATCO (via his situation awareness & own view of the correct sequence and possible use of a gap) **<u>Protective Mitigations</u>** Go around timely instructed & executed (RWY Col AIM Barrier B2)	A failure, loss or corruption of the sequence list tool will have an impact on the ATCO performance, but is safely mitigated by ATCO keeping full awareness of the sequence in the short term. ATCO will apply a more conservative strategy (e.g. instruct 2 departures in a gap instead of the 3 initially planned), will estimate the departures fitting in the arrival gaps by himself.
HUMAN PERFORMANCE	1. Current alerts? 2. Sequence tool→ coordination changes? (more silent coordination- e.g. manual input of time to be approved?) 3. What if the sequence list has inaccurate values? Would you consider it feasible for you to identify them without an alert? 4. Coordination for the gap- requirement to not make such a coordination after base leg?		

Possible Hz	Causes	Mitigations	Comments
2. Aircraft lines-up without instruction in conflict with arrival aircraft	(a) lines-up without instruction	**<u>Preventive Mitigations:</u>** Stop-bar and A-SGMCS features that might identify such non authorized runway incursions **<u>Protective Mitigations</u>**	As per current ops

Possible Hz	Causes	Mitigations	Comments
		Go around timely instructed & executed (RWY Col AIM Barrier B2)	
HUMAN PERFORMANCE	1. Different than today`s operations?		

Possible Hz	Causes	Mitigations	Comments
3. Delayed take-off brings lined up aircraft in conflict with arrival aircraft	(c)	**Preventive Mitigations:** **Protective Mitigations** Go around timely instructed & executed (RWY Col AIM Barrier B2)	As per current ops
HUMAN PERFORMANCE	1. Different than today`s operations? 2. Slow reaction times under 2nm MRS/ pilot reluctance → any change in phraseology needed?		

Appendix G PJ02.01 / PJ02.02 / PJ02.03 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 PJ02.01, PJ02.02 and PJ02.03. Note only the results from PJ02.01 and PJ02.03 were kept in this appendix.

PJ	QUESTION	RATIONALE	COMMENTS:
PJ02-01 Pj02-03	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.
PJ02-01	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.
PJ02-01 PJ02-03	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.
PJ02-01 PJ02-03	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)
PJ02-01 PJ02-03	5. Do you consider the need to double check separation values	Could WDS negatively impact the amount of R/T usage between pilots & ATCOs. →	Pilot will not perform such check (see points 1

	with ATCOs would increase, when applying reduced MRS/conditional separations?	Validation activities show an acceptable level of R/T for ATCOs during hypothetical normal operating conditions (i.e. no questioning by Pilots)	and 3 above)
PJ02-01 PJ02-03	6. Is the responsibility of the pilots remaining unchanged?	In terms of monitoring and task requirements.	No changes identified.
PJ02-01 Pj02-03	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)
PJ02-01 Pj02-03	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
PJ02-01 PJ02-03	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	Again Pilots recall their recommendation for removing the early landing clearance at CdG, in order to improve Pilots confidence.

		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)	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.
PJ02-01 PJ02-03	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. (PJ02-03 is currently checking via FTS that RA are not triggered with 2NM MRS;

			on CSPR there might be a issue)
PJ02-01	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)
Pj02-01 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)
Pj02-01 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
PJ02-01 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)
PJ02-01 PJ02-03	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 H Risk Classification Schemes for relevant accident-incident types

Appendix H covers the following Concepts Solutions:

- Accident-incident types for Arrivals Concepts Solution in Section H.1
- Accident-incident types for Arrivals and Departures Concepts Solutions in Section H.2
- Accident-incident types for Departures Concepts Solutions in Section H.3

H.1 Accident-Incident Types for Arrivals Concepts Solutions

Severity Class	***Hazardous situation***	***Operational Effect***	***MTFoO (per approach)***
Wake-SC1	Aircraft accident following an encountered wake turbulence which led to a fatal structural failure, a collision with the ground or a collision with other aircraft in the air	Wake Induced Accident (WE1)	2E-08
WK-FA-SC2a	A situation where a wake-induced accident was prevented by the aircraft wake encounter recovery (both correctly and under-separated aircraft)	Wake Encounter (WE5 i.e. WE2/3/4)	1E-05
WK-FA-SC2b	A situation where a wake encounter was prevented by the wake encounter avoidance (both correctly and under-separated aircraft)[48]	Imminent wake encounter (WE6S, WE6F)	1E-05
WK-FA-SC3a	A situation where an under-separation not managed within safe margins occurred	Under- separation not managed within safe margins (WE7F)	2E-04
WK-FA-SC3b	A situation where an unmanaged under separation is prevented by ATC separation recovery	Imminent Infringement (WE 8)	1E-02
WK-FA-SC4	A situation where a Crew/aircraft induced imminent infringement during interception or on the Final Approach path was prevented by ATC spacing conflict management	Crew/Aircraft Induced spacing Conflict during Interception (WE11) or on Final Approach (WE10)	1,00E-01

Table 52: Risk Classification Scheme for WT Accident on Final Approach for the PJ02.01 Arrivals Concepts Solutions

[48] This barrier is ineffective in current operations (will be supported by SESAR 2020 PJ02-01 Wake Risk Monitoring & Awareness)

H.2 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 53: Risk Classification Scheme for Runway Collision for the PJ02.01 Arrivals and Departures Concepts Solutions

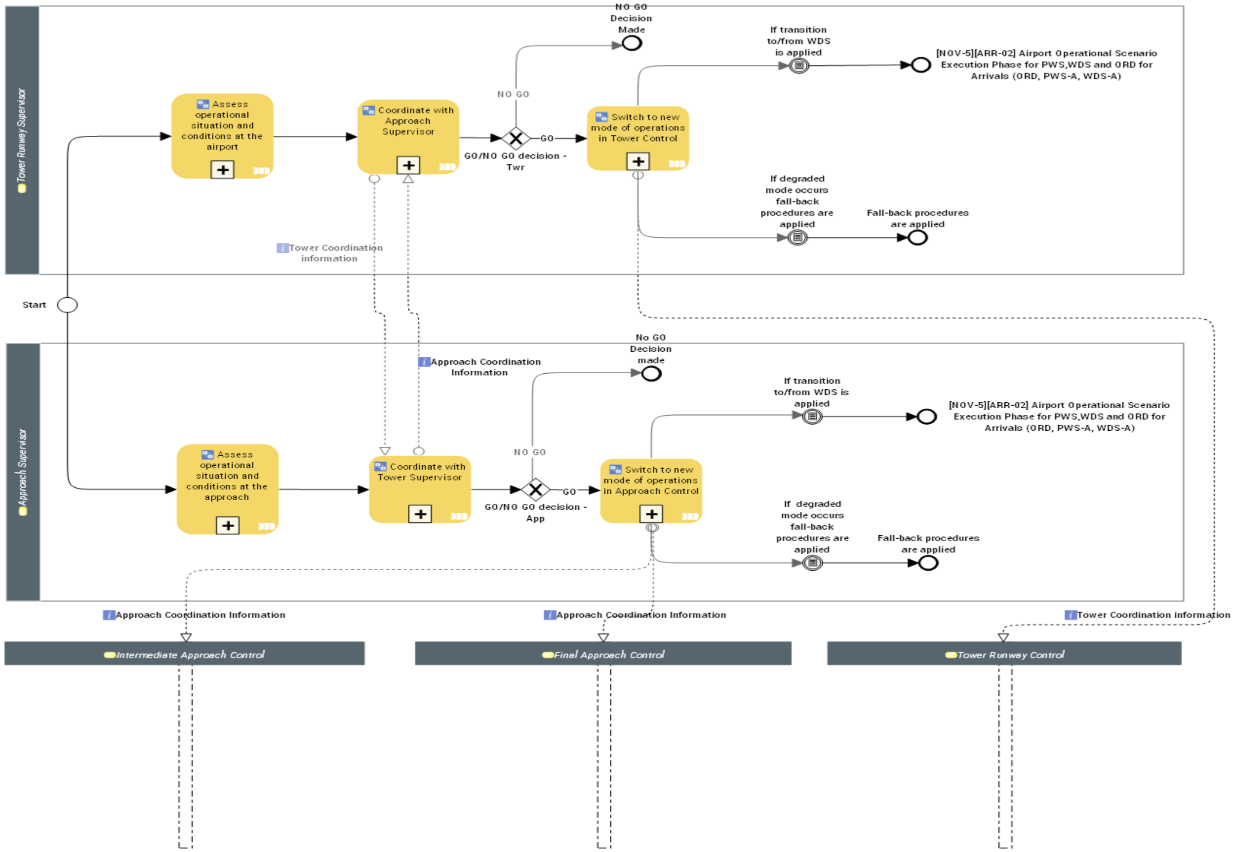
H.3 Accident-Incident Types for Departures Concepts Solutions

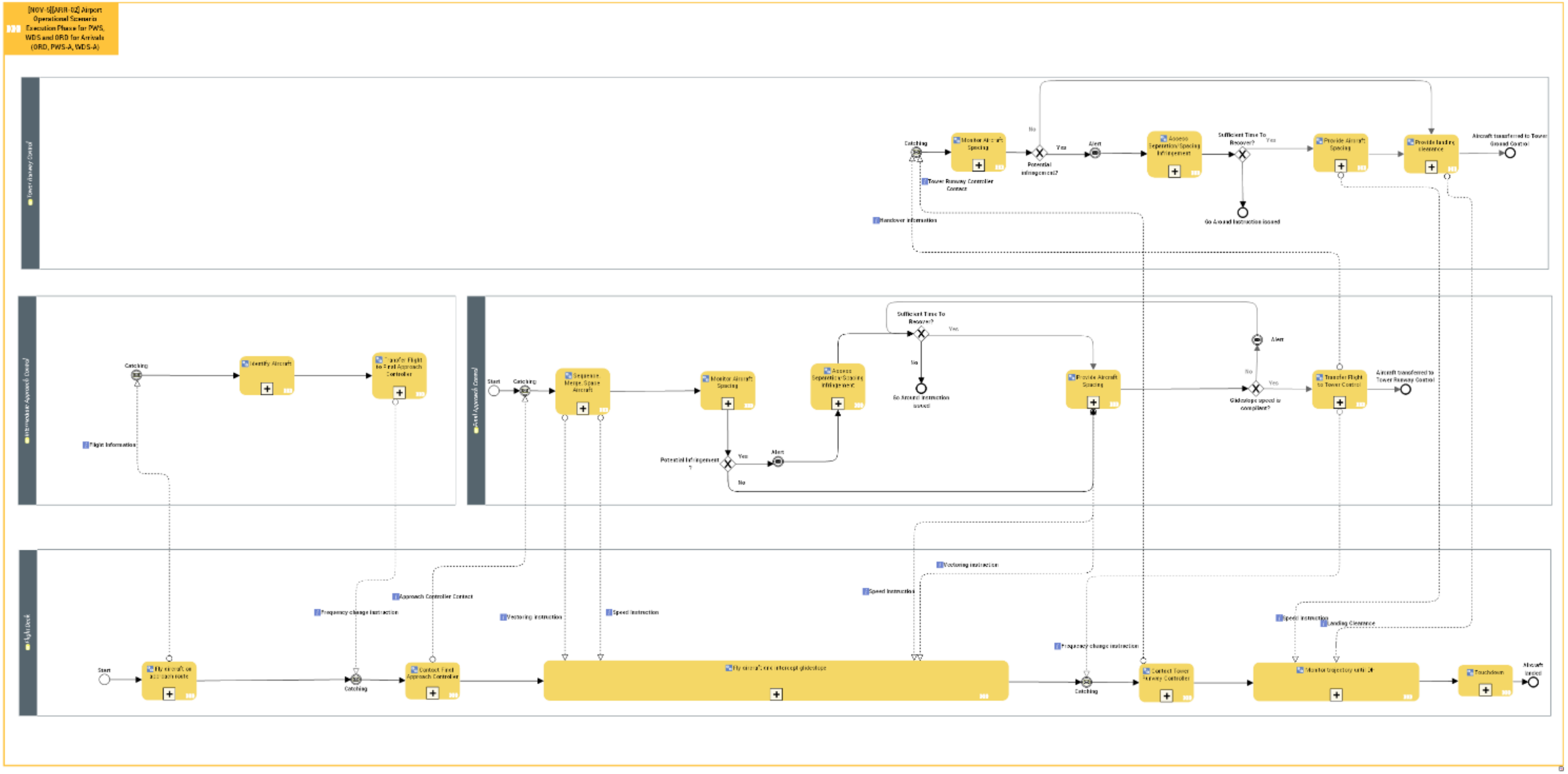
Wake AIM to be inserted here when finalised by ECTL

Appendix I EATMA Models for arrivals and departures

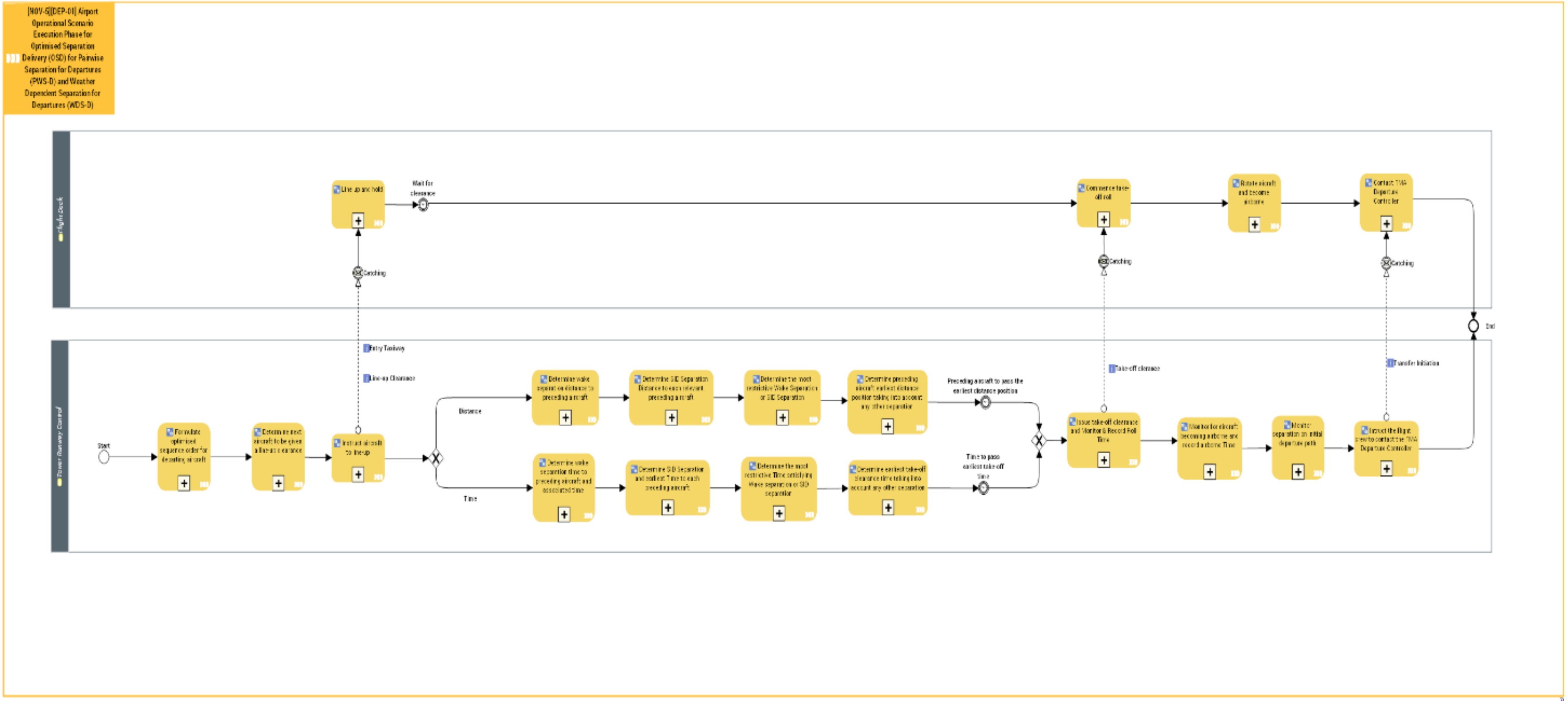
I.1 NOV-5

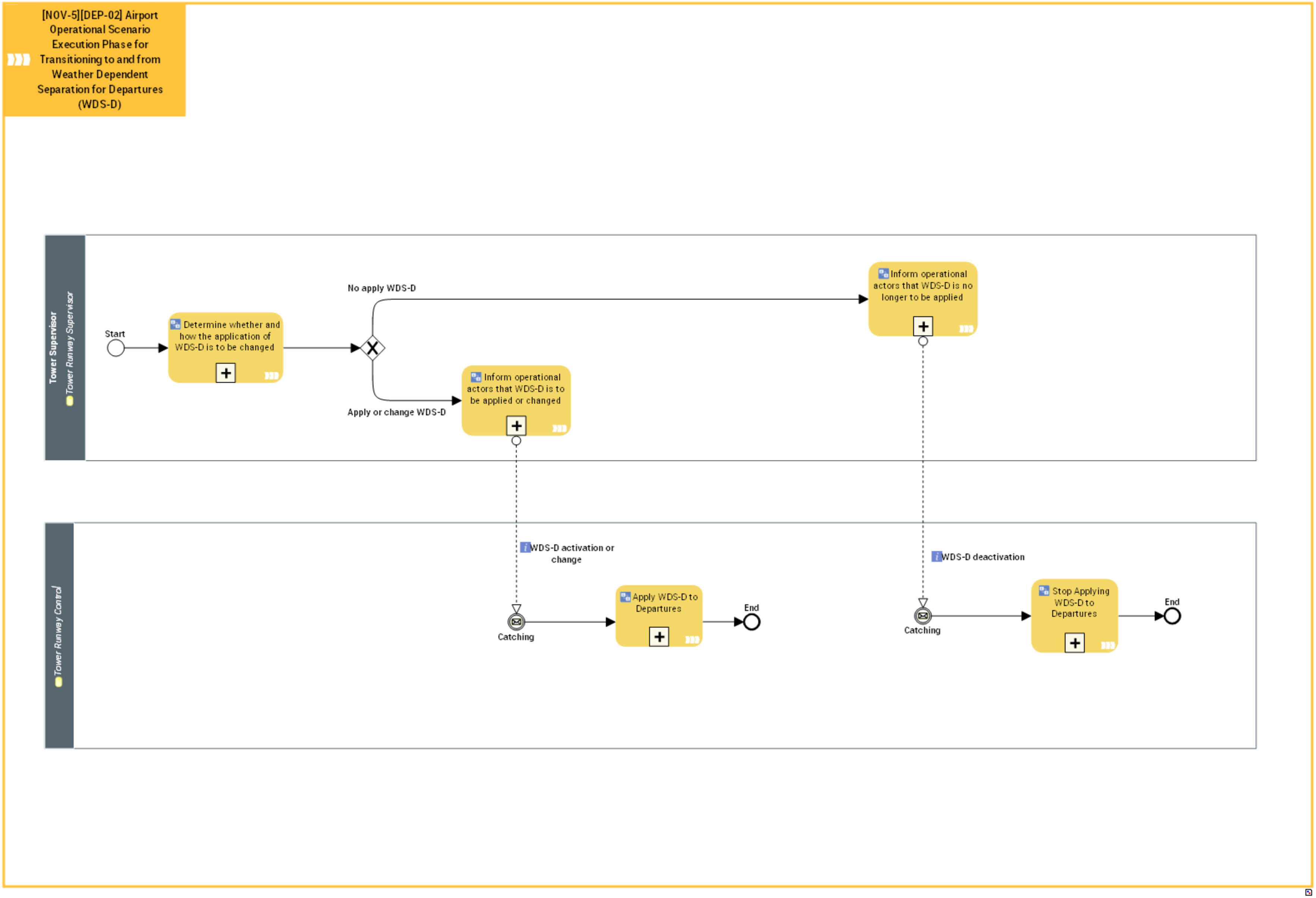
I.1.1 Arrivals



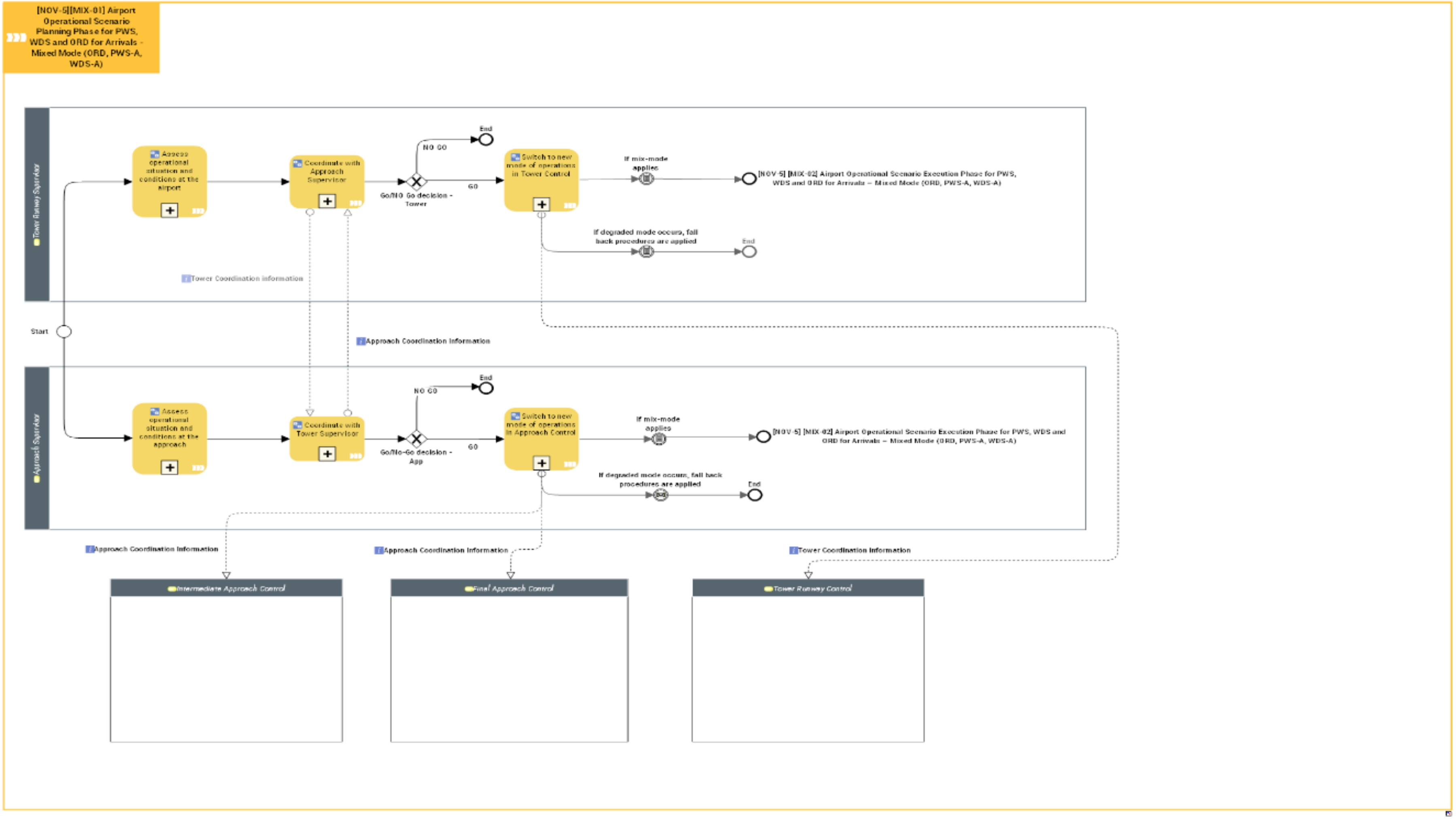

[NOV-5][ARR-02] Airport Operational Scenario Execution Phase for PWS, WDS and ORD for Arrivals (ORD, PWS-A, WDS-A)

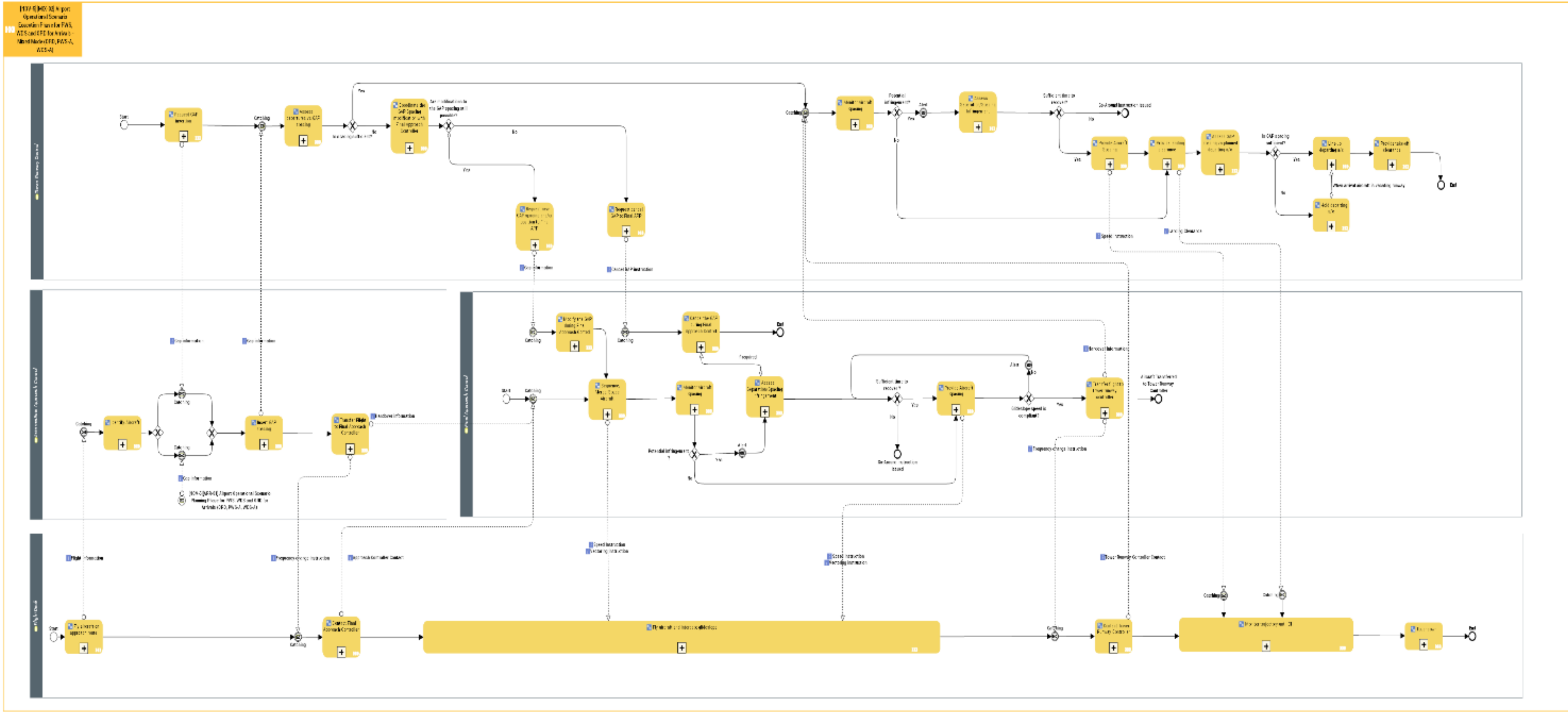
I.1.2 Departures




[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 to be applied or changed
Inform operational actors that WDS-D is no longer to be applied
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

I.1.3 Mixed Mode

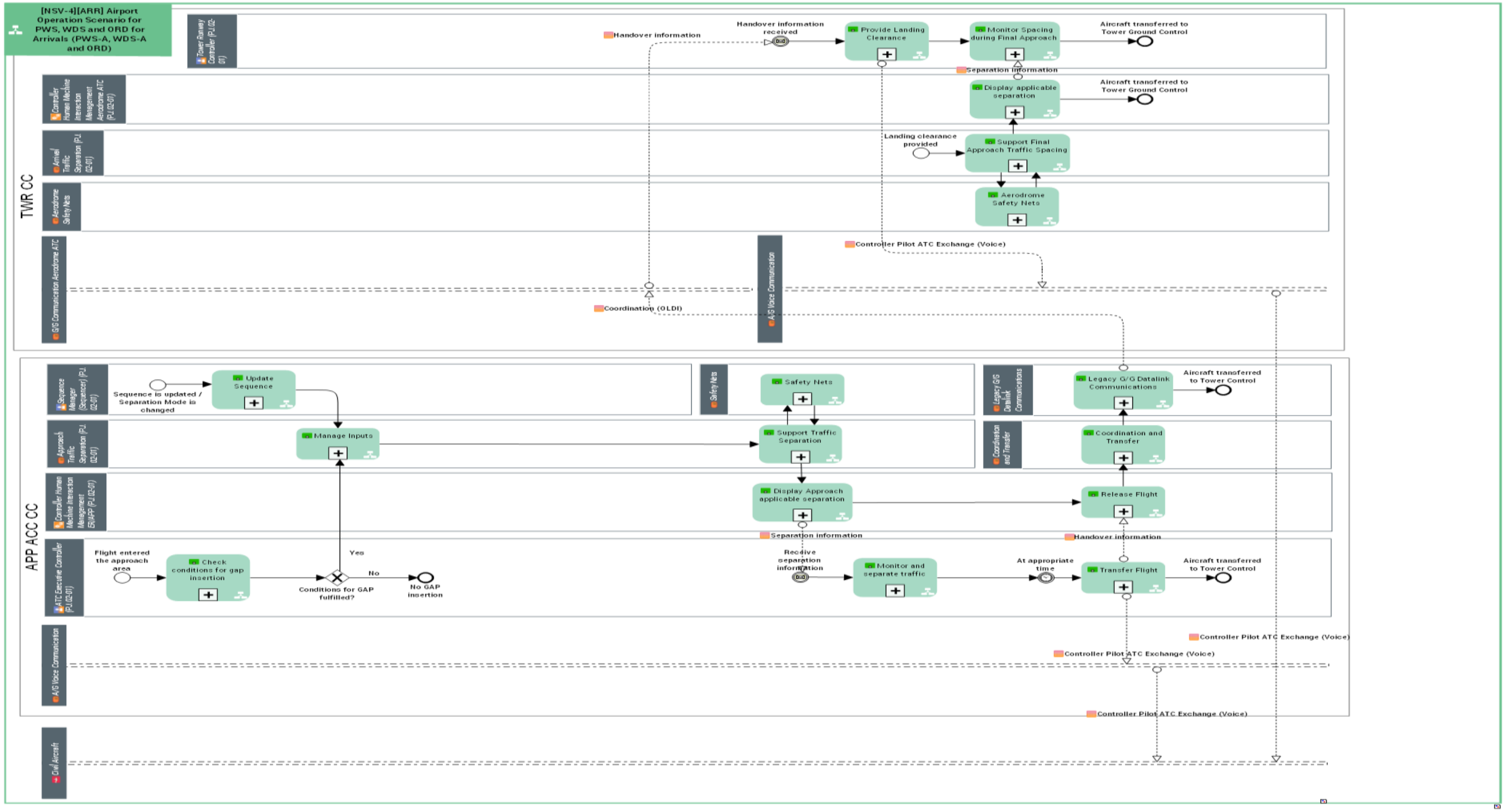




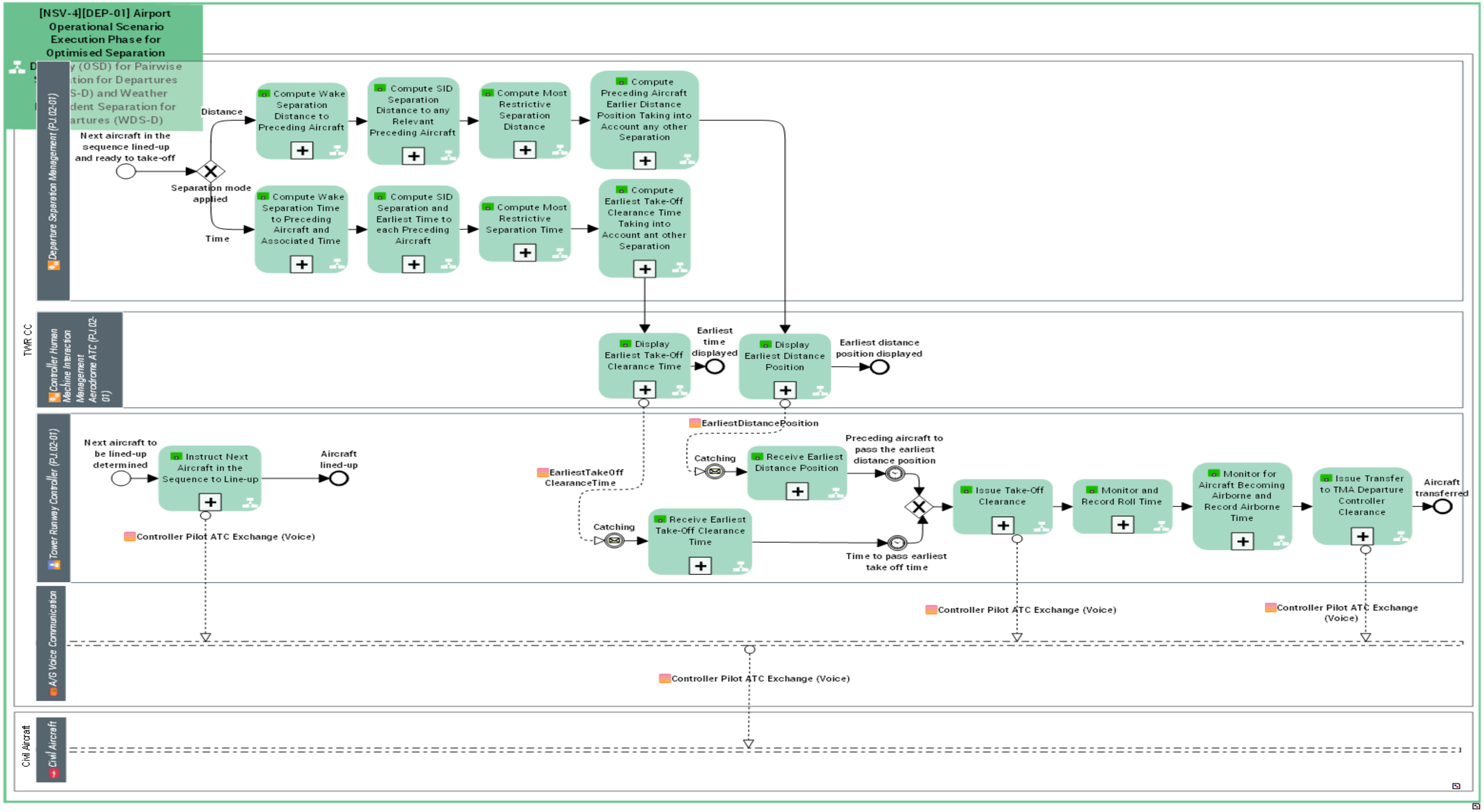
I.2 NSV-4

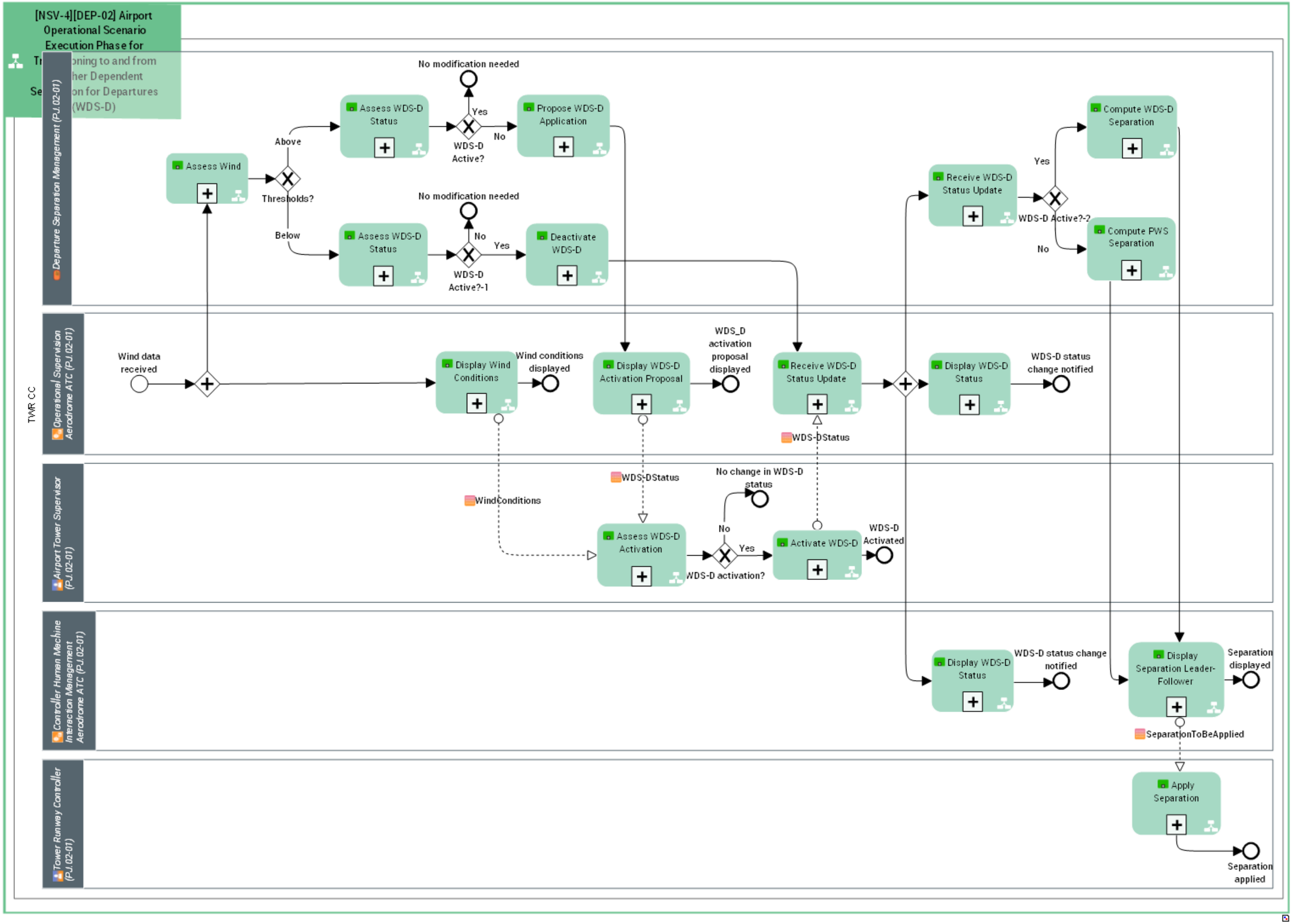
I.2.1 Arrivals

Note that, at the time when this report was written, the EATMA NSV-4 Diagrams for Arrivals were still being updated. Therefore, please refer to the NSV-4 stored in EATMA in the PJ02.01 Folder for the latest version of the EATMA NSV-4 Use Cases for arrivals.



I.2.2 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)
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
Receive WDS-D Status Update
WDS-D Active?-2
Compute WDS-D Separation
Compute PWS Separation
Wind data received
Display Wind Conditions
Wind conditions displayed
Display WDS-D Activation Proposal
WDS_D activation proposal displayed
WDS-DStatus
Display WDS-D Status
WDS-D status change notified
WindConditions
No change in WDS-D status
Assess WDS-D Activation
WDS-D activation?
Activate WDS-D
WDS-D Activated
WDS-D status change notified
Display Separation Leader-Follower
Separation displayed
SeparationToBeApplied
Apply Separation
Separation applied

Appendix J A-WDS-Xw Methodology

This appendix provides methodology and the rationale for the definition of separation minima to be applied with the WDS-A Xw concept for arrivals (A-WDS-Xw).

Determining the A-WDS-Xw time separation minima consists of computing the minimum lateral distance to be travelled by the vortices to be considered as “away” from the following aircraft. This distance depends on the characteristics of both the generator and follower aircraft.

The method to determine the time separation reduction considers two different altitude bands; in ground proximity (Section J.1) and out of ground proximity (more than half wing span) (Section J.2). This could be generalized to more altitude bands if deemed necessary.

In ground proximity, the design case considers the combined ground effect and wind effect on the lateral transport of the wake vortices, plus the lateral navigation performance uncertainty of the arrival aircraft at the position of ground proximity on short final.

Out of ground proximity (more than half wing span), the lateral transport of the wake vortices is only governed by the crosswind speed. The lateral displacement of the wake vortices is linearly related to the mean crosswind speed over the time of the lateral displacement. However, away from the ground, the lateral navigation performance uncertainty of the arrival aircraft is larger than at the position of ground proximity on short final.

J.1 A-WDS-Xw time separation reduction definition in ground proximity

Based on the work initiated in the framework of SESAR 1 and then followed-up in SESAR 2020, the A-WDS-Xw time-based minima are here established. The analysis relies on the processing of the EGLL-1 LiDAR database providing lateral transport of wake vortex for various aircraft types evolving in various crosswind conditions.

Two crosswind measurements are available in the database:

- The crosswind component of the anemometer data measured at 10m height
- The in-plane wind (IPW) provided by the LiDAR as the averaged crosswind component measured in the LiDAR scanning plane of measurement just before and just after the wake measurement.

As it provides a better estimate of the wind as experienced by the vortices (because measured at several altitudes), the IPW is here used in the analysis. Indeed, the wind vertical evolution might vary from one airport to another. Hence, providing results relying only on 10m measurements might be more difficult to generalize to other places. Note however that the methodology described below is fully applicable to any other crosswind measurement definition.

The first step when determining the A-WDS-Xw time separation minima consists in computing the minimum lateral distance to be travelled by the vortices to be considered as “away” from the following aircraft. This distance depends both on the generator and follower aircraft.

The initial two vortex system generated by an aircraft is centred on the generator aircraft position and with a lateral vortex spacing b_0 equal to a fraction of the wing span b: $b_0 = s\,b$, with s ranging from about 0.65 to 0.8 for aircraft in approach configuration. In case of crosswind the vortices will be transported by the crosswind component. In ground proximity, due to the interaction with the ground, the vortices also tend to separate from each other. The vortex moving in the wind direction due to ground effect is then denoted downwind vortex whereas the one moving in the opposite direction to the wind in case of ground proximity is denoted upwind vortex. In case of crosswind, the worst case (and hence the design case) consists in the encounter by the following aircraft of the upwind vortex that, due to the combined ground and wind effect, would remain in the follower vicinity.

For WDS separation design, we here consider that the upwind vortex must have travelled a distance such that it is located at one half vortex spacing from the follower' closest wing tip. As illustrated in Figure 30, this corresponds to a total distance of:

- ½ vortex span to travel from the initial position to the runway centreline, plus
- ½ follower wing span to reach the follower wing tip, plus
- ½ vortex span to be located at that distance from the wing tip.

The total distance to be considered is thus: one vortex span + ½ follower span:

$$\text{Distance} = \text{b}_0 + \frac{\text{b}_{\text{foll}}}{2}.$$

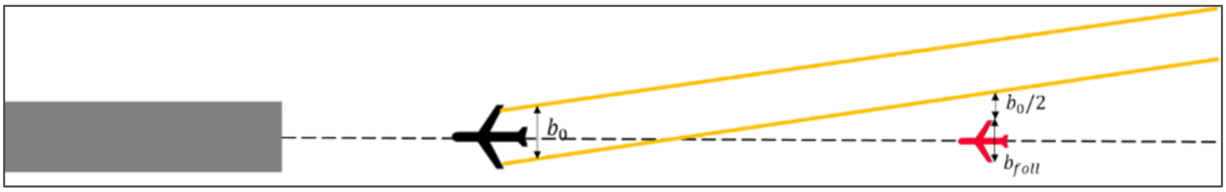


Figure 30: Schematic view of required minimum vortex lateral displacement considered for A-WDS-Xw design

Note that assuming a typical vortex velocity distribution, the velocity induced by the vortex at $b_0/2$ is equal to 1/5 of the maximum induced velocity. In terms of Rolling Moment Coefficient (RMC), using the formulae developed in (Winckelmans & De Visscher, July 2013) for an elliptic wing and assuming a core parameter of 3.5% of the generator wing span (as established in (De Visscher, Winckelmans, & Treve, 2015)) the RMC induced by a vortex located at $b_0/2 + b/2$ from the aircraft centre ranges from 2.5% up to 30% of the maximum induced RMC (obtained when the vortex is centred on the aircraft). Using typical wingspan and vortex span, the RMC ratios are provided in Table 54 per RECAT-EU Category. Note also that this relation is conservative as the largest RMC ratios are obtained for smaller leader (hence lower wake intensity) and larger follower (hence more resistant). This assumption is thus conservative as it protects the pairs where larger leaders and smaller followers are involved (i.e. RMC ratios of about 5%) whereas an RMC ratio of 30% is only obtained for CAT-F/CAT-A where no wake reductions are applied. For pairs where significant reductions are applied, the expected fraction of maximum RMC ranges from 3% to 7%. Recalling that absolute RMC values in RWC for separation design in RECAT-PWS is defined around 0.06, this would correspond to maximum RMC ranging from 0.86 to 2.00 (which is unlikely to happen with the current aircraft fleet as it is more than 10 times bigger).

Decrease for decreasing follower type →

↑ Decrease for increasing leader type

Leader/Follower	CAT-A	CAT-B	CAT-C	CAT-D	CAT-E	CAT-F
CAT-A	0.11	0.09	0.07	0.05	0.04	0.03
CAT-B	0.13	0.11	0.08	0.06	0.05	0.03
CAT-C	0.15	0.13	0.11	0.07	0.06	0.04
CAT-D	0.21	0.18	0.15	0.11	0.09	0.06
CAT-E	0.23	0.20	0.17	0.12	0.11	0.07
CAT-F	0.30	0.26	0.23	0.17	0.15	0.11

Table 54: RMC ratio between encounter at a distance b/2+b0/2 compared to centred encounter

This distance should be increased by the navigation uncertainty of the leader and follower aircraft. According to SME from EUROCONTROL Navigation Unit experts, the lateral total system error (TSE) is about 35m (twice the navigation system error (NSE)). Since the worst case corresponds to the leader and follower aircraft deviating in opposite directions, all minimum distances shall be increased by 70m.

Note that we here consider a worst-case approach since the relative lateral deviation for each pair of aircraft was not considered. The influence of the crosswind on the lateral deviation has also not been considered.

Using the above formula, the minimum distances for A-WDS-Xw separation design for each pair category are provided in Table 55; In order to allow easiest wake analysis the values are rounded up to the closest 5 multiple with a tolerance of 1m (e.g. 31.0m is rounded down to 30m whereas 31.1m is rounded up to 35m). The rounded values are provided in Table 56.

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	174	166	160	151	149	144
Cat-B	162	155	148	140	137	132
Cat-C	151	144	138	129	127	122
Cat-D	138	131	124	116	113	108
Cat-E	134	127	120	112	109	104
Cat-F	126	119	112	104	101	96

Table 55: Considered minimum displacement distance for A-WDS-Xw separation design per RECAT-EU leader and follower category

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	175	165	160	150	150	145
Cat-B	165	155	150	140	140	135
Cat-C	150	145	140	130	130	125
Cat-D	140	130	125	115	115	110
Cat-E	135	130	120	115	110	105
Cat-F	125	120	115	105	100	95

Table 56: Rounded minimum displacement distance for A-WDS-Xw separation design per RECAT-EU leader and follower category

In order to establish A-WDS-Xw time-based minima, the time required for the wake vortices to be crosswind transported distances ranging from 95m up to 175m by steps of 5m have been computed based on the EGLL-1 database; that was applied without accounting for navigation uncertainty. Given the larger distance separations and in order to obtain statistical meaningful results, a small modification of the computation procedure is however performed. The LiDAR measured lateral position are indeed also extrapolated when stopped before reaching the considered lateral transport distance up to 60s after their termination.

We here determine the time required for 99% of the vortices to be crosswind transported the considered distances as a function of the measured IPW. The results are provided in Table 57 to Table 73. In these tables "-999" values refers to cases for which less than 100 measurements tracks were available in these crosswind conditions.

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	185	137	162	174	146	170	154	196	174	-999	126	133	-999	224	-999	115	-999	102	124	159	150
2	182	136	158	174	146	169	157	188	169	-999	126	134	-999	224	-999	113	-999	102	123	157	148
3	174	136	151	170	142	157	150	188	160	-999	125	132	-999	130	-999	111	-999	102	121	150	144
4	171	129	148	151	136	144	143	188	146	-999	118	128	-999	130	-999	110	-999	98	116	144	136
5	153	114	132	142	129	130	132	131	135	-999	118	116	-999	130	-999	102	-999	95	109	131	129
6	148	106	124	123	115	119	113	120	115	-999	110	107	-999	108	-999	99	-999	89	102	120	118
7	103	103	114	107	104	105	93	97	99	-999	110	96	-999	104	-999	94	-999	88	91	107	105
8	106	96	96	89	90	90	86	76	89	-999	96	82	-999	88	-999	90	-999	82	83	92	92
9	80	75	86	74	73	76	61	66	69	-999	73	72	-999	81	-999	73	-999	72	73	78	79
10	64	61	71	65	63	71	55	56	53	-999	66	64	-999	58	-999	67	-999	69	66	65	67
11	65	53	54	52	57	63	55	54	50	-999	58	62	-999	47	-999	65	-999	71	66	55	60
12	30	47	44	56	50	52	60	50	45	-999	58	58	-999	43	-999	62	-999	68	61	48	55
13	30	46	39	49	46	47	54	43	48	-999	47	58	-999	43	-999	62	-999	73	65	44	54
14	28	34	38	59	44	49	68	45	47	-999	38	57	-999	31	-999	61	-999	67	62	43	50
15	27	32	38	59	45	50	67	31	49	-999	36	60	-999	22	-999	51	-999	67	64	43	53

Table 57: Time required for 99% of the vortices to be laterally transported on a distance of 95m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	188	139	163	179	147	175	157	203	181	-999	133	132	-999	228	-999	120	-999	102	126	161	152
2	184	138	160	181	145	173	156	194	180	-999	131	132	-999	228	-999	115	-999	101	124	158	151
3	181	138	156	174	141	156	156	194	163	-999	126	130	-999	133	-999	115	-999	100	123	154	145
4	176	132	153	153	136	147	143	194	154	-999	121	127	-999	133	-999	102	-999	94	116	147	140
5	157	119	136	147	132	133	128	135	142	-999	115	119	-999	133	-999	96	-999	94	110	135	131
6	137	112	125	119	117	123	118	115	118	-999	107	111	-999	116	-999	94	-999	91	104	122	121
7	108	109	113	111	106	109	96	96	105	-999	102	100	-999	109	-999	93	-999	90	94	109	107
8	110	102	101	92	94	97	88	75	91	-999	74	86	-999	94	-999	86	-999	83	87	96	95
9	85	80	89	80	76	80	64	65	70	-999	74	72	-999	87	-999	76	-999	72	74	80	81
10	67	64	75	71	65	74	57	59	56	-999	70	66	-999	61	-999	68	-999	71	67	67	68
11	68	57	57	54	60	64	57	58	53	-999	61	64	-999	50	-999	64	-999	72	62	57	62
12	32	45	48	59	53	55	57	52	48	-999	61	61	-999	43	-999	65	-999	68	62	50	57
13	31	41	41	52	49	54	57	45	50	-999	50	61	-999	43	-999	66	-999	75	64	46	55
14	29	36	39	62	47	51	66	47	49	-999	40	59	-999	33	-999	64	-999	68	64	44	52
15	28	34	39	62	47	53	51	34	52	-999	38	63	-999	23	-999	54	-999	64	65	45	55

Table 58: Time required for 99% of the vortices to be laterally transported on a distance of 100m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	193	139	165	180	142	174	162	209	191	-999	139	132	-999	232	-999	122	-999	103	127	160	155
2	188	137	161	182	143	169	162	200	188	-999	136	130	-999	232	-999	118	-999	102	124	159	152
3	186	135	159	164	141	158	159	200	166	-999	130	129	-999	137	-999	112	-999	100	122	153	148
4	181	131	150	158	138	152	150	200	160	-999	120	126	-999	137	-999	105	-999	96	118	146	142
5	161	124	137	149	131	136	133	141	142	-999	120	116	-999	137	-999	100	-999	96	113	136	133
6	140	119	129	127	123	125	123	126	120	-999	113	113	-999	123	-999	97	-999	94	106	125	125
7	106	114	114	117	109	110	100	100	106	-999	108	99	-999	114	-999	93	-999	93	97	112	109
8	91	109	105	97	100	104	93	79	93	-999	77	91	-999	91	-999	87	-999	86	89	101	98
9	78	83	86	82	80	82	67	72	73	-999	73	74	-999	94	-999	80	-999	75	78	82	82
10	71	66	77	73	67	79	60	60	57	-999	73	69	-999	64	-999	70	-999	74	68	70	70
11	70	60	59	57	63	68	59	57	55	-999	64	65	-999	53	-999	68	-999	74	65	59	64
12	34	47	50	55	55	58	59	55	50	-999	64	64	-999	45	-999	68	-999	71	64	52	60
13	32	42	43	54	51	56	55	47	52	-999	52	64	-999	45	-999	69	-999	76	65	47	57
14	30	37	41	55	45	54	66	49	51	-999	42	61	-999	34	-999	67	-999	68	64	46	54
15	30	35	40	64	49	55	54	37	54	-999	40	66	-999	24	-999	56	-999	67	63	47	58

Table 59: Time required for 99% of the vortices to be laterally transported on a distance of 105m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	200	142	167	172	146	161	161	205	188	-999	138	134	-999	236	-999	111	-999	100	129	161	152
2	195	140	164	181	146	165	161	200	182	-999	134	132	-999	236	-999	110	-999	103	126	160	151
3	190	133	161	163	145	161	159	200	171	-999	122	129	-999	141	-999	109	-999	99	123	154	148
4	186	132	151	155	139	151	155	200	167	-999	123	125	-999	141	-999	102	-999	98	119	148	143
5	165	125	140	150	134	144	137	144	147	-999	121	120	-999	141	-999	101	-999	99	115	140	136
6	143	122	130	136	125	129	128	131	125	-999	113	117	-999	117	-999	97	-999	92	109	129	127
7	110	117	118	122	112	116	105	105	110	-999	113	102	-999	119	-999	93	-999	90	101	116	112
8	95	105	105	99	101	109	97	84	101	-999	78	94	-999	97	-999	88	-999	89	91	103	101
9	83	78	89	86	81	88	69	76	76	-999	75	77	-999	100	-999	81	-999	78	78	85	85
10	74	68	78	77	69	80	60	61	60	-999	70	69	-999	67	-999	70	-999	75	71	71	73
11	73	60	60	59	61	69	60	59	55	-999	58	68	-999	56	-999	69	-999	74	66	60	66
12	36	50	53	57	57	62	57	58	52	-999	62	66	-999	47	-999	66	-999	69	64	54	61
13	34	44	46	55	52	55	57	49	54	-999	54	63	-999	47	-999	66	-999	69	64	48	58
14	31	39	43	58	47	52	57	51	53	-999	44	58	-999	36	-999	63	-999	71	64	46	55
15	31	37	42	67	51	58	47	36	56	-999	42	61	-999	25	-999	59	-999	70	64	48	59

Table 60: Time required for 99% of the vortices to be laterally transported on a distance of 110m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	209	146	165	187	144	160	160	210	161	-999	136	133	-999	239	-999	111	-999	105	129	161	154
2	206	142	161	187	146	164	163	207	179	-999	135	132	-999	239	-999	109	-999	102	128	161	152
3	189	141	157	166	144	158	162	206	176	-999	123	131	-999	144	-999	112	-999	99	124	156	149
4	189	140	150	159	142	148	158	206	174	-999	118	129	-999	144	-999	105	-999	97	121	151	146
5	170	131	144	153	136	139	138	148	139	-999	119	124	-999	144	-999	101	-999	97	117	144	139
6	146	128	134	143	126	131	132	130	129	-999	118	120	-999	122	-999	100	-999	92	113	133	129
7	114	121	123	120	114	116	108	109	114	-999	119	106	-999	124	-999	94	-999	90	102	118	115
8	98	100	109	106	101	109	92	89	93	-999	81	96	-999	103	-999	90	-999	89	93	105	103
9	85	81	93	87	84	93	74	79	77	-999	79	82	-999	106	-999	83	-999	81	81	88	86
10	73	70	81	80	72	84	63	64	62	-999	73	71	-999	70	-999	73	-999	79	73	74	75
11	71	62	63	61	63	72	63	62	57	-999	58	69	-999	58	-999	69	-999	76	68	63	69
12	37	52	55	55	59	62	60	60	55	-999	57	66	-999	49	-999	66	-999	70	65	57	63
13	36	46	50	57	54	57	59	51	57	-999	57	61	-999	49	-999	65	-999	67	64	51	60
14	34	40	45	60	48	53	59	54	55	-999	46	56	-999	38	-999	65	-999	69	64	48	56
15	34	38	43	69	53	47	49	38	58	-999	44	58	-999	26	-999	62	-999	73	60	50	58

Table 61: Time required for 99% of the vortices to be laterally transported on a distance of 115m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	205	148	159	184	144	159	165	208	160	-999	130	136	-999	243	-999	116	-999	103	130	160	153
2	200	146	158	192	146	160	168	206	187	-999	135	135	-999	243	-999	114	-999	102	129	160	152
3	193	135	157	170	145	155	168	206	182	-999	112	133	-999	148	-999	117	-999	100	126	157	150
4	192	136	149	165	143	151	159	206	181	-999	124	131	-999	148	-999	108	-999	101	123	150	148
5	174	134	145	160	138	143	140	157	148	-999	124	125	-999	148	-999	103	-999	100	118	144	141
6	155	132	138	146	128	137	131	125	129	-999	124	122	-999	127	-999	102	-999	96	113	136	132
7	119	127	124	125	119	118	111	111	120	-999	124	110	-999	129	-999	96	-999	92	104	120	118
8	104	105	109	108	104	111	90	89	97	-999	84	97	-999	109	-999	91	-999	92	96	107	104
9	90	84	95	91	87	98	77	82	80	-999	77	80	-999	112	-999	88	-999	83	84	90	89
10	75	72	79	85	74	90	65	68	64	-999	73	73	-999	73	-999	74	-999	79	73	77	78
11	73	66	67	63	66	73	63	65	62	-999	60	71	-999	61	-999	69	-999	76	71	66	70
12	39	55	56	57	61	65	62	63	58	-999	59	65	-999	51	-999	68	-999	68	66	59	63
13	38	50	53	60	55	60	62	53	57	-999	59	60	-999	51	-999	63	-999	65	64	53	61
14	36	42	47	63	49	56	62	56	52	-999	48	59	-999	39	-999	64	-999	66	65	50	58
15	36	40	45	65	47	49	51	39	47	-999	46	61	-999	27	-999	64	-999	68	62	49	59

Table 62: Time required for 99% of the vortices to be laterally transported on a distance of 120m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	212	149	162	176	146	158	168	214	165	-999	123	137	-999	247	-999	122	-999	104	131	162	155
2	205	147	157	179	146	158	167	212	169	-999	129	137	-999	247	-999	120	-999	103	130	161	153
3	197	139	154	170	146	158	159	212	160	-999	116	137	-999	152	-999	123	-999	100	128	156	150
4	195	141	152	168	146	155	158	212	159	-999	124	133	-999	152	-999	113	-999	101	124	153	149
5	178	139	147	161	143	145	143	142	147	-999	124	128	-999	152	-999	107	-999	98	122	146	142
6	165	136	141	148	130	140	136	130	131	-999	124	126	-999	132	-999	102	-999	96	113	137	132
7	122	131	127	120	118	119	115	117	124	-999	124	112	-999	134	-999	96	-999	93	104	123	120
8	109	110	113	113	103	106	96	92	101	-999	87	101	-999	101	-999	93	-999	95	96	110	108
9	94	80	96	94	91	102	80	85	84	-999	80	83	-999	101	-999	90	-999	85	85	93	91
10	77	74	81	82	77	94	68	70	67	-999	76	76	-999	76	-999	77	-999	80	75	78	81
11	75	70	69	66	68	76	66	68	65	-999	61	72	-999	63	-999	71	-999	75	71	69	73
12	42	58	59	59	63	68	65	65	60	-999	62	65	-999	55	-999	69	-999	68	67	60	65
13	39	50	54	62	57	62	65	55	59	-999	62	62	-999	55	-999	66	-999	67	64	56	62
14	38	44	50	66	51	58	65	58	54	-999	50	61	-999	41	-999	67	-999	67	63	52	59
15	38	42	50	68	49	51	53	41	49	-999	48	63	-999	29	-999	67	-999	67	65	53	59

Table 63: Time required for 99% of the vortices to be laterally transported on a distance of 125m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	218	153	162	180	150	164	172	220	163	-999	123	138	-999	251	-999	125	-999	104	132	163	156
2	209	150	158	183	152	162	171	219	173	-999	135	138	-999	251	-999	118	-999	103	129	163	153
3	200	140	157	175	150	162	164	216	164	-999	117	137	-999	137	-999	125	-999	101	128	159	152
4	199	142	156	173	149	160	157	207	162	-999	118	133	-999	138	-999	113	-999	102	127	156	149
5	182	138	151	166	143	145	146	142	151	-999	113	131	-999	134	-999	109	-999	100	123	150	143
6	157	131	145	143	129	144	139	134	133	-999	108	125	-999	137	-999	105	-999	99	115	140	133
7	121	127	129	123	122	125	117	122	126	-999	107	114	-999	139	-999	100	-999	96	107	125	120
8	113	109	115	118	107	110	96	94	103	-999	91	102	-999	98	-999	95	-999	95	98	112	109
9	99	84	99	98	92	97	84	88	87	-999	84	84	-999	80	-999	93	-999	85	87	94	95
10	79	77	83	87	77	96	70	73	70	-999	80	78	-999	80	-999	80	-999	81	76	80	83
11	76	74	72	68	70	79	68	67	68	-999	64	75	-999	66	-999	73	-999	77	73	71	74
12	46	60	62	62	64	70	67	61	63	-999	64	65	-999	58	-999	70	-999	70	68	63	66
13	41	52	59	65	59	65	67	57	62	-999	64	63	-999	58	-999	69	-999	70	66	58	63
14	38	45	52	69	53	61	67	60	57	-999	52	62	-999	42	-999	68	-999	70	66	54	60
15	38	43	52	71	51	53	55	43	51	-999	50	66	-999	30	-999	66	-999	70	66	54	60

Table 64: Time required for 99% of the vortices to be laterally transported on a distance of 130m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	207	158	163	186	150	163	176	203	164	-999	123	137	-999	255	-999	125	-999	107	133	166	155
2	205	145	161	188	154	162	175	207	165	-999	124	138	-999	255	-999	121	-999	107	133	163	154
3	206	144	161	176	153	163	169	202	162	-999	117	140	-999	141	-999	121	-999	104	130	161	153
4	205	144	157	174	150	158	164	160	159	-999	116	138	-999	141	-999	114	-999	104	129	157	151
5	188	133	155	165	145	145	149	146	144	-999	112	134	-999	134	-999	109	-999	103	125	153	147
6	163	130	149	147	132	146	141	138	136	-999	109	127	-999	129	-999	107	-999	101	118	143	136
7	128	122	132	121	123	128	120	116	125	-999	110	114	-999	129	-999	103	-999	98	110	127	123
8	118	110	118	110	109	113	102	95	114	-999	96	105	-999	103	-999	98	-999	95	100	114	111
9	103	88	101	102	94	99	85	85	87	-999	87	86	-999	83	-999	93	-999	88	90	97	97
10	81	80	85	91	81	99	71	73	73	-999	83	81	-999	83	-999	80	-999	84	79	82	85
11	78	75	74	72	72	79	70	68	69	-999	68	78	-999	69	-999	76	-999	80	76	73	76
12	51	62	64	64	65	68	66	64	64	-999	66	68	-999	61	-999	74	-999	71	69	65	68
13	43	53	61	67	61	65	61	59	62	-999	67	65	-999	61	-999	70	-999	71	67	61	63
14	40	47	54	72	54	59	66	62	59	-999	54	65	-999	44	-999	70	-999	72	67	54	62
15	40	45	54	73	51	55	57	44	53	-999	52	69	-999	32	-999	63	-999	72	68	52	62

Table 65: Time required for 99% of the vortices to be laterally transported on a distance of 135m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	212	148	161	190	150	166	179	208	164	-999	127	140	-999	259	-999	120	-999	107	132	164	157
2	211	148	159	190	152	165	178	213	164	-999	128	141	-999	259	-999	116	-999	107	130	161	156
3	212	148	160	179	152	166	174	208	164	-999	121	143	-999	144	-999	113	-999	107	130	160	155
4	211	140	159	178	151	153	163	164	160	-999	121	142	-999	144	-999	109	-999	108	132	159	153
5	198	138	154	166	146	148	153	154	146	-999	116	136	-999	138	-999	109	-999	103	128	154	147
6	168	129	151	158	136	148	137	142	139	-999	112	131	-999	130	-999	108	-999	101	120	143	137
7	135	126	133	125	126	131	121	113	125	-999	112	117	-999	130	-999	105	-999	99	112	128	125
8	126	106	120	115	113	119	106	98	105	-999	100	107	-999	108	-999	99	-999	93	102	116	114
9	108	89	106	105	98	104	89	88	89	-999	90	88	-999	87	-999	97	-999	92	91	100	99
10	84	84	89	95	83	96	74	76	76	-999	86	84	-999	87	-999	83	-999	88	82	84	88
11	80	74	76	75	74	82	73	71	72	-999	71	80	-999	72	-999	76	-999	83	78	75	79
12	54	62	67	66	66	70	64	66	67	-999	69	68	-999	68	-999	74	-999	72	68	67	70
13	44	55	63	70	63	67	63	61	64	-999	69	67	-999	68	-999	66	-999	73	66	62	64
14	42	49	52	74	57	61	69	65	61	-999	56	67	-999	46	-999	65	-999	75	66	55	62
15	42	47	50	76	54	57	59	46	54	-999	54	71	-999	33	-999	65	-999	75	67	52	62

Table 66: Time required for 99% of the vortices to be laterally transported on a distance of 140m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	217	155	162	189	152	168	183	215	167	-999	131	140	-999	262	-999	124	-999	109	134	164	156
2	217	151	160	184	152	162	183	220	170	-999	132	143	-999	262	-999	118	-999	109	134	162	158
3	217	151	164	177	154	166	181	214	167	-999	123	149	-999	146	-999	112	-999	108	134	163	158
4	217	141	162	176	153	152	165	170	160	-999	121	145	-999	146	-999	112	-999	109	136	159	155
5	207	136	158	165	148	148	153	157	152	-999	121	141	-999	137	-999	109	-999	104	128	154	149
6	174	135	148	160	139	142	143	140	142	-999	115	135	-999	126	-999	107	-999	104	122	143	138
7	142	131	136	128	127	134	125	121	130	-999	110	119	-999	126	-999	106	-999	102	114	129	126
8	130	115	122	119	115	124	112	101	111	-999	99	107	-999	112	-999	101	-999	97	103	118	117
9	112	91	106	107	101	103	91	91	95	-999	94	91	-999	90	-999	100	-999	95	93	103	100
10	86	87	92	88	87	101	78	79	79	-999	89	86	-999	90	-999	89	-999	92	85	88	90
11	82	76	80	74	77	81	76	73	75	-999	73	82	-999	77	-999	79	-999	86	77	77	80
12	57	65	70	67	68	73	65	68	69	-999	69	68	-999	77	-999	77	-999	74	69	69	71
13	46	57	65	72	64	70	62	62	66	-999	71	68	-999	77	-999	68	-999	75	68	64	66
14	43	51	54	77	59	63	68	67	63	-999	58	69	-999	47	-999	68	-999	78	68	57	64
15	43	49	52	79	56	59	62	47	56	-999	56	70	-999	35	-999	68	-999	77	68	55	63

Table 67: Time required for 99% of the vortices to be laterally transported on a distance of 145m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	222	146	163	194	153	171	186	197	169	-999	134	142	-999	152	-999	128	-999	111	132	167	157
2	222	135	162	189	154	167	186	203	170	-999	134	144	-999	152	-999	118	-999	110	131	164	159
3	223	143	164	186	156	169	183	192	168	-999	122	150	-999	150	-999	115	-999	109	131	164	159
4	221	146	163	182	156	154	168	158	166	-999	126	146	-999	150	-999	115	-999	109	131	162	155
5	211	138	162	165	150	150	156	147	153	-999	126	144	-999	142	-999	110	-999	103	130	158	151
6	180	138	150	159	144	145	149	142	144	-999	119	136	-999	117	-999	109	-999	103	124	147	140
7	149	137	139	132	129	137	131	120	133	-999	114	121	-999	117	-999	106	-999	100	117	132	129
8	126	112	124	122	116	128	109	104	111	-999	103	110	-999	117	-999	104	-999	98	106	120	120
9	99	94	105	111	101	106	95	94	98	-999	97	93	-999	94	-999	99	-999	97	96	105	103
10	88	91	94	92	90	102	77	82	82	-999	90	89	-999	94	-999	91	-999	92	87	90	93
11	84	79	83	76	79	84	74	76	78	-999	76	82	-999	85	-999	82	-999	84	80	81	82
12	61	68	74	69	70	75	67	67	71	-999	72	70	-999	85	-999	80	-999	74	70	71	74
13	48	59	68	69	65	72	65	63	68	-999	74	70	-999	85	-999	70	-999	78	70	65	67
14	45	53	56	77	60	66	65	60	66	-999	60	68	-999	49	-999	70	-999	80	69	59	65
15	45	51	54	80	57	61	64	49	58	-999	58	64	-999	36	-999	70	-999	80	68	57	65

Table 68: Time required for 99% of the vortices to be laterally transported on a distance of 150m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	228	151	163	194	155	174	190	203	172	-999	128	145	-999	-999	-999	126	-999	112	139	168	158
2	226	140	166	190	154	170	190	186	173	-999	137	146	-999	-999	-999	117	-999	111	135	168	159
3	226	147	167	185	157	172	175	172	173	-999	125	151	-999	-999	-999	114	-999	111	134	168	159
4	225	151	167	172	155	157	170	157	169	-999	131	151	-999	-999	-999	112	-999	111	134	163	157
5	209	143	165	165	152	151	165	149	158	-999	131	145	-999	-999	-999	110	-999	102	130	159	152
6	170	143	150	162	144	147	152	142	147	-999	123	136	-999	-999	-999	110	-999	102	124	145	142
7	156	142	137	135	129	136	133	126	135	-999	119	124	-999	-999	-999	108	-999	101	115	133	132
8	128	116	125	126	118	126	107	107	115	-999	106	115	-999	-999	-999	102	-999	101	107	123	123
9	99	97	108	115	104	111	97	98	98	-999	101	96	-999	-999	-999	102	-999	98	97	108	107
10	90	95	97	95	93	107	80	85	81	-999	93	90	-999	-999	-999	93	-999	94	88	94	95
11	86	82	86	79	81	88	77	78	79	-999	76	84	-999	-999	-999	85	-999	87	81	83	84
12	65	70	75	69	71	77	67	69	73	-999	67	71	-999	-999	-999	83	-999	76	72	74	75
13	49	61	66	67	67	70	67	65	69	-999	62	70	-999	-999	-999	72	-999	80	70	66	68
14	47	55	58	70	62	64	67	62	59	-999	62	69	-999	-999	-999	73	-999	83	70	59	67
15	47	53	56	83	59	63	66	50	60	-999	60	66	-999	-999	-999	72	-999	83	67	58	66

Table 69: Time required for 99% of the vortices to be laterally transported on a distance of 155m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	236	142	162	199	155	168	181	210	176	-999	132	144	-999	-999	-999	121	-999	112	136	165	157
2	230	141	166	183	154	162	186	192	176	-999	130	142	-999	-999	-999	118	-999	109	136	167	160
3	231	149	169	173	159	164	182	175	172	-999	126	147	-999	-999	-999	117	-999	104	134	166	161
4	229	150	166	169	157	159	174	154	169	-999	129	149	-999	-999	-999	116	-999	104	134	164	159
5	214	145	165	168	152	157	159	151	158	-999	128	140	-999	-999	-999	113	-999	102	130	160	154
6	161	145	147	159	144	152	148	146	149	-999	126	136	-999	-999	-999	113	-999	103	124	147	143
7	161	126	140	137	132	140	131	126	138	-999	123	124	-999	-999	-999	109	-999	102	118	134	135
8	133	116	127	127	121	124	116	114	118	-999	110	115	-999	-999	-999	102	-999	104	110	125	124
9	104	98	112	115	105	112	102	101	101	-999	105	98	-999	-999	-999	100	-999	99	98	110	108
10	92	95	100	91	96	101	83	85	84	-999	96	92	-999	-999	-999	91	-999	97	90	97	96
11	88	85	90	81	84	91	82	76	82	-999	79	84	-999	-999	-999	88	-999	86	83	86	86
12	68	73	77	71	73	79	68	72	76	-999	69	72	-999	-999	-999	86	-999	78	74	76	77
13	51	63	67	67	69	72	67	67	70	-999	64	72	-999	-999	-999	68	-999	74	72	67	70
14	48	57	60	71	64	66	67	64	61	-999	64	72	-999	-999	-999	77	-999	76	70	62	67
15	48	55	57	86	61	65	61	52	62	-999	62	68	-999	-999	-999	68	-999	85	69	60	66

Table 70: Time required for 99% of the vortices to be laterally transported on a distance of 160m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	238	145	162	192	158	161	185	215	175	-999	132	144	-999	-999	-999	128	-999	114	139	166	161
2	235	144	166	183	156	157	192	197	175	-999	131	143	-999	-999	-999	121	-999	111	136	168	164
3	235	154	169	174	157	164	188	179	175	-999	131	143	-999	-999	-999	121	-999	106	135	169	164
4	234	155	168	171	157	161	177	157	169	-999	133	144	-999	-999	-999	117	-999	105	135	166	161
5	219	149	168	170	152	160	162	153	160	-999	131	141	-999	-999	-999	115	-999	103	133	160	154
6	163	149	153	159	146	154	156	150	151	-999	131	138	-999	-999	-999	116	-999	104	128	151	145
7	148	131	139	140	133	141	135	126	140	-999	128	129	-999	-999	-999	106	-999	104	121	137	137
8	144	119	130	132	125	129	119	111	124	-999	113	118	-999	-999	-999	101	-999	106	114	128	126
9	113	102	115	122	108	111	104	102	104	-999	108	101	-999	-999	-999	101	-999	102	101	111	110
10	94	95	103	95	98	104	84	87	87	-999	92	94	-999	-999	-999	96	-999	99	92	99	98
11	90	78	91	83	85	93	78	78	85	-999	82	87	-999	-999	-999	90	-999	89	86	88	88
12	71	74	80	73	75	81	68	66	78	-999	71	75	-999	-999	-999	85	-999	81	77	77	79
13	53	65	68	69	71	73	67	65	72	-999	66	75	-999	-999	-999	71	-999	76	74	68	71
14	50	59	62	73	66	68	64	65	63	-999	66	74	-999	-999	-999	82	-999	79	73	63	68
15	50	57	59	74	63	67	56	54	64	-999	64	70	-999	-999	-999	70	-999	87	71	61	66

Table 71: Time required for 99% of the vortices to be laterally transported on a distance of 165m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	244	141	166	188	157	164	187	196	176	-999	136	146	-999	-999	-999	136	-999	115	141	168	162
2	239	148	168	179	157	160	195	185	176	-999	136	146	-999	-999	-999	124	-999	113	139	170	165
3	240	157	171	179	157	167	190	174	172	-999	136	146	-999	-999	-999	124	-999	108	139	171	166
4	238	159	170	175	155	160	181	160	171	-999	139	146	-999	-999	-999	118	-999	107	138	167	165
5	223	155	168	175	154	157	165	154	159	-999	136	144	-999	-999	-999	117	-999	105	133	163	156
6	166	155	153	163	145	154	160	154	156	-999	134	140	-999	-999	-999	118	-999	105	127	153	147
7	166	136	140	143	136	143	138	127	137	-999	132	129	-999	-999	-999	110	-999	105	122	140	139
8	146	116	134	137	127	128	120	110	126	-999	116	121	-999	-999	-999	104	-999	104	115	130	127
9	114	106	120	122	108	113	101	103	109	-999	109	104	-999	-999	-999	104	-999	103	104	112	112
10	97	98	106	99	102	106	88	90	89	-999	94	97	-999	-999	-999	99	-999	100	95	100	100
11	93	81	93	86	88	96	82	81	87	-999	84	90	-999	-999	-999	93	-999	82	88	90	90
12	76	76	81	75	75	83	71	68	75	-999	73	78	-999	-999	-999	89	-999	78	80	76	81
13	55	67	69	70	73	73	66	67	74	-999	68	77	-999	-999	-999	74	-999	78	78	68	73
14	52	61	64	73	66	68	60	67	65	-999	68	76	-999	-999	-999	87	-999	81	75	64	69
15	52	59	60	76	64	68	57	55	65	-999	66	72	-999	-999	-999	65	-999	90	73	61	67

Table 72: Time required for 99% of the vortices to be laterally transported on a distance of 170m depending on the averaged in-plane wind [knots] and on the leader generator

wind	A388	B77W	B744	A346	B772	B773	A332	A333	A343	MD11	B764	B763	A306	A30B	A310	B752	B753	A321	CatC	CatB	Heavy
1	249	142	166	192	158	160	189	177	181	-999	140	148	-999	-999	-999	139	-999	110	137	169	161
2	244	151	171	184	157	164	199	183	180	-999	140	148	-999	-999	-999	123	-999	109	138	172	165
3	245	156	175	181	159	169	197	179	176	-999	140	149	-999	-999	-999	120	-999	109	141	173	167
4	242	161	171	179	159	164	184	161	176	-999	144	148	-999	-999	-999	113	-999	107	140	170	164
5	226	153	169	172	153	158	169	158	161	-999	141	144	-999	-999	-999	111	-999	107	134	163	156
6	175	151	156	160	141	154	166	156	160	-999	131	143	-999	-999	-999	108	-999	107	129	153	148
7	175	140	143	146	136	147	140	133	141	-999	119	131	-999	-999	-999	107	-999	106	125	143	141
8	147	119	135	136	128	133	121	114	130	-999	114	123	-999	-999	-999	108	-999	106	115	133	129
9	117	111	116	125	111	117	107	107	114	-999	104	107	-999	-999	-999	106	-999	106	107	115	114
10	99	98	109	103	104	109	91	93	92	-999	98	97	-999	-999	-999	99	-999	100	96	102	102
11	94	82	95	88	88	98	85	83	85	-999	87	93	-999	-999	-999	97	-999	84	90	90	93
12	80	79	82	77	77	85	72	72	77	-999	76	80	-999	-999	-999	93	-999	79	83	79	83
13	56	69	69	72	75	75	68	69	77	-999	69	80	-999	-999	-999	78	-999	80	79	70	74
14	53	63	66	76	67	70	62	69	67	-999	70	75	-999	-999	-999	92	-999	83	75	66	71
15	53	61	61	78	66	70	59	57	67	-999	68	66	-999	-999	-999	64	-999	93	75	62	69

Table 73: Time required for 99% of the vortices to be laterally transported on a distance of 175m depending on the averaged in-plane wind [knots] and on the leader generator

Note that, for some aircraft types in some wind conditions, the observed times required does not increase with the increasing transport distance. This is due to the lack of data of long-lasting wakes in some wind conditions. This is the reason why a consistency check is introduced in what follows.

Using the results of these tables, the time separation minima for each IPW value and each aircraft pair category are computed. The selected time separation corresponds to the maximum value obtained for the considered generator aircraft category for the distance corresponding to those of Table 56. Note that for all ICAO Medium and Lights (RECAT-EU D, E and F categories), A321 results are conservatively used as sole data available in the LiDAR dataset.

Note that due to lack of measurements for certain pairs, some inconsistencies might appear in the matrix when strictly applying the method described above. Some consistency checks and corresponding corrections are then applied:

- For a given follower category, the required time separation for a considered leader category cannot be larger than the minimum prescribed for the same follower category but a larger leader category. If it is the case, the minima are aligned on that of the larger leader category
- For a given leader-follower category, the time separation minima cannot be larger than that allowed for a lower crosswind condition. If it is the case, the minima are aligned on those obtained for this lower wind condition.

The consolidated results are provided in Table 74 to Table 83 for IPW values ranging from 6 knots to 15 knots.

6 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	175	163	161	180	180	174
Cat-B	159	162	159	158	158	149
Cat-C	136	135	131	137	137	132
Cat-D	101	99	96	92	92	92
Cat-E	101	99	96	92	92	92
Cat-F	96	96	92	92	91	89

Table 74: Minimum A-WDS-Xw time separation [s] for an IPW of 6 knots depending on the leader and follower RECAT-EU category

7 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	175	148	161	149	149	142
Cat-B	141	142	139	133	133	132
Cat-C	121	126	130	133	133	132
Cat-D	99	96	93	90	90	90
Cat-E	98	96	92	90	90	90
Cat-F	93	92	90	90	90	88

Table 75: Minimum A-WDS-Xw time separation [s] for an IPW of 7 knots depending on the leader and follower RECAT-EU category

8 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	147	144	133	126	126	130
Cat-B	132	126	128	120	120	118
Cat-C	117	112	108	102	102	101
Cat-D	93	95	93	89	89	89
Cat-E	93	95	92	89	89	86
Cat-F	93	92	89	86	83	82

Table 76: Minimum A-WDS-Xw time separation [s] for an IPW of 8 knots depending on the leader and follower RECAT-EU category

9 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	117	113	104	99	99	112
Cat-B	117	113	104	99	99	102
Cat-C	99	100	97	93	93	101
Cat-D	92	85	85	81	81	78
Cat-E	88	85	83	81	78	75
Cat-F	85	83	81	75	72	72

Table 77: Minimum A-WDS-Xw time separation [s] for an IPW of 9 knots depending on the leader and follower RECAT-EU category

10 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	99	94	92	88	88	86
Cat-B	99	94	92	88	88	86
Cat-C	94	90	87	80	80	77
Cat-D	88	81	80	79	79	75
Cat-E	84	81	79	79	75	74
Cat-F	80	79	79	74	71	69

Table 78: Minimum A-WDS-Xw time separation [s] for an IPW of 10 knots depending on the leader and follower RECAT-EU category

11 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	94	90	88	84	84	82
Cat-B	93	88	84	82	82	79
Cat-C	85	82	80	75	75	72
Cat-D	83	77	75	75	75	72
Cat-E	80	77	75	75	74	72
Cat-F	75	76	75	74	71	69

Table 79: Minimum A-WDS-Xw time separation [s] for an IPW of 11 knots depending on the leader and follower RECAT-EU category

12 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	80	71	68	61	61	57
Cat-B	80	71	68	61	61	57
Cat-C	80	71	68	61	61	57
Cat-D	72	70	68	61	61	57
Cat-E	71	70	68	61	61	57
Cat-F	68	68	68	61	61	57

Table 80: Minimum A-WDS-Xw time separation [s] for an IPW of 12 knots depending on the leader and follower RECAT-EU category

13 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	56	53	51	48	48	46
Cat-B	56	53	51	48	48	46
Cat-C	56	53	51	48	48	46
Cat-D	56	53	51	48	48	46
Cat-E	56	53	51	48	48	46
Cat-F	56	53	51	48	48	46

Table 81: Minimum A-WDS-Xw time separation [s] for an IPW of 13 knots depending on the leader and follower RECAT-EU category

14 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	53	50	48	45	45	43
Cat-B	53	50	48	45	45	43
Cat-C	53	50	48	45	45	43
Cat-D	53	50	48	45	45	43
Cat-E	53	50	48	45	45	43
Cat-F	53	50	48	45	45	43

Table 82: Minimum A-WDS-Xw time separation [s] for an IPW of 14 knots depending on the leader and follower RECAT-EU category

15 kts	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	53	50	48	45	45	43
Cat-B	53	50	48	45	45	43
Cat-C	53	50	48	45	45	43
Cat-D	53	50	48	45	45	43
Cat-E	53	50	48	45	45	43
Cat-F	53	50	48	45	45	43

Table 83: Minimum A-WDS-Xw time separation [s] for an IPW of 15 knots depending on the leader and follower RECAT-EU category

Based on these results, an IPW of 13 knots is seen to be needed in order to suppress all wake separation minima.

Note that these tables are for wake separation design only, not taking in account other constraints like ROT that might impact the requested separation.

J.2 A-WDS-Xw time separation reduction definition out of ground proximity

When evolving away from the ground, the wake vortex lateral transport is only governed by the crosswind. The vortex lateral displacement is then linearly related to the crosswind. However, away from the ground, the uncertainty on the aircraft position is larger. As for ground proximity region, the minimum distance to be travelled by the vortices, illustrated in Figure 31, is given by:

$$\text{Distance} = \mathrm{b}_0 + \frac{\mathrm{b}_{\mathrm{foll}}}{2} + 2\,TSE_{lat}\,,$$

The total lateral system error ($2\,TSE_{lat}$) has to be defined with a certain probability level.

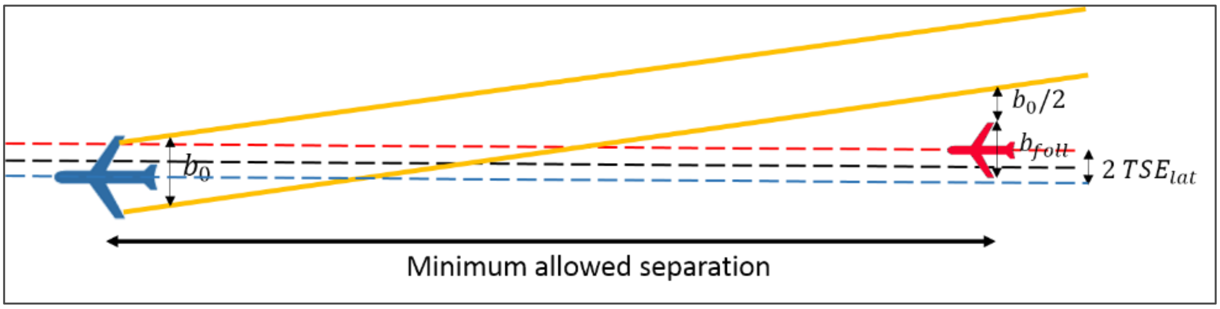


Figure 31: Minimum distance to be travelled for A-WDS-Xw separation design

OGE, the allowed time-based A-WDS-Xw is then simply obtained as that distance divided by the crosswind:

$$\text{Time sep} = \frac{\text{Distance}}{\text{Xw}}$$

The minimum distances to be crosswind transported, without navigation uncertainty, are provided in Table 55. The only remaining unknown is thus the arrival lateral navigation uncertainty.

J.2.1 Arrival lateral navigation uncertainty - RADAR database description, filtering and processing

To determine this quantity, RADAR database is used. This RADAR track database covers almost two years of operations in Vienna airport ranging from September 2014 to February 2016. It provides for each flight:

- The aircraft ICAO type; and
- The latitude, longitude, altitude and ground speed for various time stamps.

The database is then processed to retain only meaningful cases. In particular, the following filtering steps are followed:

- Helicopter flights are excluded
- Flight tracks intercepting the glide closer than 6 NM from the runway threshold are excluded
- Flight tracks for which the final target heading (computed as the median heading between 1 NM and 3 NM from threshold) exceeds by more than 2 degrees the runway heading are excluded

- Flight tracks for which the maximum final target heading (computed as the maximum heading between 1 NM and 3 NM from threshold) exceeds by more than 10 degrees the runway heading are excluded
- Flight tracks for which the minimum final target heading (computed as the minimum heading between 1 NM and 3 NM from threshold) exceeds by more than 10 degrees the runway heading are excluded

The aircraft is considered to have intercepted the glide when its target heading is within 1 degrees of the final median target heading of that track (i.e. median heading value measured between 3 NM and 1 NM from threshold) and if it's heading with respect to the runway threshold is within 0.5 degrees of the median final heading.

Note that, once intercepted, the complete track is taken into account in the analysis. This allows us to account for aircraft that would oscillate around the runway centreline.

Note also that this analysis takes the RADAR measurements (and the associated error) as they are. The obtained values hence correspond to upper bounds of the total system errors

J.2.2 Lateral deviation compared to ILS

The lateral deviation of aircraft with respect to ILS is estimated at various distances from the runway threshold ranging from 10 NM to 1 NM by step of 1 NM. This estimation is performed using the latitude and longitude values provided by the RADAR. For each selected track, the latitude and longitude values at each DME station is recorded starting from the interception position as defined above. Note that the analysis is here restricted to distances up to 10 NM due to RADAR data availability. However, the same methodology can be applied locally to larger distances if data are available.

Using all latitude and longitude values measured in one station, the ILS location is determined as the centre of mass of all the points (i.e. the point minimising the distance to all other points), assuming that, on average, the aircraft are centred on the ILS (i.e. no navigation bias). Note that, when looking at the relative deviation between leader and follower, a systematic bias would not impact the results as both aircraft would have been subject to the same bias. The distribution of distance to that ILS position is then computed together with some statistics (median, standard deviation and some extreme percentiles). This exercise is performed by considering separately each runway threshold and then by aggregating all data from all arrival runway operations. The obtained distributions for RWY34 are provided in Figure 32 and Figure 33. They are provided for aggregated data from all arrival runways in Figure 34 and Figure 35.

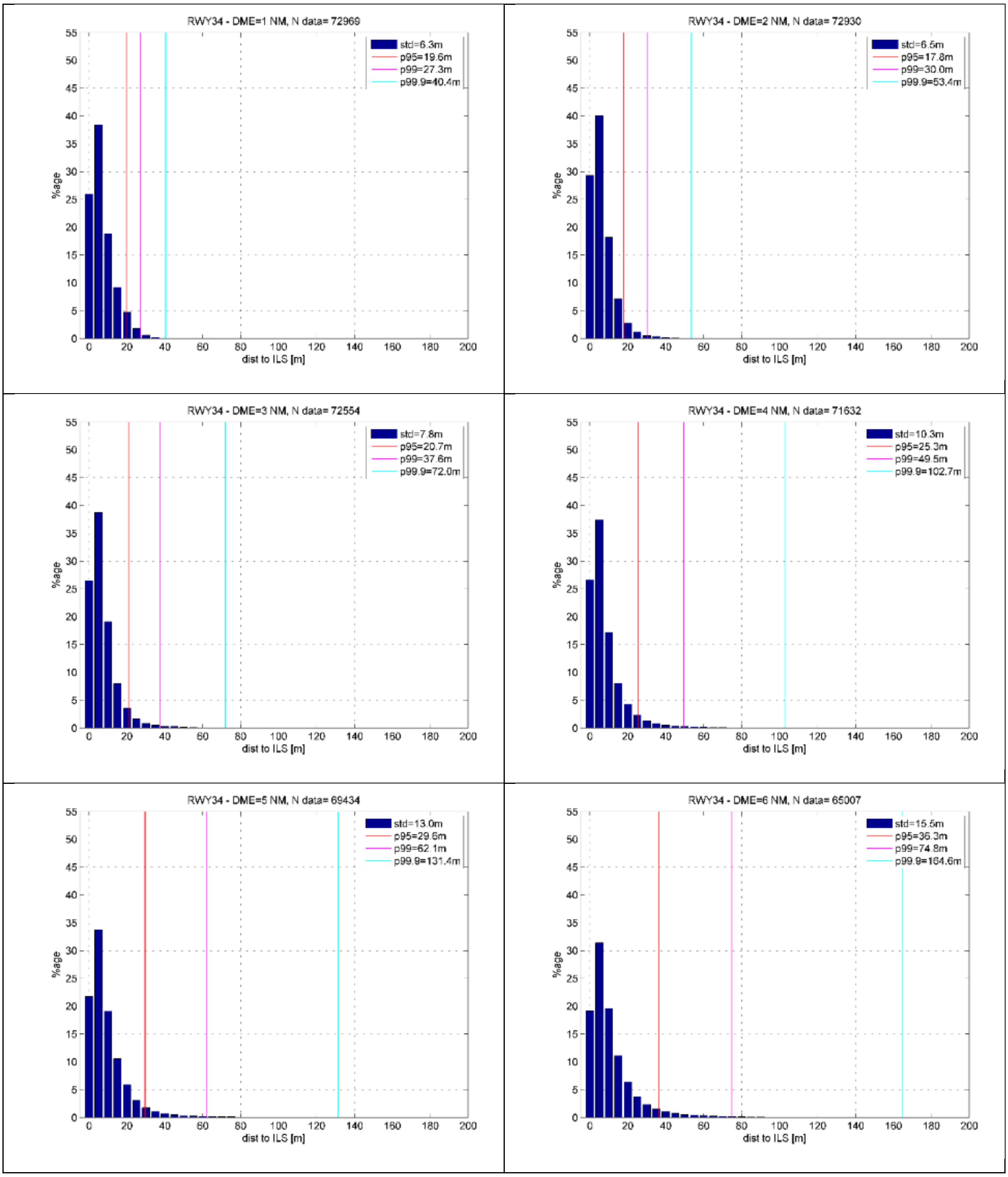


Figure 32: Distribution of lateral deviation from ILS [m] when considering arrivals to runway 34 at (from top left to bottom right) 1, 2, 3, 4, 5 and 6 NM from runway threshold

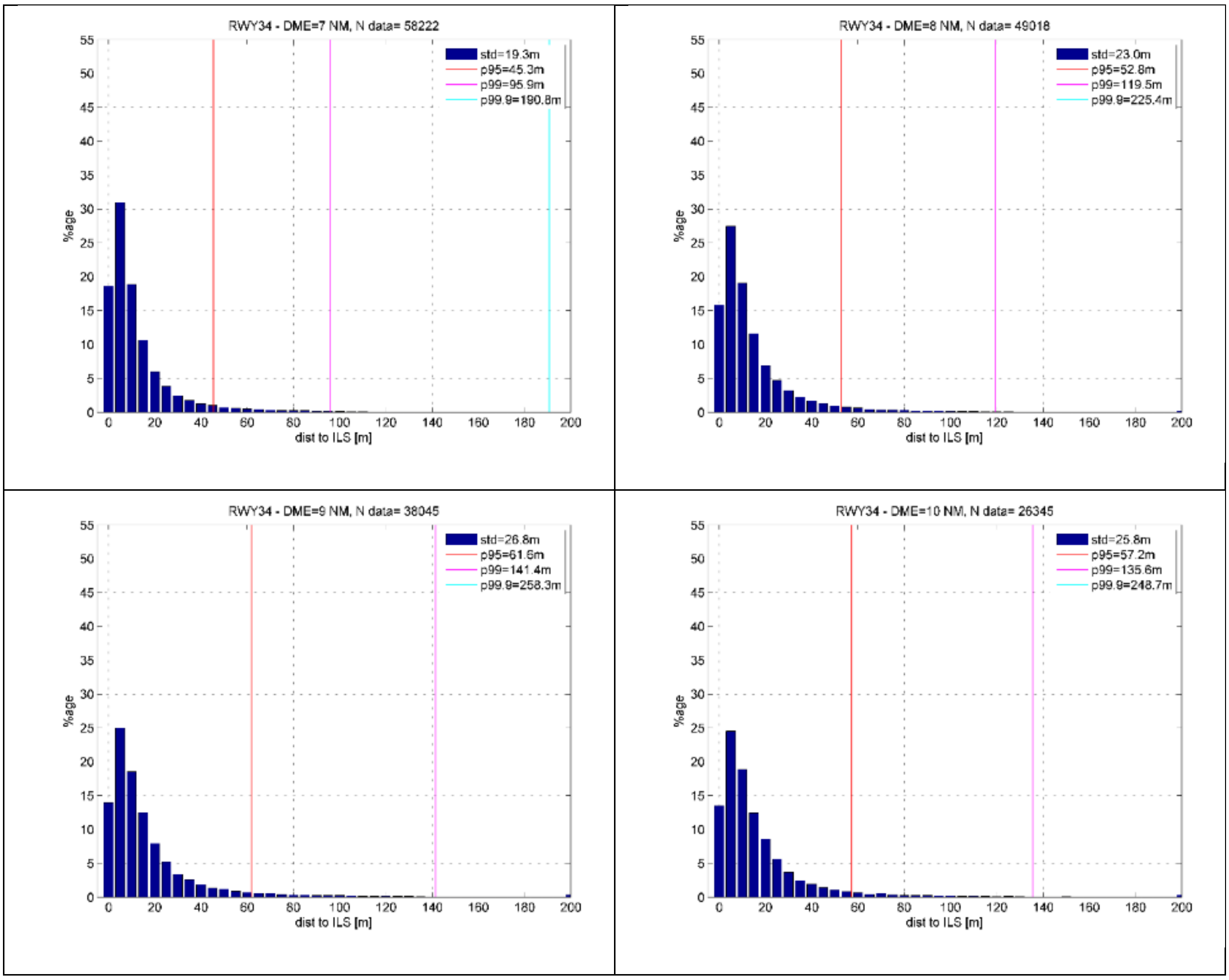


Figure 33: Distribution of lateral deviation from ILS [m] when considering arrivals to runway 34 at (from top left to bottom right) 7, 8, 9 and 10 NM from runway threshold

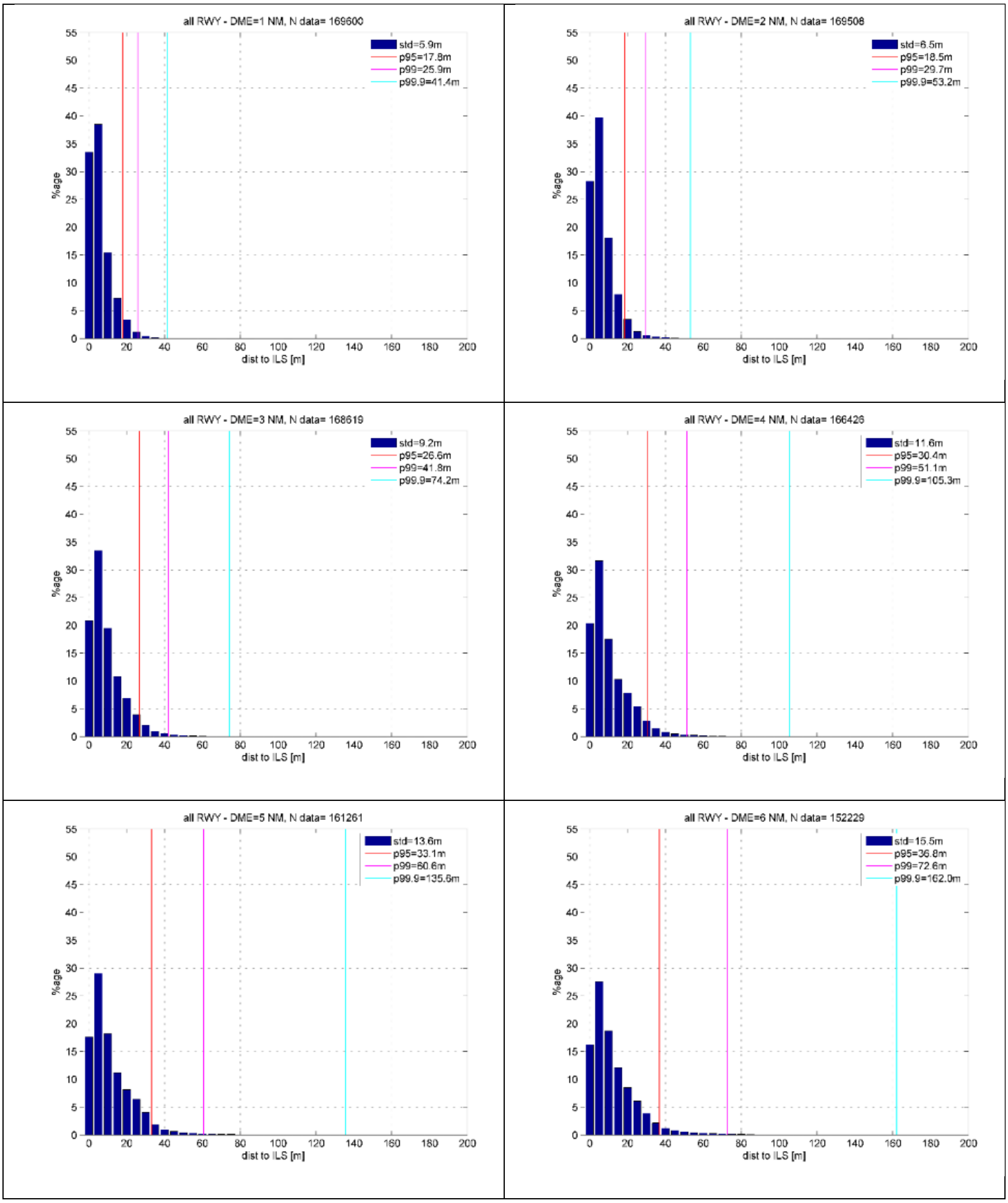


Figure 34: Distribution of lateral deviation from ILS [m] when considering arrivals to all runway thresholds at (from top left to bottom right) 1, 2, 3, 4, 5 and 6 NM from runway threshold

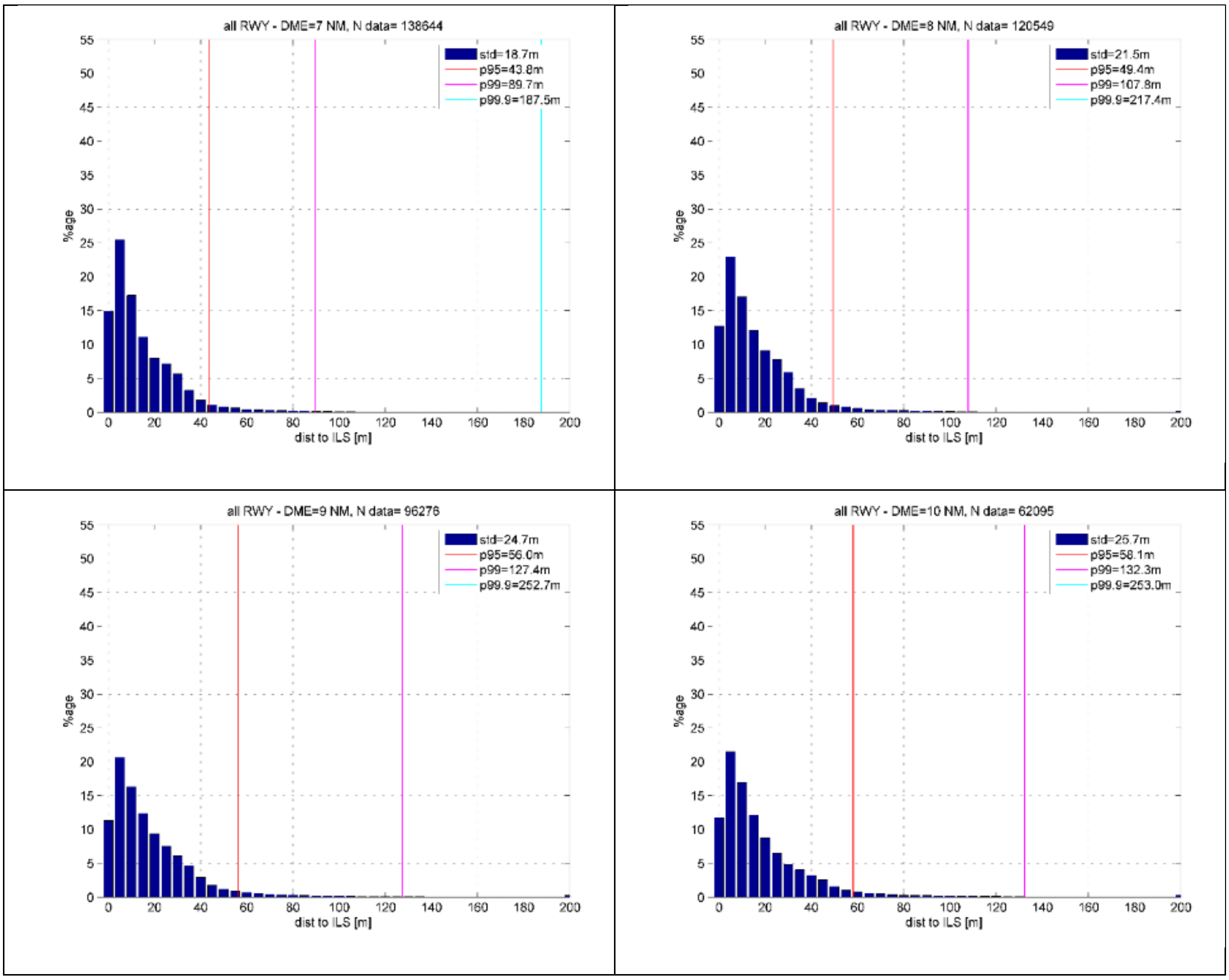


Figure 35: Distribution of lateral deviation from ILS [m] when considering arrivals to all runway thresholds at (from top left to bottom right) 7, 8, 9 and 10 NM from runway threshold

Table 84 to Table 88 provide the statistics of the lateral distance to ILS at various distances from runway threshold when considering each arrival runway separately or when aggregating the data.

dme	p50	Std dev	p90	p95	p99	p99.9	p99.99
1	4.1	5.9	13.9	17.8	25.9	41.4	58.9
2	4.8	6.5	14.5	18.5	29.7	53.2	99.6
3	6.7	9.2	21.1	26.6	41.8	74.2	117.0
4	7.1	11.6	24.2	30.4	51.1	105.3	200.8
5	8.2	13.6	26.9	33.1	60.6	135.6	251.7
6	8.9	15.5	28.3	36.8	72.6	162.0	275.6
7	10.0	18.7	33.0	43.8	89.7	187.5	294.5

8	11.6	21.5	35.6	49.4	107.8	217.4	327.0
9	13.1	24.7	40.0	56.0	127.4	252.7	364.2
10	12.5	25.7	43.0	58.1	132.3	253.0	392.4

Table 84: Statistics of the lateral deviation from ILS [m] depending on the distance to runway threshold [NM] when considering all runways

dme	p50	Std dev	p90	p95	p99	p99.9	p99.99
1	5.3	6.3	15.8	19.6	27.3	40.4	61.9
2	4.6	6.5	13.7	17.8	30.0	53.4	99.2
3	5.1	7.8	15.5	20.7	37.6	72.0	116.6
4	5.2	10.3	18.1	25.3	49.5	102.7	174.4
5	6.5	13.0	21.4	29.6	62.1	131.4	245.1
6	7.4	15.5	25.2	36.3	74.8	164.6	273.3
7	7.6	19.3	29.4	45.3	95.9	190.8	305.7
8	9.0	23.0	35.3	52.8	119.5	225.4	318.8
9	10.3	26.8	39.8	61.6	141.4	258.3	388.4
10	10.5	25.8	37.9	57.2	135.6	248.7	358.2

Table 85: Statistics of the lateral deviation from ILS [m] depending on the distance to runway threshold [NM] when considering runway 34

dme	p50	Std dev	p90	p95	p99	p99.9	p99.99
1	2.4	3.3	7.1	9.2	15.3	29.3	43.6
2	3.7	5.1	10.1	13.5	23.7	46.8	103.6
3	8.3	10.7	26.2	31.0	45.6	76.2	107.6
4	9.5	12.7	28.6	34.3	53.5	106.0	227.5
5	10.4	14.3	30.5	35.4	60.0	138.2	256.5
6	11.9	16.0	31.8	38.9	72.1	162.6	295.5
7	12.8	18.0	34.5	43.1	84.5	185.6	258.3
8	14.3	20.7	36.4	48.1	104.1	206.2	326.0
9	15.8	23.0	41.1	53.7	117.7	238.6	320.1

10	16.6	25.4	47.3	60.0	131.2	239.9	392.9

Table 86: Statistics of the lateral deviation from ILS [m] depending on the distance to runway threshold [NM] when considering runway 16

dme	p50	Std dev	p90	p95	p99	p99.9	p99.99
1	3.0	3.3	8.2	10.1	14.6	23.8	35.5
2	4.9	4.9	11.8	14.7	22.2	38.4	78.0
3	5.9	7.9	15.7	20.7	39.1	72.6	103.1
4	5.2	10.2	16.5	23.2	49.7	107.6	169.5
5	5.6	12.5	18.1	27.2	60.9	135.0	238.2
6	5.4	15.6	20.7	32.8	77.3	165.6	263.2
7	5.8	17.5	21.9	35.6	92.1	191.2	254.7
8	6.3	19.8	25.8	41.7	96.1	208.7	293.5
9	7.2	23.3	29.3	48.4	111.8	257.1	564.8
10	7.3	21.3	27.4	46.9	111.3	232.1	309.6

Table 87: Statistics of the lateral deviation from ILS [m] depending on the distance to runway threshold [NM] when considering runway 29

dme	p50	Std dev	p90	p95	p99	p99.9	p99.99
1	9.0	7.1	18.8	22.1	33.8	52.3	62.3
2	10.4	8.1	20.6	24.4	38.2	61.1	105.2
3	11.1	9.1	22.3	26.8	42.2	78.7	144.7
4	13.5	11.3	26.0	32.1	50.6	108.5	222.1
5	14.7	13.1	28.3	34.8	58.1	156.0	286.9
6	12.9	13.5	26.5	34.5	64.1	151.2	291.5
7	19.1	17.1	36.0	46.1	77.2	172.3	385.3
8	19.4	18.8	37.8	49.5	91.9	205.1	366.3
9	20.8	22.4	40.7	56.2	115.8	252.0	365.7
10	19.0	28.1	42.0	62.9	145.8	293.7	434.3

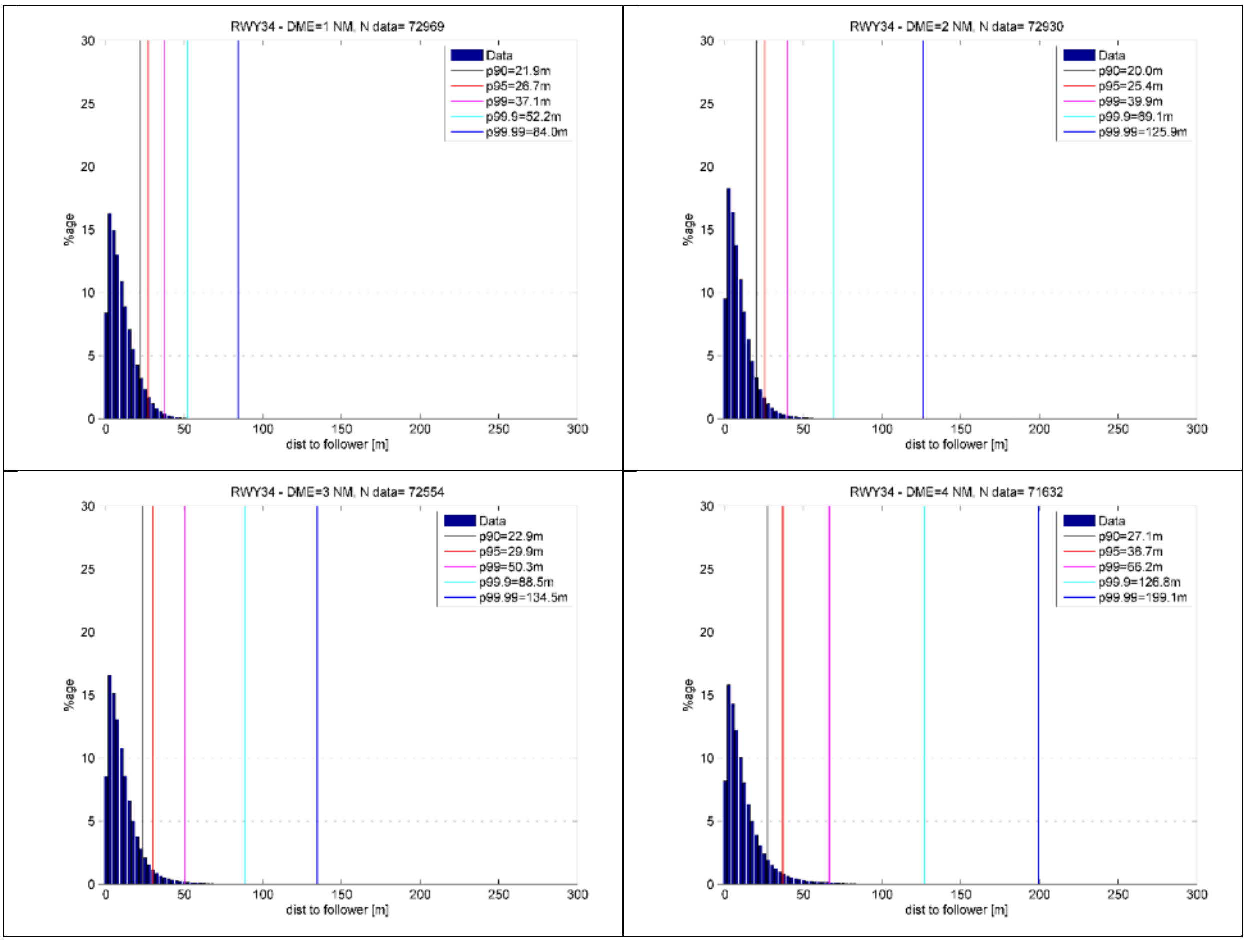
Table 88: Statistics of the lateral deviation from ILS [m] depending on the distance to runway threshold [NM] when considering runway 11

In the above-tables, the percentile to be used for WDS definition is a local choice and might also be dependent on the separation reduction that is to be applied. The local choice of acceptable failure rate might also depend on a failure case analysis considering under-separation.

Most of the approaches are here ILS. Yet, this methodology should be applied for each navigation procedure. The influence of the crosswind on the lateral deviation was here not investigated since crosswind at high altitudes was not available and that the influence of the crosswind on the flight deviation might also be aircraft type dependent.

J.2.3 Uncertainty on the lateral distance between two trailing aircraft

From the results obtained in the Section above, we here compute the distribution of the lateral distance between two aircraft in trail at various distances from the runway threshold. That distance is evaluated assuming that the lateral deviation from the ILS is symmetrical left/right and that the deviation of the leader and follower are independent. Crossing twice the distributions for leader and follower, one obtains the distributions showed in Figure 36 and Figure 37 for arrival on RWY34 and in Figure 38 and Figure 39 for aggregated data of all arrival runways. The statistics of the distributions are provided in Table 89 to Table 93 when considering each arrival runway separately or aggregated data from all arrival runways.



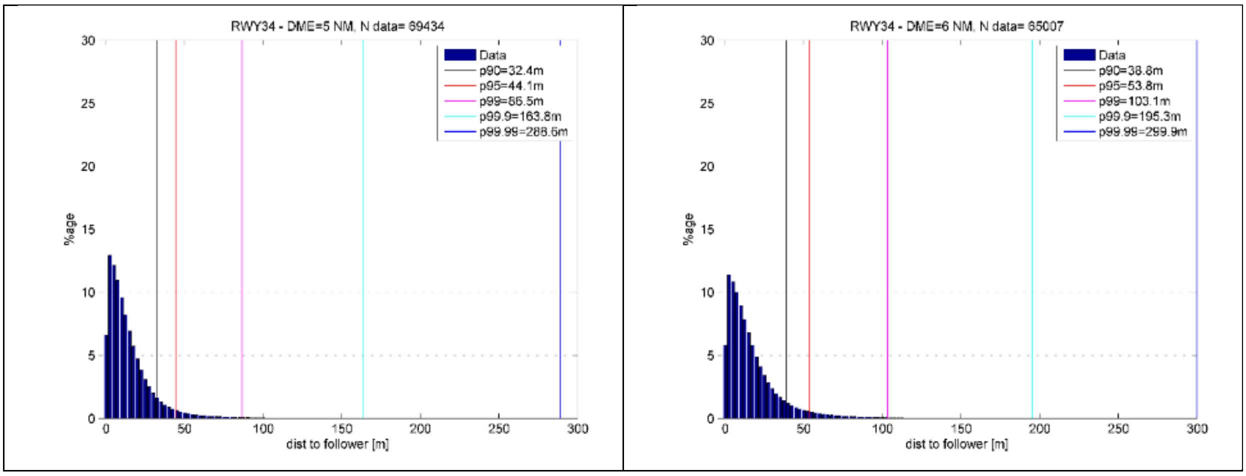


Figure 36: Distribution of lateral distance between two trailing aircraft flights when considering arrivals to runway 34 at (from top left to bottom right) 1, 2, 3, 4, 5 and 6 NM from runway threshold

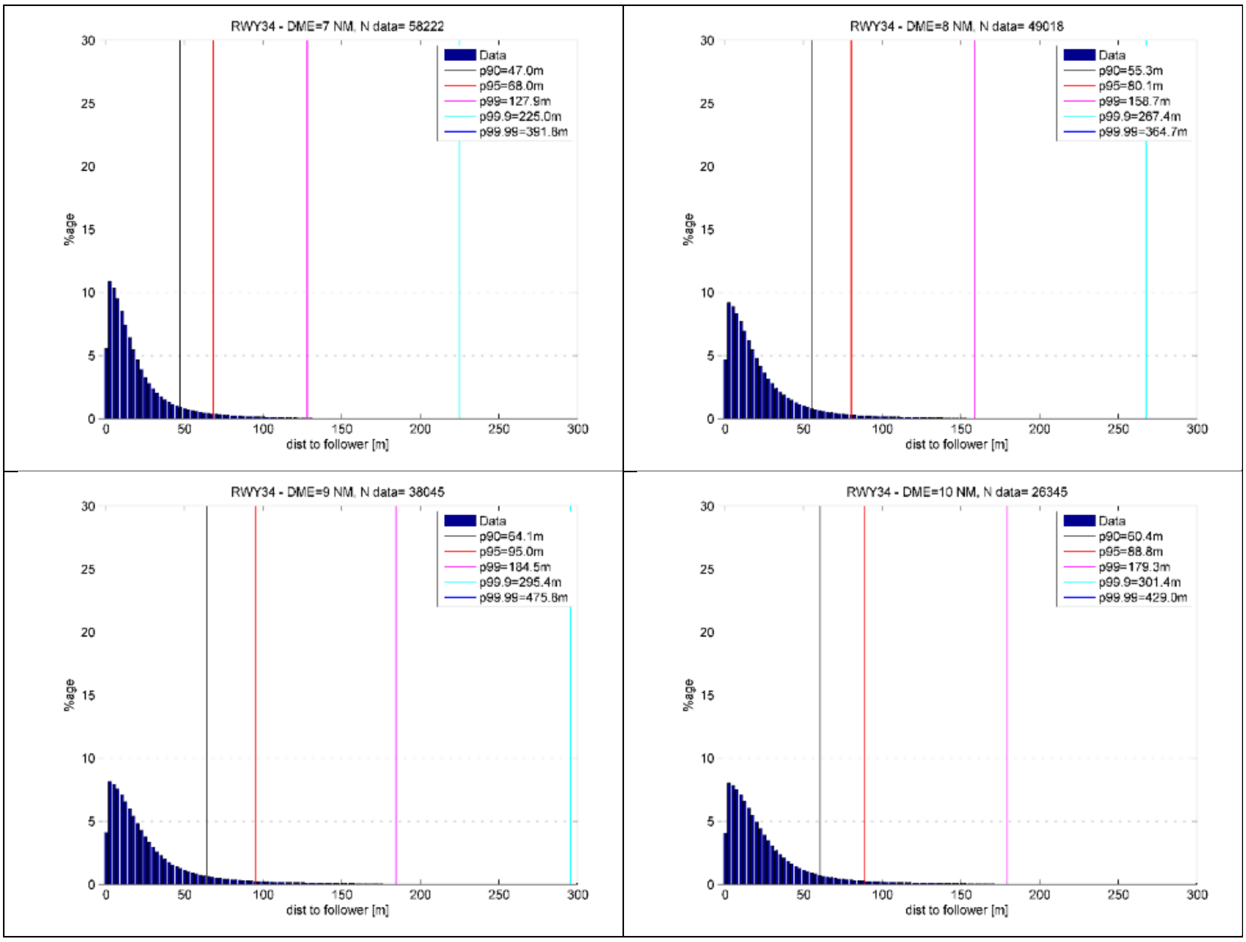


Figure 37: Distribution of lateral distance between two trailing aircraft flights when considering arrivals to runway 34 at (from top left to bottom right) 7, 8, 9 and 10 NM from runway threshold

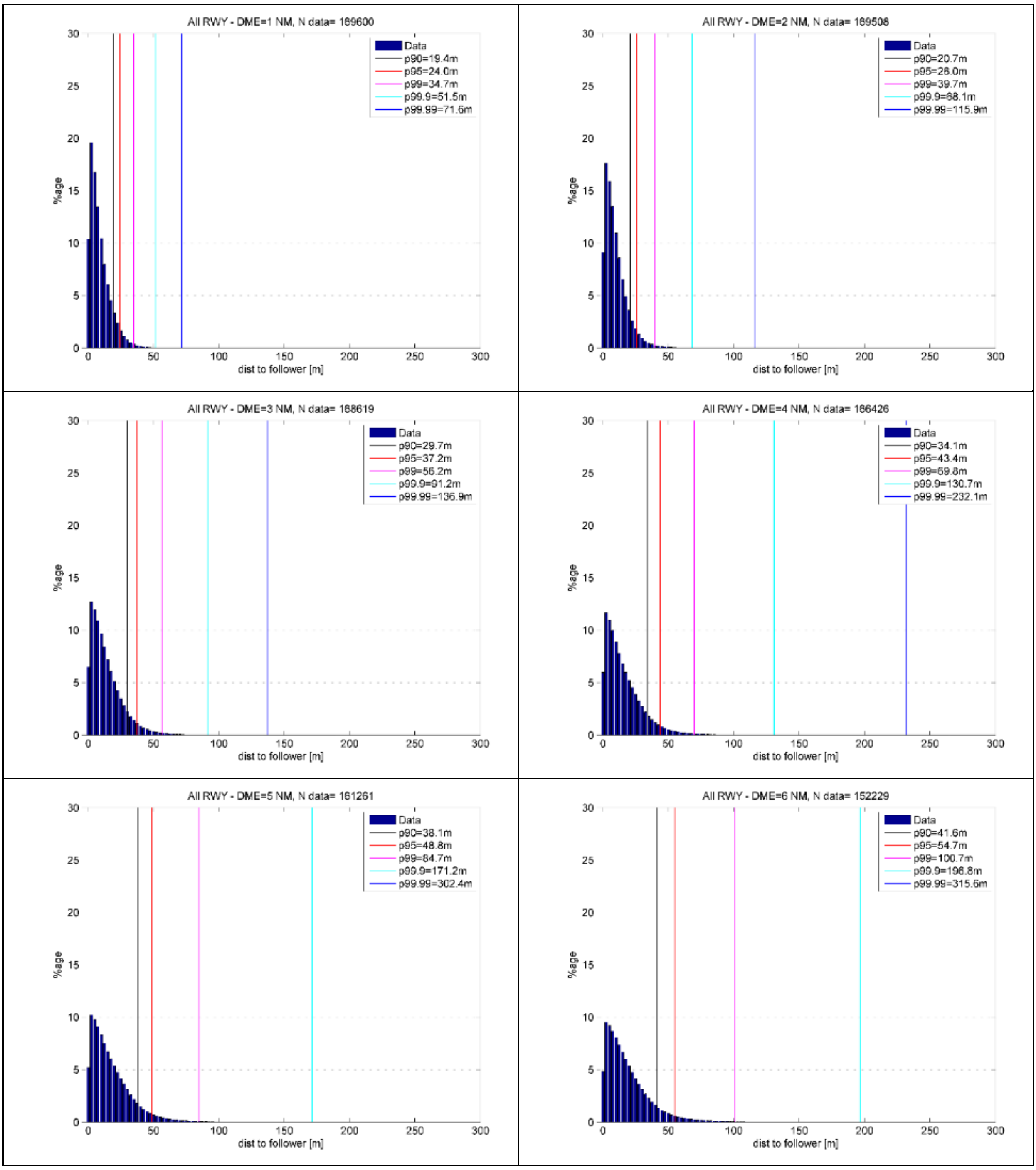


Figure 38: Distribution of lateral distance between two trailing aircraft flights when considering arrivals to any runway at (from top left to bottom right) 1, 2, 3, 4, 5 and 6 NM from runway threshold

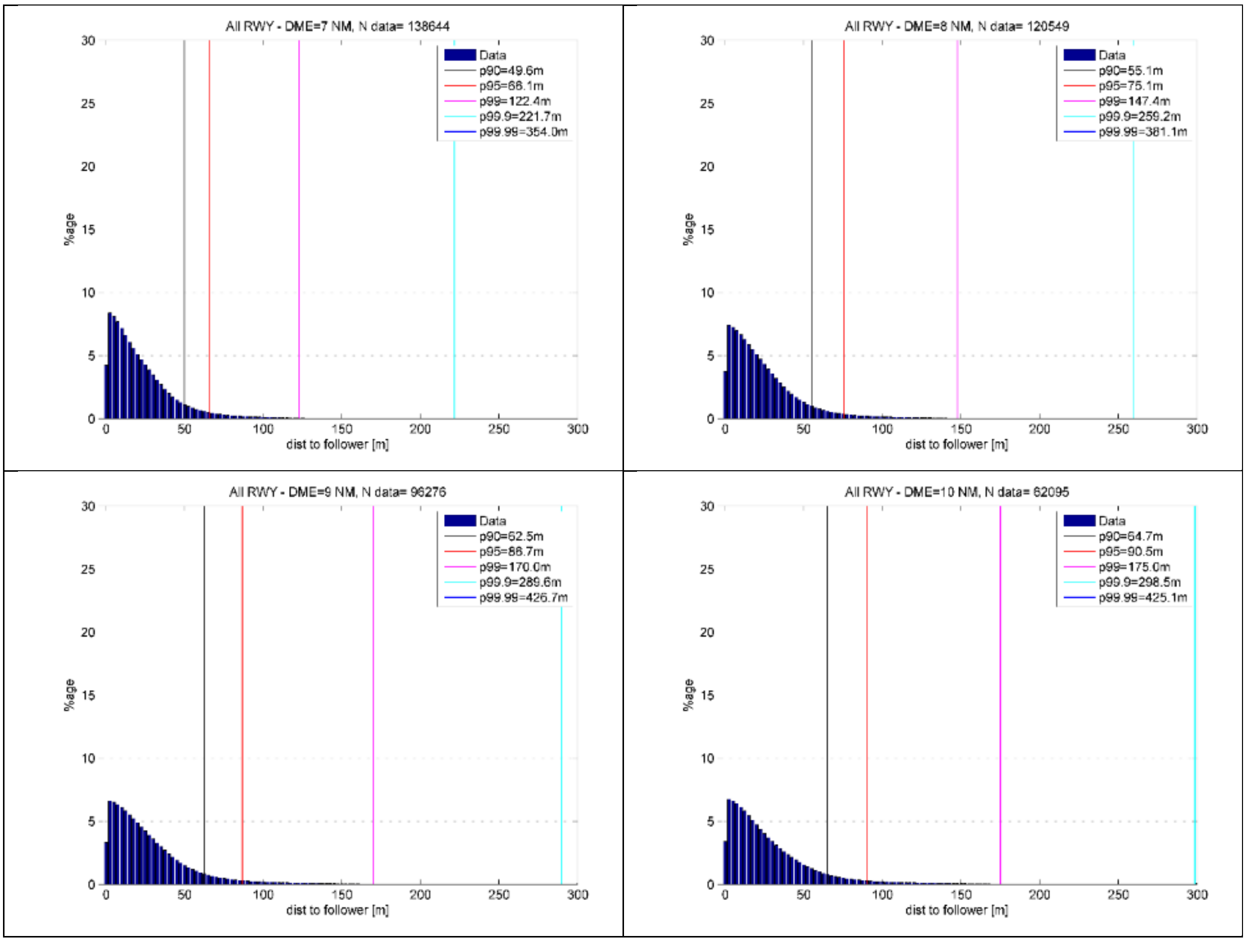


Figure 39: Distribution of lateral distance between two trailing aircraft flights when considering arrivals to any runway at (from top left to bottom right) 7, 8, 9, and 10 NM from runway threshold

dme	p50	p90	p95	p99	p99.9	p99.99
1	6.8	19.4	24	34.7	51.5	71.6
2	7.6	20.7	26	39.7	68.1	115.9
3	10.8	29.7	37.2	56.2	91.2	136.9
4	12.1	34.1	43.4	69.8	130.7	232.1
5	13.7	38.1	48.8	84.7	171.2	302.4
6	14.6	41.6	54.7	100.7	196.8	315.6
7	17.1	49.6	66.1	122.4	221.7	354
8	19	55.1	75.1	147.4	259.2	381.1
9	21.2	62.5	86.7	170	289.6	426.7
10	21.1	64.7	90.5	175	298.5	425.1

Table 89: Statistics of the lateral distance between two trailing aircraft [m] depending on the distance to runway threshold [NM] when considering all runways

dme	p50	p90	p95	p99	p99.9	p99.99
1	8.2	21.9	26.7	37.1	52.2	84
2	7.3	20	25.4	39.9	69.1	125.9
3	8.1	22.9	29.9	50.3	88.5	134.5
4	8.6	27.1	36.7	66.2	126.8	199.1
5	10.7	32.4	44.1	86.5	163.8	288.6
6	12.2	38.8	53.8	103.1	195.3	299.9
7	13	47	68	127.9	225	391.8
8	15.5	55.3	80.1	158.7	267.4	364.7
9	17.5	64.1	95	184.5	295.4	475.8
10	17.6	60.4	88.8	179.3	301.4	429

Table 90: Statistics of the lateral distance between two trailing aircraft [m] depending on the distance to runway threshold [NM] when considering runway 34

dme	p50	p90	p95	p99	p99.9	p99.99
1	3.8	10.3	13.1	20.2	35	56.9
2	5.5	15.1	19.4	32.2	62.2	116
3	14	36.3	44.6	62.8	94.6	125.4
4	16.1	41.1	50.6	74.5	131.9	258.3
5	17.5	44.2	54.7	84.6	172.7	316.1
6	18.6	47.8	59.4	101.6	195.1	340.5
7	20.2	52.6	66.4	118.3	220.3	294.2
8	21.5	56.8	73.8	142.4	252.4	411.5
9	24.2	64.2	83.8	157	275.8	361.5
10	27.1	72.5	94.3	172.3	283.8	413.9

Table 91: Statistics of the lateral distance between two trailing aircraft [m] depending on the distance to runway threshold [NM] when considering runway 16

dme	p50	p90	p95	p99	p99.9	p99.99
1	4.5	11.6	14.2	20	29.8	43.5
2	6.9	17.3	21.1	30.3	50.4	88.1
3	8.8	23.7	30.6	52.6	83.5	137.5
4	8.3	25.2	34.7	67.8	130.9	200
5	9	28.9	41.3	84.4	163.4	251.5
6	9.2	33.7	49.6	106.8	214.3	339
7	9.6	36.7	57.2	128	215.5	279.6
8	10.8	42.5	62.5	147.4	240.9	371.8
9	12.4	49	73.5	153.9	288.2	749.9
10	12.2	47.6	74.1	146.1	265	325.7

Table 92: Statistics of the lateral distance between two trailing aircraft [m] depending on the distance to runway threshold [NM] when considering runway 29

dme	p50	p90	p95	p99	p99.9	p99.99
1	11.8	28.2	33.5	46.2	64.8	78.8
2	13.3	31.6	37.3	52	81.9	129.4
3	14.3	34.3	40.8	58.7	99.9	158.8
4	17	40.5	48.3	71.4	144.9	249.9
5	18.6	44.3	53.2	81.9	192.7	314.3
6	16.8	41.3	51.8	87.3	191.8	319.9
7	24	57.1	69.3	109.5	219.8	515.9
8	24.7	59.7	75	126.8	256.2	397.9
9	26.8	65.4	85	162.5	304.2	405.3
10	25.6	70.5	102.7	195.2	375.5	465.1

Table 93: Statistics of the lateral distance between two trailing aircraft [m] depending on the distance to runway threshold [NM] when considering runway 11

J.2.4 A-WDS-Xw time separation minima for OGE situation

The statistics of lateral distance between two aircraft allow ones to compute the required distance to be travelled by the vortices in order not to be encountered by the follower with a certain probability level. Those distances are provided for 95, 99, 99.9 and 99.99% probabilities in Table 94 to Table 97 by adding the lateral deviation statistics established in Section B.2.3 to the minimum distance to be travelled without navigation uncertainty (i.e. one generator vortex span + half follower wing span).

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	194	187	180	172	169	164
Cat-B	182	175	169	160	158	153
Cat-C	172	165	158	150	147	142
Cat-D	158	151	145	136	134	129
Cat-E	154	147	141	132	130	125
Cat-F	146	139	133	124	122	117

Table 94: Minimum displacement distance for A-WDS-Xw separation design per RECAT-EU leader and follower category when considering navigation uncertainty at 95%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	279	271	265	256	254	249
Cat-B	267	260	253	245	242	237
Cat-C	256	249	243	234	232	227
Cat-D	243	236	229	221	218	213
Cat-E	239	232	225	217	214	209
Cat-F	231	224	217	209	206	201

Table 95: Minimum displacement distance for A-WDS-Xw separation design per RECAT-EU leader and follower category when considering navigation uncertainty at 99%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	402	395	388	380	377	372
Cat-B	390	383	377	368	366	361
Cat-C	380	373	366	358	355	350
Cat-D	366	359	353	344	342	337
Cat-E	362	355	349	340	338	333
Cat-F	354	347	341	332	330	325

Table 96: Minimum displacement distance for A-WDS-Xw separation design per RECAT-EU leader and follower category when considering navigation uncertainty at 99.9%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	529	521	515	506	504	499
Cat-B	517	510	503	495	492	487
Cat-C	507	499	493	484	482	477
Cat-D	493	486	479	471	468	463
Cat-E	489	482	475	467	464	459
Cat-F	481	474	467	459	456	451

Table 97: Minimum displacement distance for A-WDS-Xw separation design per RECAT-EU leader and follower category when considering navigation uncertainty at 99.99%

Using those results, the crosswind needed to transport the vortices from these distances after 60s are reported in Table 98 to Table 101 for the various probability levels. The obtained thresholds are 6 knots for 95% probability, 9 knots for 99%, 13 knots for 99.9%, and 17 knots for 99.99% probability level.

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	6	6	6	6	5	5
Cat-B	6	6	5	5	5	5
Cat-C	6	5	5	5	5	5
Cat-D	5	5	5	4	4	4
Cat-E	5	5	5	4	4	4
Cat-F	5	5	4	4	4	4

Table 98: Crosswind thresholds [knots] to allow 60s A-WDS-Xw wake time separation per RECAT-EU leader and follower category when considering navigation uncertainty at 95%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	9	9	9	8	8	8
Cat-B	9	8	8	8	8	8
Cat-C	8	8	8	8	8	7
Cat-D	8	8	7	7	7	7
Cat-E	8	8	7	7	7	7
Cat-F	7	7	7	7	7	7

Table 99: Crosswind thresholds [knots] to allow 60s A-WDS-Xw wake time separation per RECAT-EU leader and follower category when considering navigation uncertainty at 99%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	13	13	13	12	12	12
Cat-B	13	12	12	12	12	12
Cat-C	12	12	12	12	12	11
Cat-D	12	12	11	11	11	11
Cat-E	12	12	11	11	11	11
Cat-F	11	11	11	11	11	11

Table 100: Crosswind thresholds [knots] to allow 60s A-WDS-Xw wake time separation per RECAT-EU leader and follower category when considering navigation uncertainty at 99.9%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	17	17	17	16	16	16
Cat-B	17	17	16	16	16	16
Cat-C	16	16	16	16	16	15
Cat-D	16	16	16	15	15	15
Cat-E	16	16	15	15	15	15
Cat-F	16	15	15	15	15	15

Table 101: Crosswind thresholds [knots] to allow 60s A-WDS-Xw wake time separation per RECAT-EU leader and follower category when considering navigation uncertainty at 99.99%

The same exercise is performed for a 90s time separation. The results are reported in Table 102 to Table 105 for the various probability levels. The obtained thresholds are 4 knots for 95% probability, 6 knots for 99%, 9 knots for 99.9%, and 11 knots for 99.99% probability level.

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	4	4	4	4	4	4
Cat-B	4	4	4	3	3	3
Cat-C	4	4	3	3	3	3
Cat-D	3	3	3	3	3	3
Cat-E	3	3	3	3	3	3
Cat-F	3	3	3	3	3	3

Table 102: Crosswind thresholds [knots] to allow 90s A-WDS-Xw wake time separation per RECAT-EU leader and follower category when considering navigation uncertainty at 95%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	6	6	6	6	5	5
Cat-B	6	6	5	5	5	5
Cat-C	6	5	5	5	5	5
Cat-D	5	5	5	5	5	5
Cat-E	5	5	5	5	5	5
Cat-F	5	5	5	5	4	4

Table 103: Crosswind thresholds [knots] to allow 90s A-WDS-Xw wake time separation per RECAT-EU leader and follower category when considering navigation uncertainty at 99%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	9	9	8	8	8	8
Cat-B	8	8	8	8	8	8
Cat-C	8	8	8	8	8	8
Cat-D	8	8	8	7	7	7
Cat-E	8	8	8	7	7	7
Cat-F	8	7	7	7	7	7

Table 104: Crosswind thresholds [knots] to allow 90s A-WDS-Xw wake time separation per RECAT-EU leader and follower category when considering navigation uncertainty at 99.9%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	11	11	11	11	11	11
Cat-B	11	11	11	11	11	11
Cat-C	11	11	11	10	10	10
Cat-D	11	10	10	10	10	10
Cat-E	11	10	10	10	10	10
Cat-F	10	10	10	10	10	10

Table 105: Crosswind thresholds [knots] to allow 90s A-WDS-Xw wake time separation per RECAT-EU leader and follower category when considering navigation uncertainty at 99.99%

Finally, the time separation minima for crosswind thresholds of 8, 10 and 13 knots are provided in Table 106 to Table 115 for the various probability levels. Note that for 95% probability only the 8 knots table is provided since for that threshold already all separations are below 50s.

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	47	45	44	42	41	40
Cat-B	44	43	41	39	38	37
Cat-C	42	40	38	36	36	35
Cat-D	38	37	35	33	32	31
Cat-E	38	36	34	32	31	30
Cat-F	36	34	32	30	30	28

Table 106: A-WDS-Xw wake time separation minima for an 8 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 95%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	68	66	64	62	62	60
Cat-B	65	63	61	59	59	58
Cat-C	62	61	59	57	56	55
Cat-D	59	57	56	54	53	52
Cat-E	58	56	55	53	52	51
Cat-F	56	54	53	51	50	49

Table 107: A-WDS-Xw wake time separation minima for an 8 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	54	53	51	50	49	48
Cat-B	52	50	49	48	47	46
Cat-C	50	48	47	46	45	44
Cat-D	47	46	45	43	42	41
Cat-E	46	45	44	42	42	41
Cat-F	45	43	42	41	40	39

Table 108: A-WDS-Xw wake time separation minima for a 10 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	42	41	40	38	38	37
Cat-B	40	39	38	37	36	35
Cat-C	38	37	36	35	35	34
Cat-D	36	35	34	33	33	32
Cat-E	36	35	34	32	32	31
Cat-F	35	33	32	31	31	30

Table 109: A-WDS-Xw wake time separation minima for a 13 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	98	96	94	92	92	90
Cat-B	95	93	91	89	89	88
Cat-C	92	91	89	87	86	85
Cat-D	89	87	86	84	83	82
Cat-E	88	86	85	83	82	81
Cat-F	86	84	83	81	80	79

Table 110: A-WDS-Xw wake time separation minima for an 8 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99.9%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	78	77	75	74	73	72
Cat-B	76	74	73	72	71	70
Cat-C	74	72	71	70	69	68
Cat-D	71	70	69	67	66	65
Cat-E	70	69	68	66	66	65
Cat-F	69	67	66	65	64	63

Table 111: A-WDS-Xw wake time separation minima for a 10 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99.9%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	60	59	58	57	56	56
Cat-B	58	57	56	55	55	54
Cat-C	57	56	55	53	53	52
Cat-D	55	54	53	51	51	50
Cat-E	54	53	52	51	50	50
Cat-F	53	52	51	50	49	49

Table 112: A-WDS-Xw wake time separation minima for a 13 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99.9%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	128	127	125	123	122	121
Cat-B	126	124	122	120	120	118
Cat-C	123	121	120	118	117	116
Cat-D	120	118	116	114	114	113
Cat-E	119	117	115	113	113	112
Cat-F	117	115	113	111	111	110

Table 113: A-WDS-Xw wake time separation minima for an 8 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99.99%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	103	101	100	98	98	97
Cat-B	100	99	98	96	96	95
Cat-C	98	97	96	94	94	93
Cat-D	96	94	93	91	91	90
Cat-E	95	94	92	91	90	89
Cat-F	93	92	91	89	89	88

Table 114: A-WDS-Xw wake time separation minima for a 10 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99.99%

Leader/Follower	Cat-A	Cat-B	Cat-C	Cat-D	Cat-E	Cat-F
Cat-A	79	78	77	76	75	75
Cat-B	77	76	75	74	74	73
Cat-C	76	75	74	72	72	71
Cat-D	74	73	72	70	70	69
Cat-E	73	72	71	70	69	69
Cat-F	72	71	70	69	68	67

Table 115: A-WDS-Xw wake time separation minima for a 13 knots crosswind per RECAT-EU leader and follower category when considering navigation uncertainty at 99.99%

J.2.5 Correction of the WDS-XW time separation minima for OGE situation with Headwind

In case of headwind, younger vortices are blown toward the follower. Those vortices have thus less time to be transported by the crosswind and the WDS-XW time separation minima must be corrected accordingly.

Considering an aircraft crossing a given cross-plane x=X at time t=0. In case of headwind, at time t=tsep, the vortices observed in x=X have not been generated in x=X but further out at x=X-Δx and blown toward the cross-plane. Dx is related to the headwind through:

$$\Delta x = HW\left(t_{sep} - \Delta t_{ac}\right),$$

Where Δt_ac is the difference in generation time and is related to Δx through:

$$\Delta t_{ac} = \frac{\Delta x}{GS}$$

With GS, the aircraft groundspeed.

Combining the two-above equations, one obtains:

$$\Delta x = HW\frac{GS}{TAS}\, t_{sep}$$

$$\Delta t_{ac} = \frac{HW}{TAS}\, t_{sep}$$

The vortex age is thus the time separation reduced by Δt_ac reading:

$$\mathrm{t_{vortex}} = \mathrm{t_{sep}} - \Delta t_{ac} = \left(1 - \frac{HW}{TAS}\right) t_{sep}$$

One notes that the correction function is larger for stronger headwind values (as expected) and for slower flight speed.

In case of headwind, the WDS-XW time separations shall be corrected according to:

$$\text{Time sep} = \frac{\text{Distance}}{\text{XW}}\left(\frac{TAS}{TAS - HW}\right)$$

Considering typical glide slope airspeed values, the correction function values range from 1 up to 1.18 for HW values ranging from 0 up to 25 kts, see Figure 40.

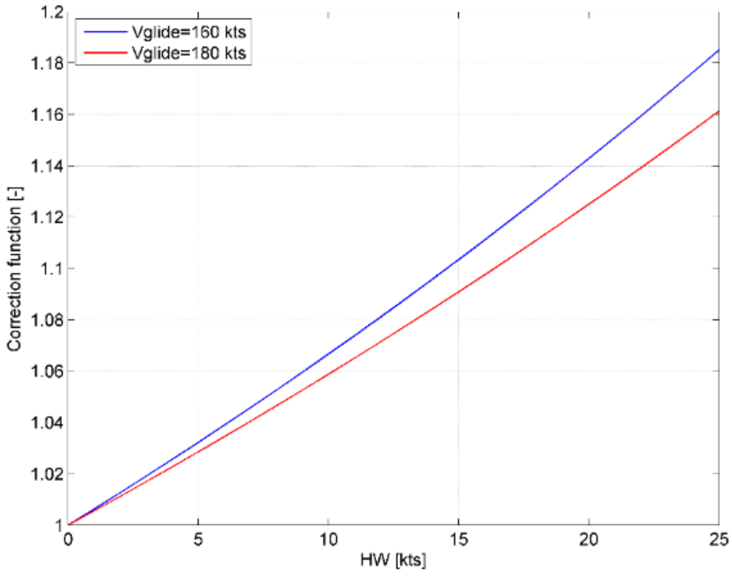


Figure 40: Headwind correction function for typical glide slope airspeed values of 160 kts and 180 kts

Appendix K D-WDS-Xw Methodology

This appendix provides a methodology and the associated rationale for the definition of separation minima to be applied with the WDS-D Xw for departures concept (D-WDS-Xw).

K.1 Overview of the WDS-D Crosswind Transport Reduced Separation Concept

Applicable immediately after take-off, on a predetermined extent during climb-out on the initial departure path segment:

- The straight-out initial common departure path segment to the first turn fix of the SIDs until aircraft reach wake independent paths

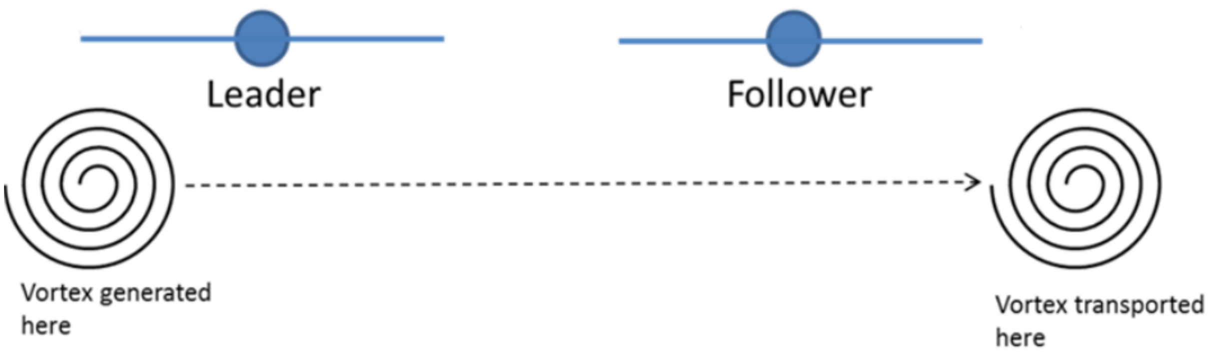


Figure 41: Figure illustrating the OGE situation where the wake vortex transport is only affected by the crosswind

K.2 Departure Aircraft Behaviour

The rotation positions, the vertical climb profiles, and the airspeed profiles of the departing aircraft vary depending on the wake category and aircraft type of the departing aircraft, the take-off weight, the prevailing meteorological conditions, and the performance / economy mode in which the departing aircraft is being flown; the example Heathrow environment is illustrated in Figure 42.

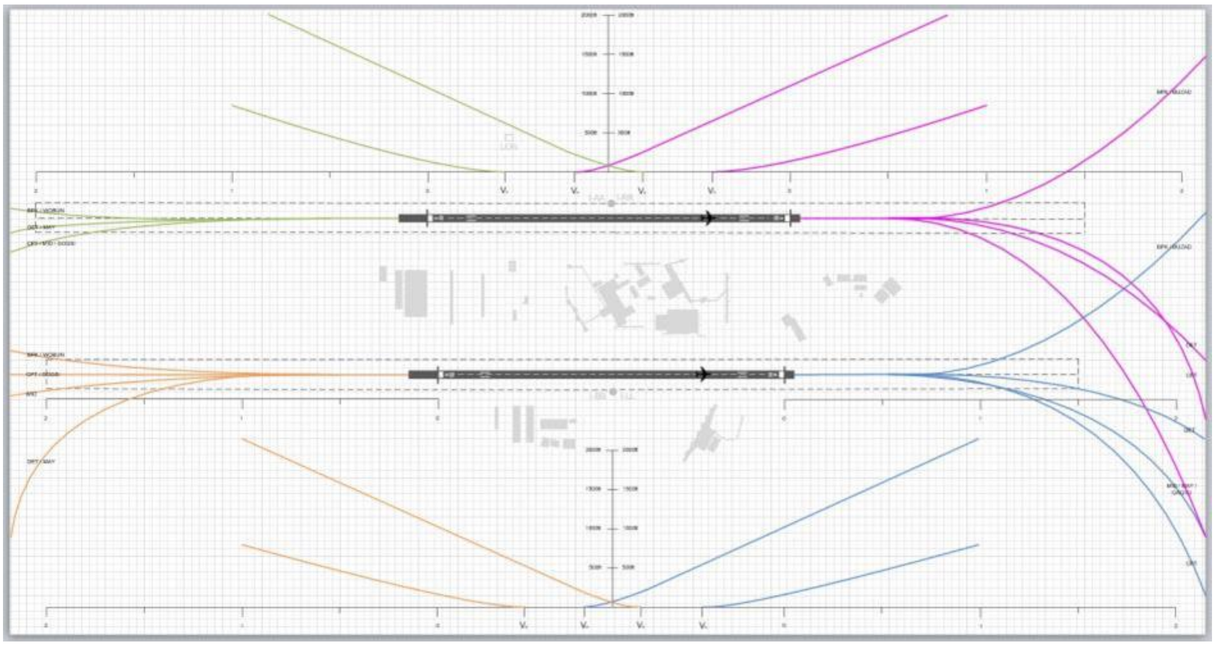


Figure 42: Illustrated Initial Departure Paths and Climb Profiles for Parallel Runway Operations

The A380 and Heavy wake category aircraft types tend to rotate later and climb slower than the Medium and Light wake category aircraft types:

- There is a need to establish whether this behaviour is consistent enough to provide complete mitigation or only partial mitigation of the wake turbulence encounter risk of the follower aircraft through analysis of the vertical difference in climb profiles.

For the WDS-D Crosswind Concept there is a need to understand:

- How much the time separation between the lead and follower aircraft may evolve over the straight-out initial common departure path through analysis of time separation evolution.
- How much the lateral navigational orientation of the lead and follower aircraft may evolve over the straight-out initial common departure path through analysis of lateral navigational deviations.
- The extent of the vertical profile of the straight-out initial common departure path.

Due to the extent of the straight-out initial departure paths being specific to each airport environment and to each runway there is a need to carry out local analysis.

This appendix contains the analysis conducted with 12 months of Heathrow recorded operational data for RWY 27L.

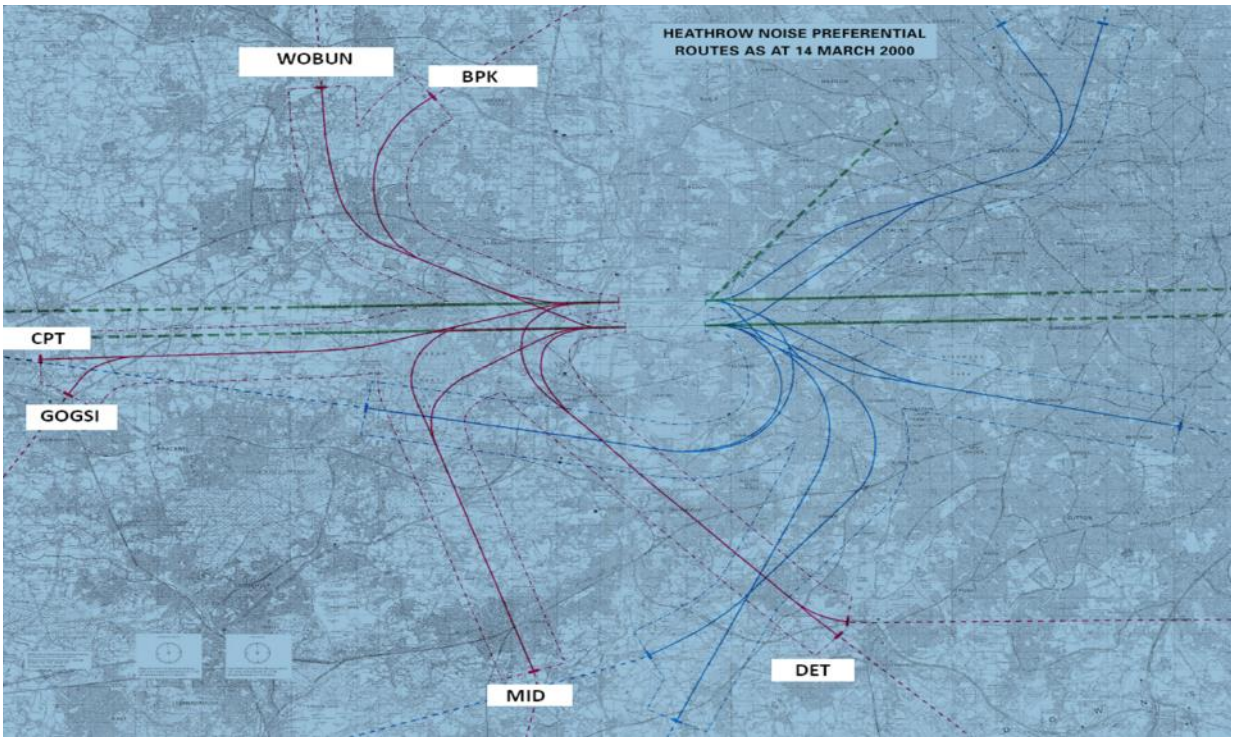


Figure 43: Heathrow Westerly SIDs

When applying a WDS-D crosswind reduced wake separation reduction there is a need to ensure that the follower aircraft SID is upwind of the lead aircraft SID so as to ensure avoidance of the crosswind transported wake vortices generated by the lead aircraft:

- Crosswind from South
  - WOB, BPK followed by DET, MID, GOGSI, CPT
  - GOGSI, CPT followed by DET, MID
- Crosswind from North
  - DET, MID followed by WOB, BPK, GOGSI, CPT
  - GOGSI, CPT followed by WOB, BPK

In the analysis presented in the following sections the charts are split into two general grouping of RECAT-EU wake categories:

- 'Behind Heavy': WC Pairs CAT 'B – D', 'B – E', 'B – F', 'C – D', 'C – E', 'C – F'
- 'Behind Super': WC Pairs CAT 'A – B', 'A – C', 'A – D', 'A – E', A – F'

K.2.1 Analysis of the Vertical Difference in the Climb Profiles at Heathrow for RWY 27L Departure Operations

This is the vertical difference analysis for the WDS-D crosswind concept pairs.

The charts that follow show the difference in altitude between a leader and a follower aircraft, where there is a crosswind of 6 knots or greater, and where the follower SID is upwind of the leader SID.

The results are split between the 'Behind Heavy' and 'Behind Super' categories.

The results are also split further into:

- 'Behind Heavy CAT B leader'
- 'Behind Heavy CAT C leader'
- 'Behind Super with CAT B & C follower'
- 'Behind Super with CAT D, E & F follower'

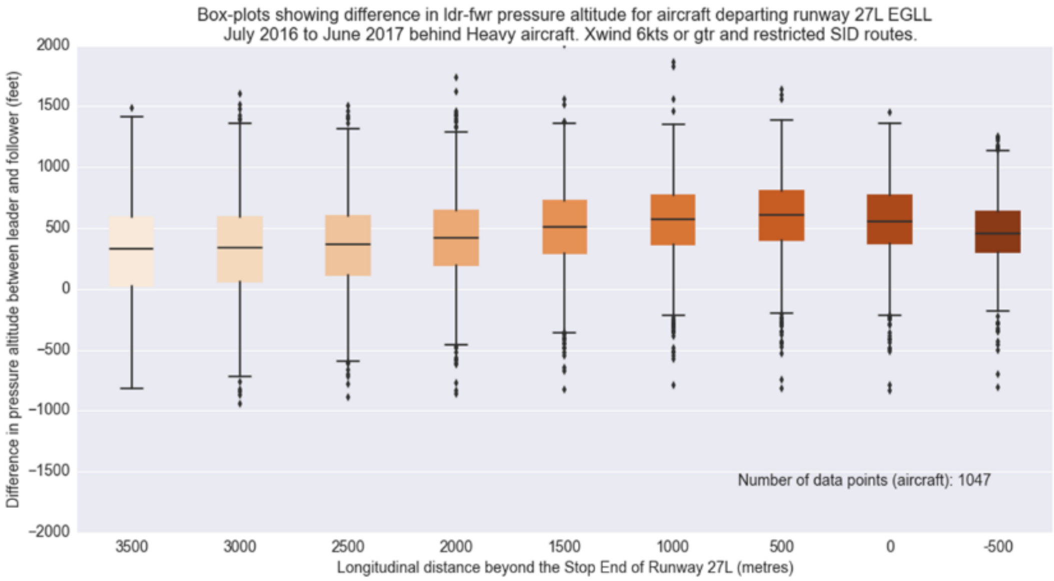


Figure 44: Vertical Difference Analysis for 'Behind Heavy' with CAT D, E & F Followers

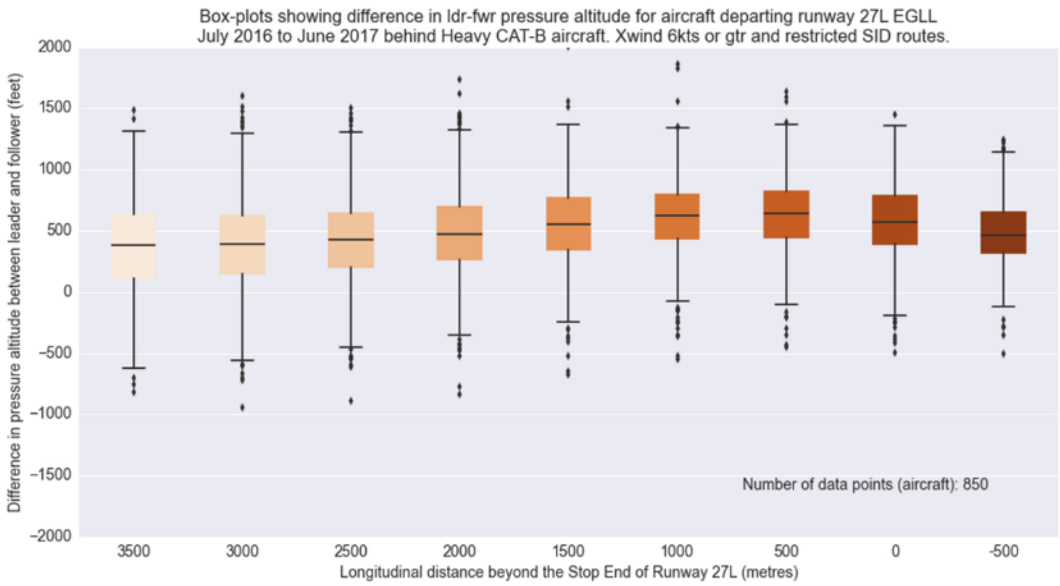


Figure 45: Vertical Difference Analysis for 'Behind CAT B' with CAT D, E & F Followers

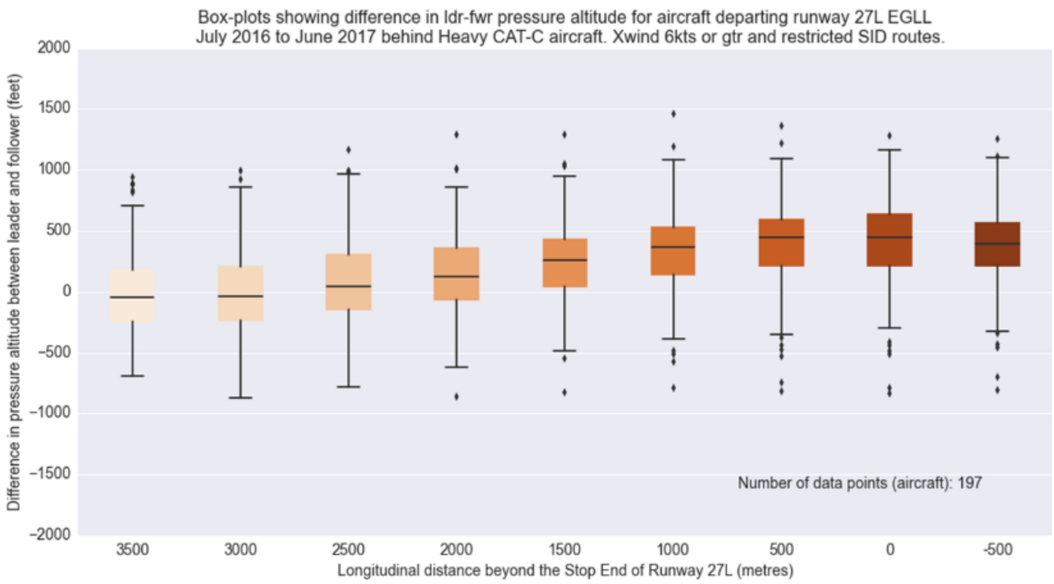


Figure 46: Vertical Difference Analysis for 'Behind CAT C' with CAT D, E & F Followers

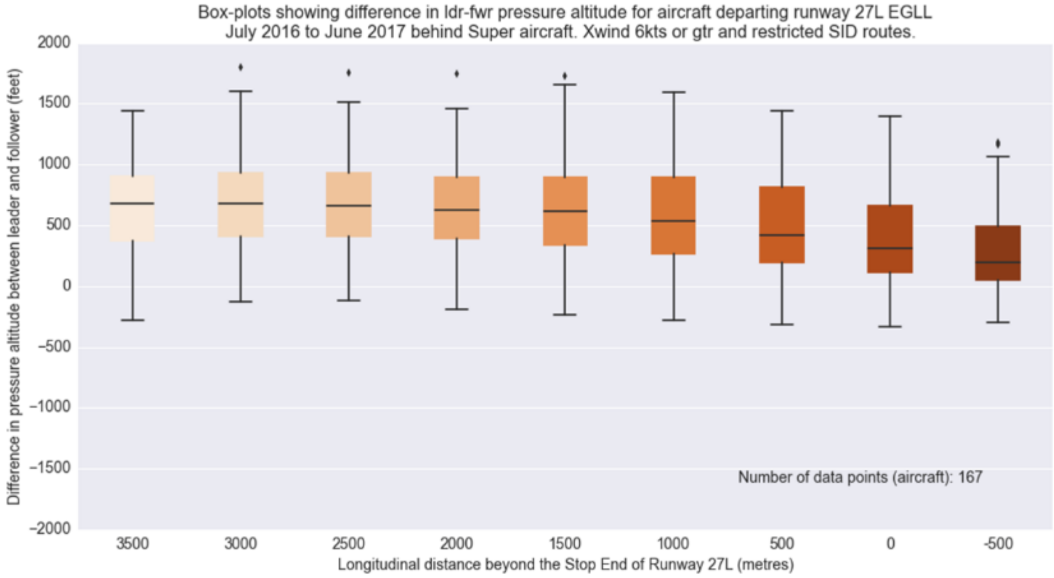


Figure 47: Vertical Difference Analysis for 'Behind Super' with CAT B, C, D, E & F Followers

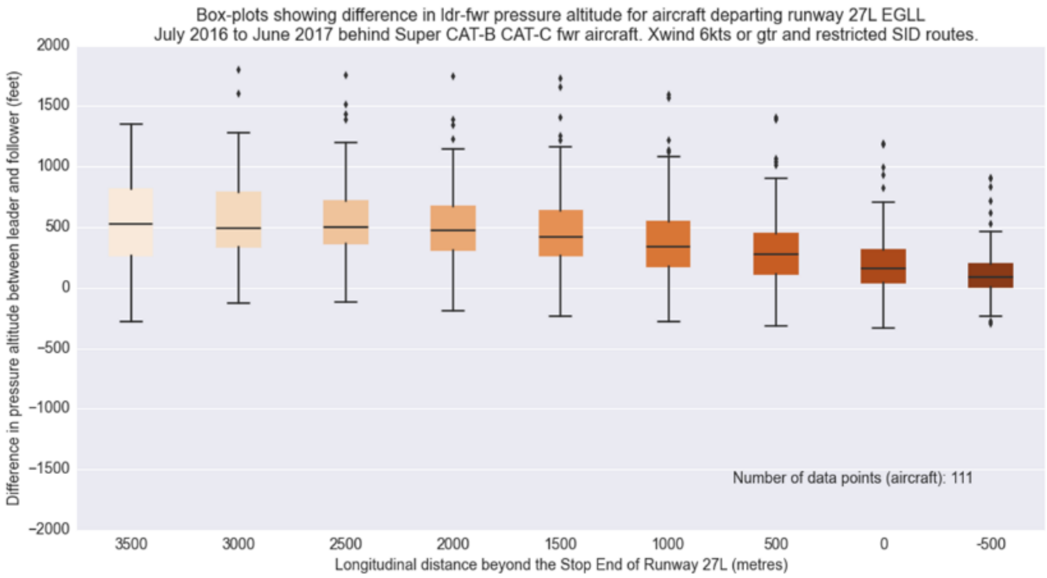


Figure 48: Vertical Difference Analysis for 'Behind Super' with CAT B & C Followers

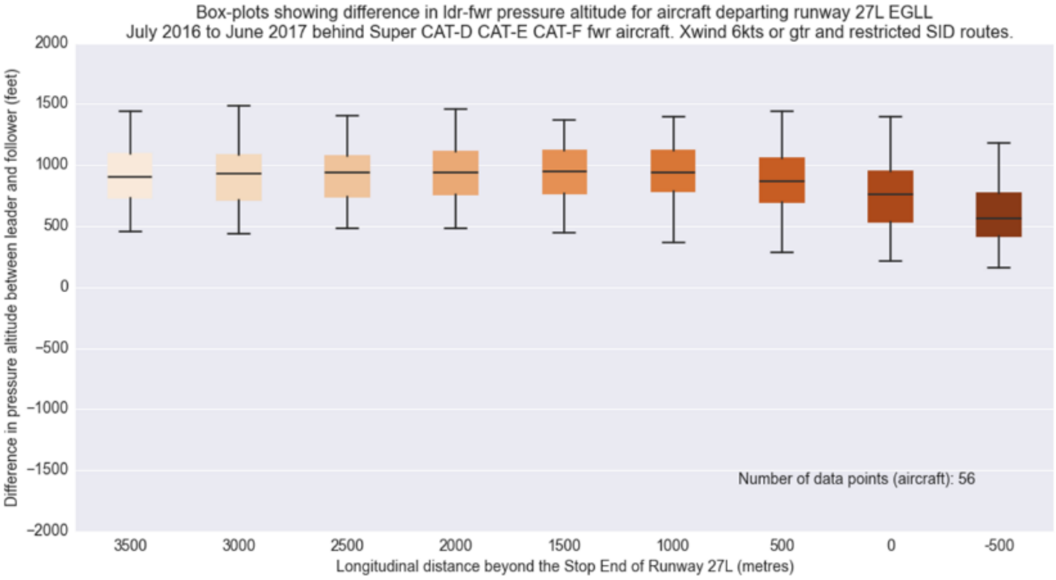


Figure 49: Vertical Difference Analysis for 'Behind Super' with CAT D, E & F Followers

The initial conclusions from the vertical difference analysis is that the A380 and Heavy wake category aircraft types tend to become airborne later and climb slower than the Medium and Light wake category aircraft types. However, there are a significant number of instances where this is not the case, with the follower being at or below the path of the leader climb profile.

It is thus not possible to rely on the differentiated rotation positions and climb profiles to ensure wake avoidance

- The behaviour is not consistent enough for to support the development of the Differentiated Rotation Positions and Climb Profiles for Departures concept
- There is a need to ensure crosswind transport for the WDS-D Crosswind concept over the straight-out initial common departure path
- There is a need to ensure wake decay for the WDS-D Total Wind concept over the straight-out initial common departure path

K.2.2 Analysis of Lateral Deviation at Heathrow for RWY 27L Departure Operations

This is the lateral deviation analysis for the WDS-D crosswind concept pairs.

The charts that follow show the difference in lateral deviation from the centre-line of the straight-out initial common departure path between a leader and a follower aircraft, where there is a crosswind of 6 knots or greater, and where the follower SID is upwind of the leader SID.

When the follower is upwind of the leader:

- When the crosswind is from the south there is a positive lateral deviation from the centre-line
- When the crosswind is from the north there is a negative lateral deviation from the centre-line

The results are split between northerly and southerly crosswinds, and between the 'Behind Heavy' and 'Behind Super' categories. Note outlier behaviour is still retained in these results.

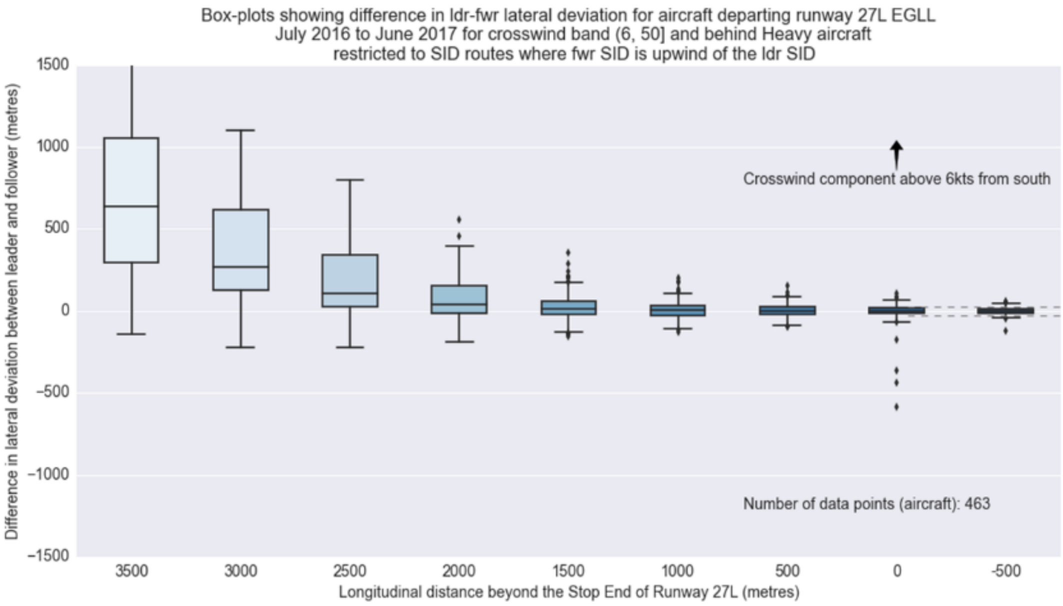


Figure 50: Lateral Deviation Analysis for 'Behind Heavy' with CAT D, E & F Followers

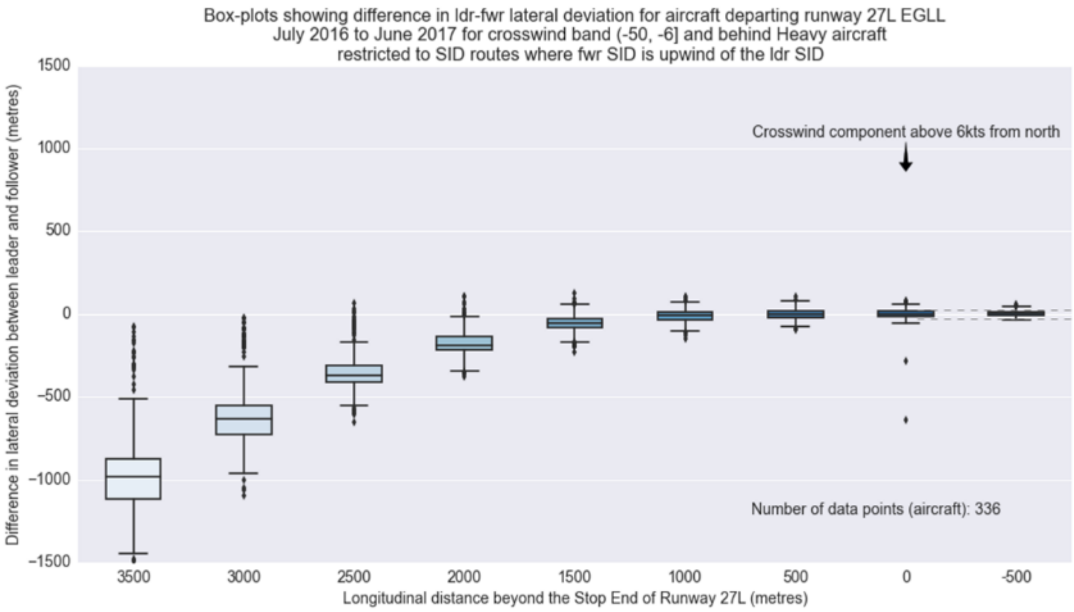


Figure 51: Lateral Deviation Analysis for 'Behind Heavy' with CAT D, E & F Followers

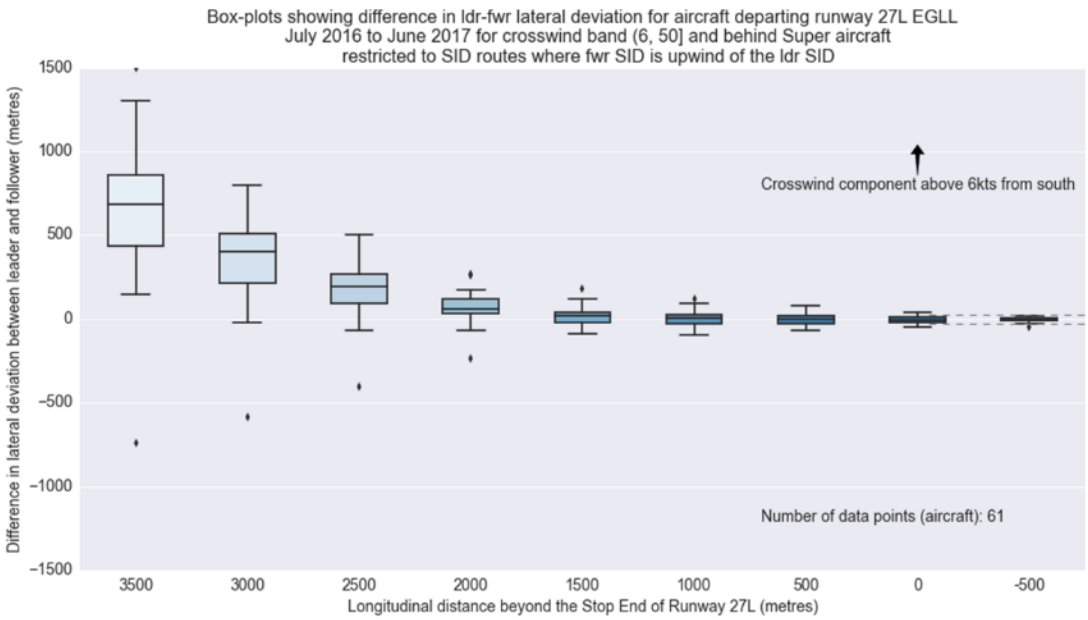


Figure 52: Lateral Deviation Analysis for 'Behind Super' with CAT B, C, D, E & F Followers

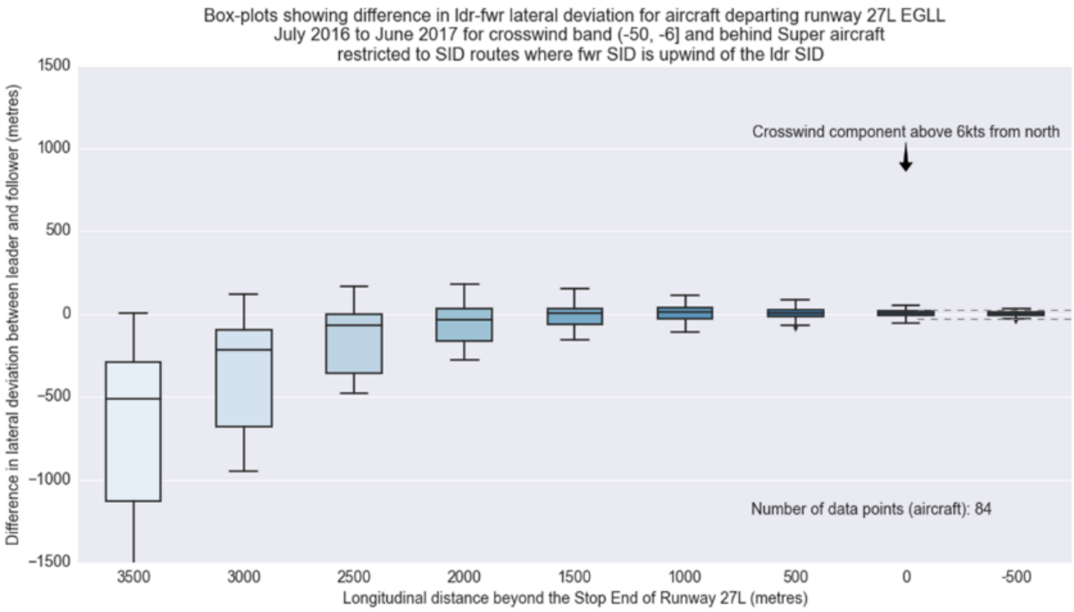


Figure 53: Lateral Deviation Analysis for 'Behind Super' with CAT B, C, D, E & F Followers

Table 116 details the maximum lateral deviation in the 'wrong' direction between the leader and follower at each gate for each of the 4 plots. Note, the last two lines show the max lateral deviation with outliers removed.

Sample	Measurement Gate									"Wrong" Direction
	-500	0	500	1000	1500	2000	2500	3000	3500	
Behind_Heavy_N	61	81	105	107	124	106	69	-20	-73	+ve
Behind_Heavy_S	-125	-586	-98	-130	-157	-191	-223	-226	-141	-ve
Behind_Super_N	35	53	84	113	153	183	169	119	7	+ve
Behind_Super_S	-50	-47	-69	-96	-89	-239	-401	-585	-742	-ve
Behind_Super_S - Outlier Removed	-50	-47	-69	-96	-89	-66	-68	-24	149	-ve
Behind_Heavy_S - Outliers Removed	-51	-68	-98	-130	-157	-191	-223	-226	-141	-ve

Table 116: Maximum Lateral Deviation in metres for each Measurement Gate

The initial conclusions for the lateral deviation analysis is that from a WDS-D crosswind concept perspective there is a need to take into account the extent of the lateral deviation whereby the lead aircraft is upwind of the follower aircraft as this represents the worst case scenario for crosswind transport of the wake vortices out of the path of the follower aircraft:

- The extent of the difference in lateral deviation varies depending on the longitudinal distance from the stop end of the runway along the straight-out initial common departure path, from the follower aircraft becoming airborne until the follower aircraft reaches the fix for the first SID turn.

- The extent of the difference in lateral deviation along the straight-out initial common departure path may impact the crosswind criteria at each altitude band required to ensure the transport of the wake vortices out of the path of the follower aircraft.

K.2.3 Analysis of Time Separation Evolution at Heathrow for RWY 27L Departure Operations

This is the time separation evolution analysis for the WDS-D crosswind concept pairs.

The charts that follow show time separation evolution between a leader and a follower aircraft, where there is a crosswind of 6 knots or greater from the South, and where the follower SID is upwind of the leader SID.

A negative change in the time separation represents a reduction in the time separation with the follower aircraft catching-up, and a positive change in the time separation represents an increase in the time separation with pull-away.

The results are split between the 'Behind Heavy' and 'Behind Super' categories.

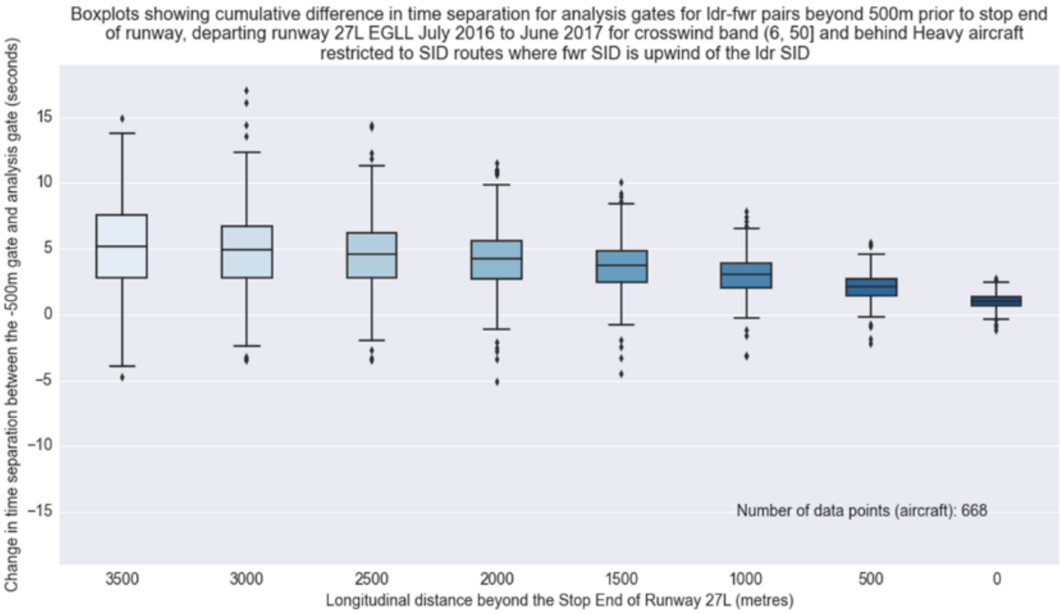


Figure 54: Time Separation Evolution Analysis for 'Behind Heavy' with CAT D, E & F Followers

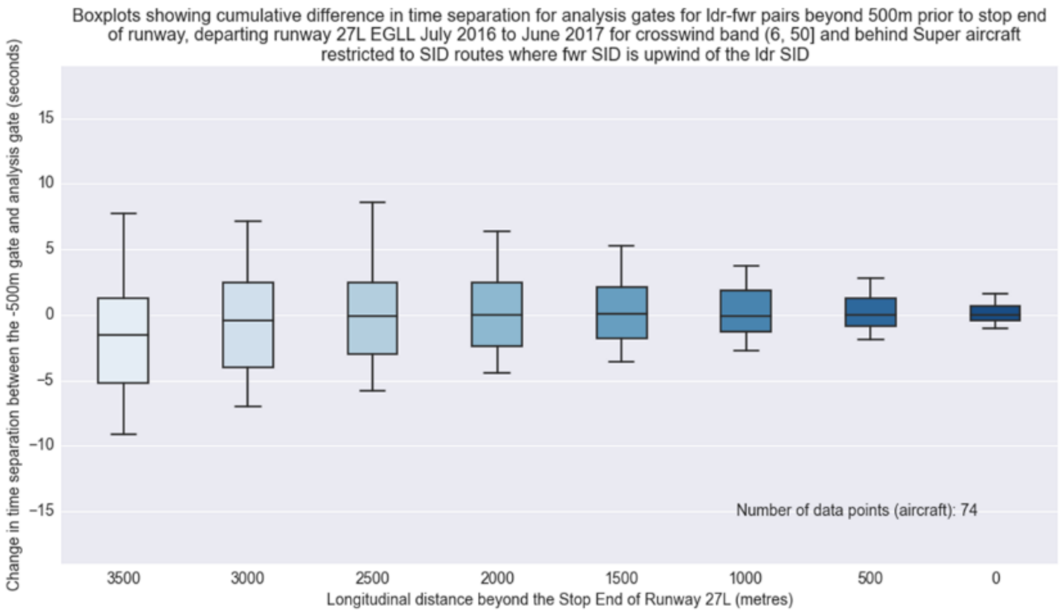


Figure 55: Time Separation Evolution Analysis for 'Behind Super' with CAT B, C, D, E & F Followers

The initial conclusions from the time separation evolution analysis over the straight-out initial common departure path to the first SID turn for Heathrow RWY 27L is that:

- For 'Behind Heavy' the time separation evolution to follower CAT D, E and F aircraft
    - Predominately experience pull-away of up to around 15s
    - A small number of pairs experience catch-up of up to around 5s
- For 'Behind Super' the time separation evolution to follower CAT B, C, D, E and F aircraft
    - Experience catch-up of up to around 9s
        - Up to 5s at 2000m from stop end of the runway
    - Experience pull-away of up to around 8s

There is a need to take this time separation evolution into account with the WDS-D crosswind concept in order to ensure that when there is catch-up that there is still sufficient time separation to transport the wake vortices out of the path of the follower aircraft.

K.2.4 Analysis of True Height Profiles at Heathrow for RWY 27L Departure Operations

This is the true height profile analysis for the WDS-D crosswind concept pairs.

The charts that follow show the true height above the runway for leader aircraft, where there is a crosswind of 6 knots or greater, and where the follower SID is upwind of the leader SID.

True height has been derived from the downlinked pressure altitude and is subject to the limits in accuracy of the downlinked pressure altitude and the true height derivation algorithm.

Note that the analysis is for true height above the runway so 'above ground' equates to 'above runway' in the charts.

The results are split between northerly and southerly crosswinds, and between the 'Behind Heavy' and 'Behind Super' categories.

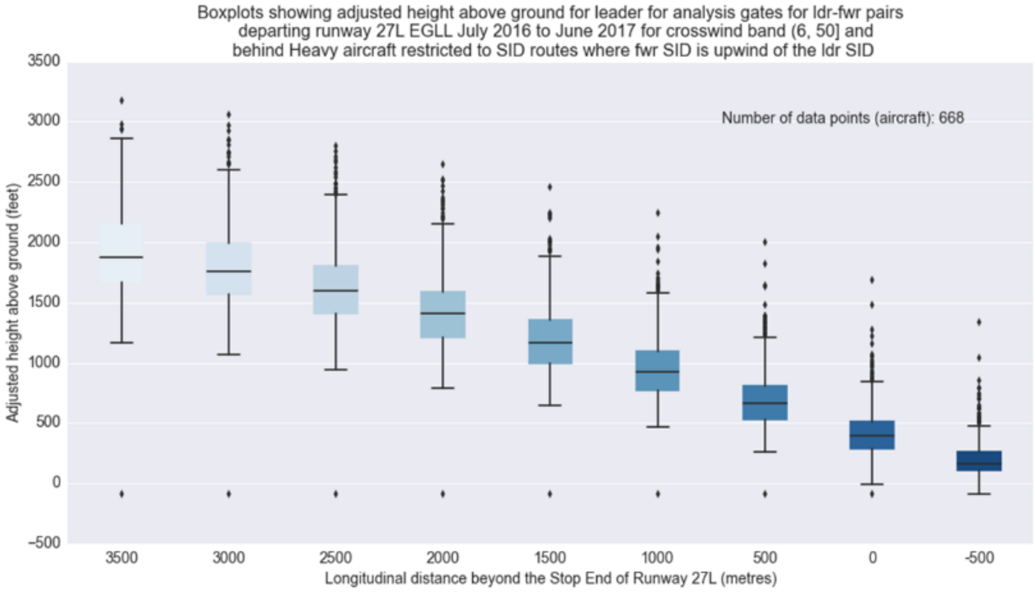


Figure 56: True Height Profile Analysis for 'Behind Heavy' with CAT D, E & F Followers for Crosswind Conditions from the South

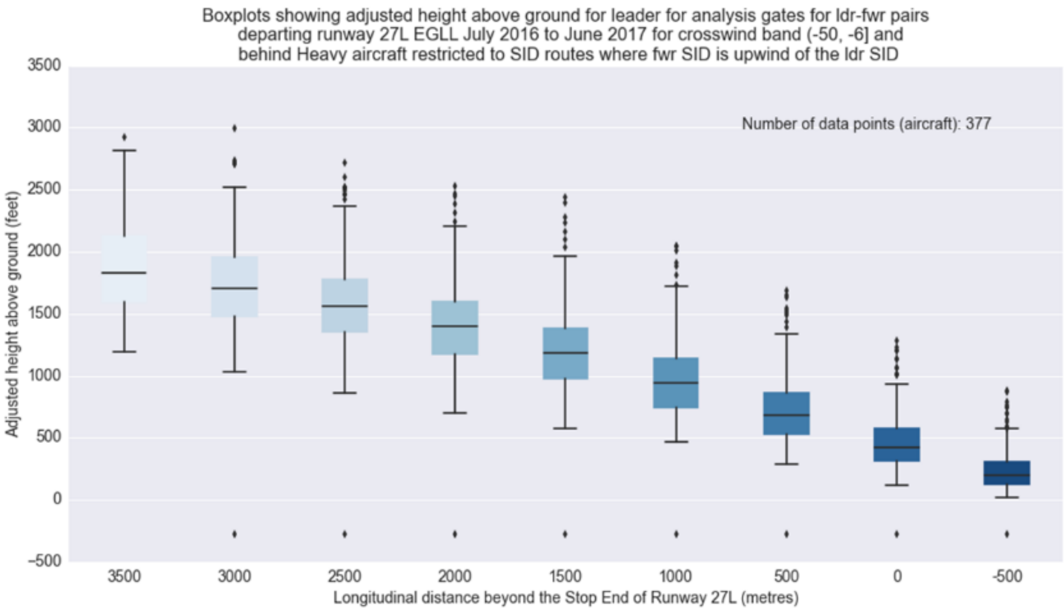


Figure 57: True Height Profile Analysis for 'Behind Heavy' for CAT D, E & F Followers for Crosswind Conditions from the North

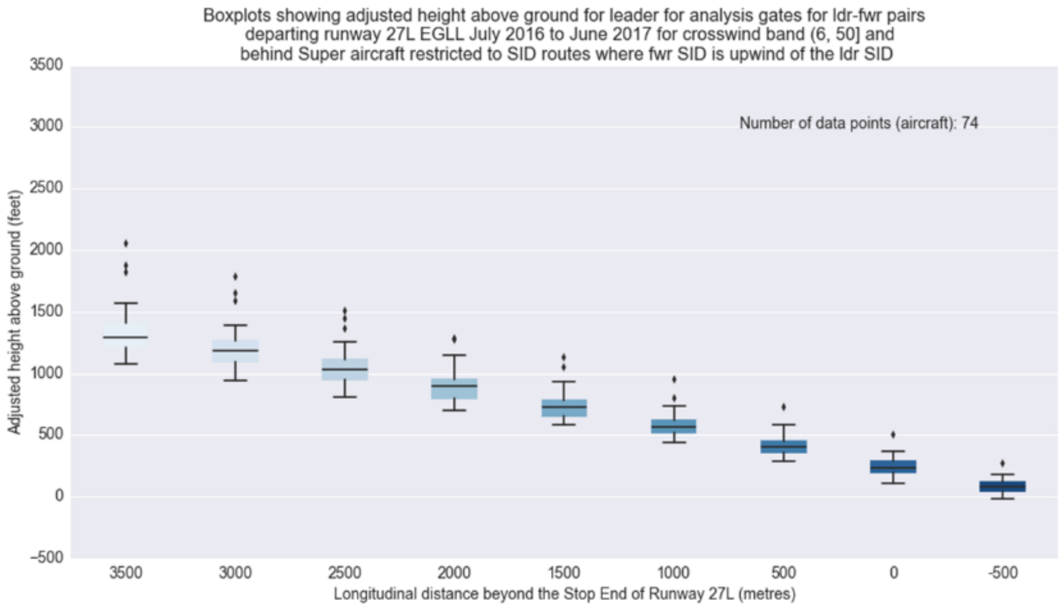


Figure 58: True Height Profile Analysis for 'Behind Super' with CAT B, C, D, E & F Followers for Crosswind Conditions from the South

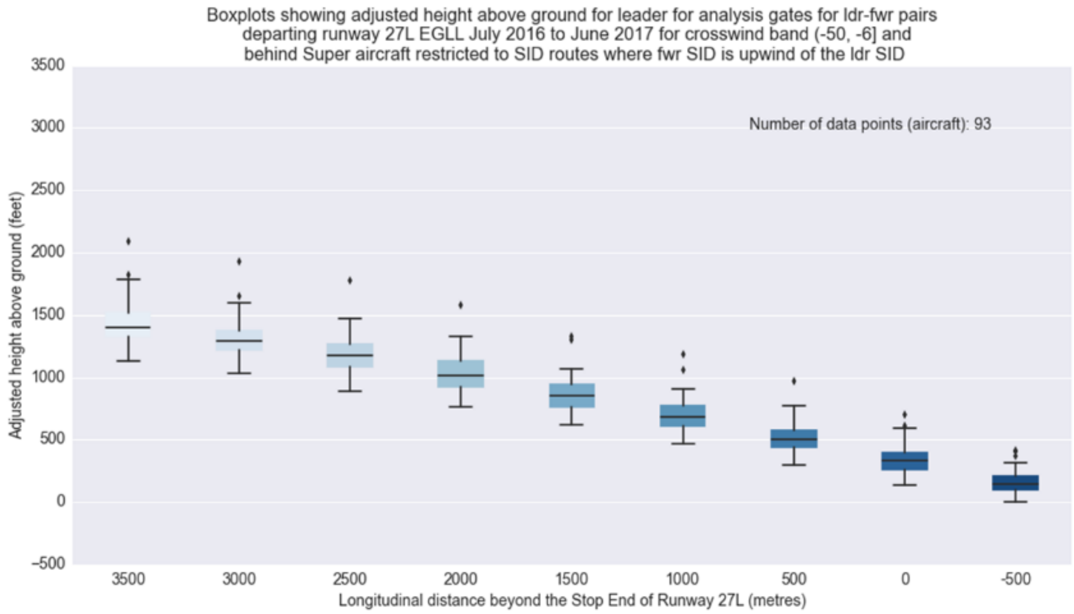


Figure 59: True Height Profile Analysis for 'Behind Super' with CAT B, C, D, E & F Followers for Crosswind Conditions from the North

The initial conclusions from the true height profile analysis is that there is a need to provide for crosswind profiles aloft for Heathrow RWY 27L operations:

- To up to 1,300ft at the stop end of the runway
- To up to 2,000ft at 1,000m from the stop end of the runway

- To up to 2,500ft at 2,000m from the stop end of the runway
- To up to 3,000ft at the SID turn fix at 3,500m from the stop end of the runway

K.3 Heathrow Wind Conditions Behaviour Analysis

For the WDS-D Crosswind Concept there is a need to understand the following aspects of the wind conditions behaviour over the straight-out initial common departure path:

- If the crosswind criteria are satisfied by the runway surface wind conditions, are they also satisfied by the wind conditions aloft across the straight-out initial common departure path?
- What is the probability that the crosswind conditions can change below the crosswind criteria between committing to a WDS-D reduced wake separation and the follower aircraft turning on to a wake independent path after the fix for the first SID turn?
- How stable will the WDS-D GO/NOGO status be depending on the difference in crosswind criteria used between the NOGO to GO transition and the GO to NOGO transition?
- How prevalent are the crosswind conditions at the runway surface and over the straight-out initial departure path?

K.3.1 Wind Conditions Criteria: Is Surface Wind Alone Sufficient?

There is a need to assess whether surface wind alone is sufficient for determining when WDS-D crosswind reduced wake separations can be applied.

Winds aloft profiles on final approach have been used in this analysis. These are from recorded final approach wind profiles from the TBS ORD Tool on the basis that these profiles would be representative of the wind profiles over the straight-out initial departure path. The runway surface wind conditions are from the recorded wind profiles from the anemometers at the end of each runway at Heathrow.

Due to some anomalies in the stability of the wind profiles for some of the wind bands aloft the analysis results are presented including and excluding the unstable wind aloft periods.

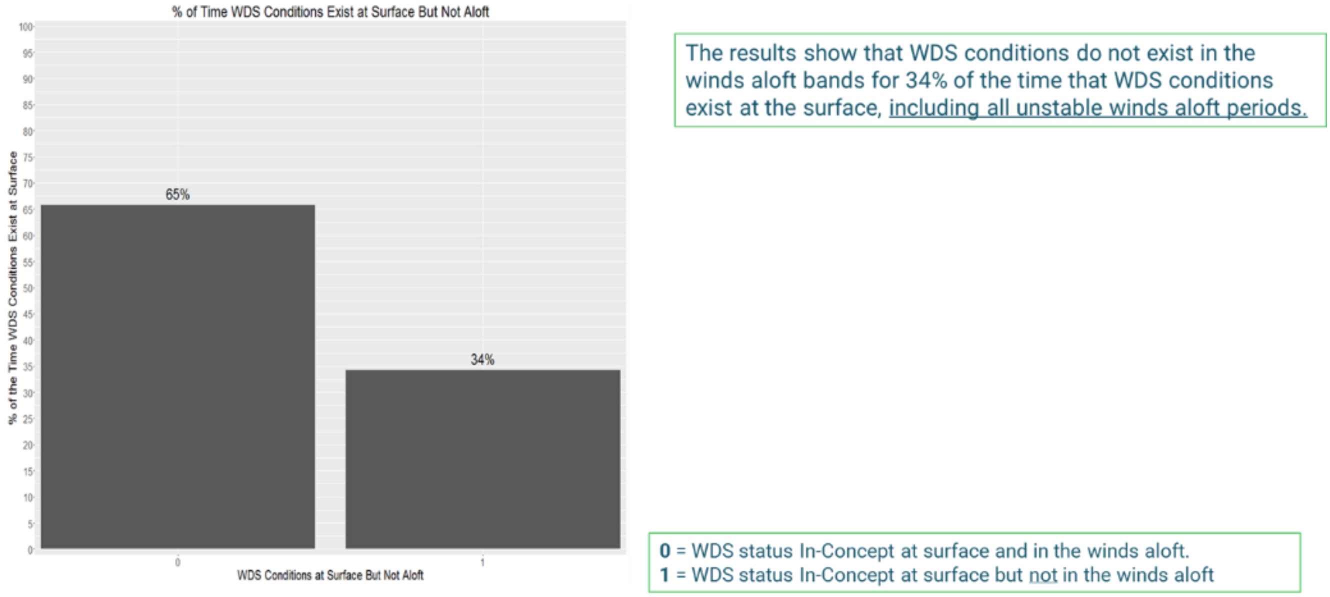


Figure 60: Percentage of Time WDS Conditions Exist at the Runway Surface but not Aloft Including Unstable Wind Aloft Periods

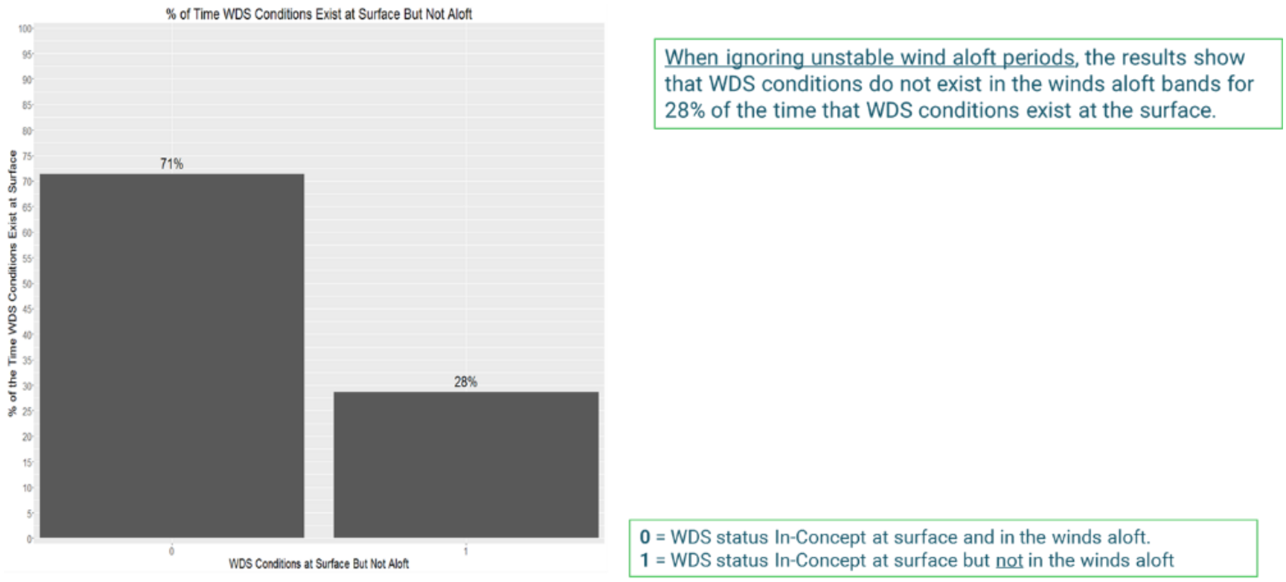


Figure 61: Percentage of Time WDS Conditions Exist at the Runway Surface but not Aloft Excluding Unstable Wind Aloft Periods

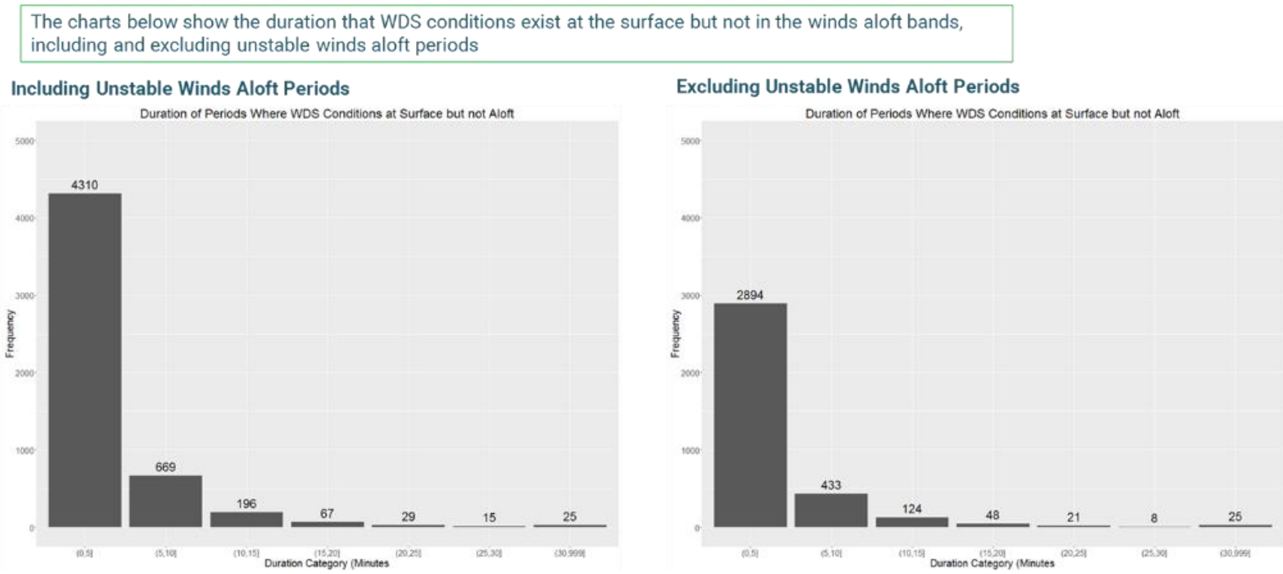


Figure 62: Duration of Periods Where WDS Conditions Exist at the Runway Surface but not Aloft

The initial conclusion from the analysis is that surface wind alone is not sufficient for determining when the WDS-D crosswind conditions criteria are satisfied.

K.3.2 Risk that the Crosswind Conditions Can Change Below the Crosswind Criteria

There is a need to assess and mitigate the risk of the crosswind conditions changing below the crosswind criteria between committing to a WDS-D reduced wake separation and the follower aircraft turning on to a wake independent path after the fix for the first SID turn. A drop in the crosswind conditions could result in the wake turbulence not being crosswind transported out of the path of the follower aircraft.

The WDS-D reduced wake separation is committed to as the preceding departure aircraft commences their take-off roll. The time for the follower aircraft to turn on to their wake independent path after the first SID turn is around 2 minutes to 4 minutes later made up of:

- The WDS-D reduced wake separation of 90s (or 60s if it is acceptable to revert to the standard wake separation provided there is at least 60s of the countdown time remaining).
- The flying time from becoming airborne until turning on to their wake independent path. For Heathrow RWY 27L the is over approximately up to a 2NM flying distance so from around 50s to over 60s dependent on the wind conditions impact on the ground speed of the aircraft
- The difference between the standard wake separation and the WDS-D reduced wake separation so as to ensure crosswind transport protection when additional spacing is delivered above the WDS-D reduced wake separation. Worst case being when an A388 – Light pair where RECAT-EU is 180s.

The probability of a reduction in the crosswind over 5 minutes was analysed. Further analysis can be conducted over 4 minutes, 3 minutes and 2 minutes.

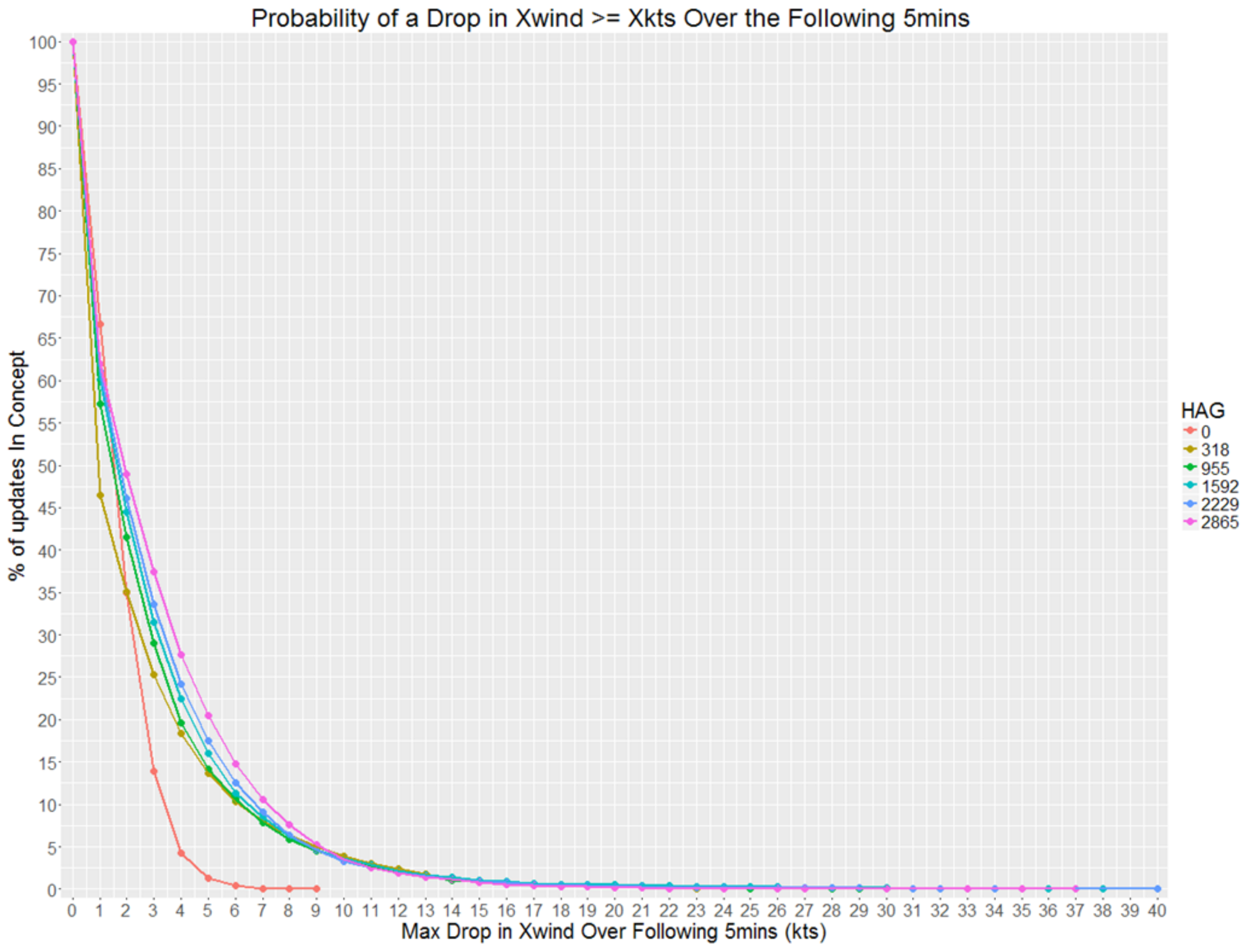


Figure 63: Probability of a Drop in Crosswind Over the Following 5 Minutes

The initial conclusion from the analysis is that there is a need to protect against wind drop of at least 1 to 2 knots and possibly up to 4 knots at the runway surface. Further analysis of the wind drop over 4 minutes, 3 minutes and 2 minutes is required to assess how necessary it is to protect against the larger wind drops at the runway surface, and also the larger wind drops aloft.

K.3.3 Stability of the WDS-D GO/NO GO Status

There is a need to assess the stability of the WDS-D GO/NO GO status and the associated acceptability to the Tower Supervisor and Controllers.

The stability will be dependent on the criteria used for the GO to NOGO and NOGO to GO transitions and the amount of difference between the crosswind transition criteria. Several criteria have been assessed:

- Increasing to 8 knots for NO GO to GO transition; dropping to below 7 knots for GO to NO GO transition
- Increasing to 9 knots for NO GO to GO transition; dropping to below 6 knots for GO to NO GO transition
- Increasing to 10 knots for NO GO to GO transition; dropping to below 8 knots for GO to NO GO transition

Twelve months of runway surface anemometer data and wind conditions aloft data was used to count the number of WDS-D status changes (NO GO to GO as x-knots “in”; GO to NO GO as x-knots “out”) within each 10 minutes period. The analysis was conducted for both all wind layers (“all”) and for just surface wind (“sfc”).

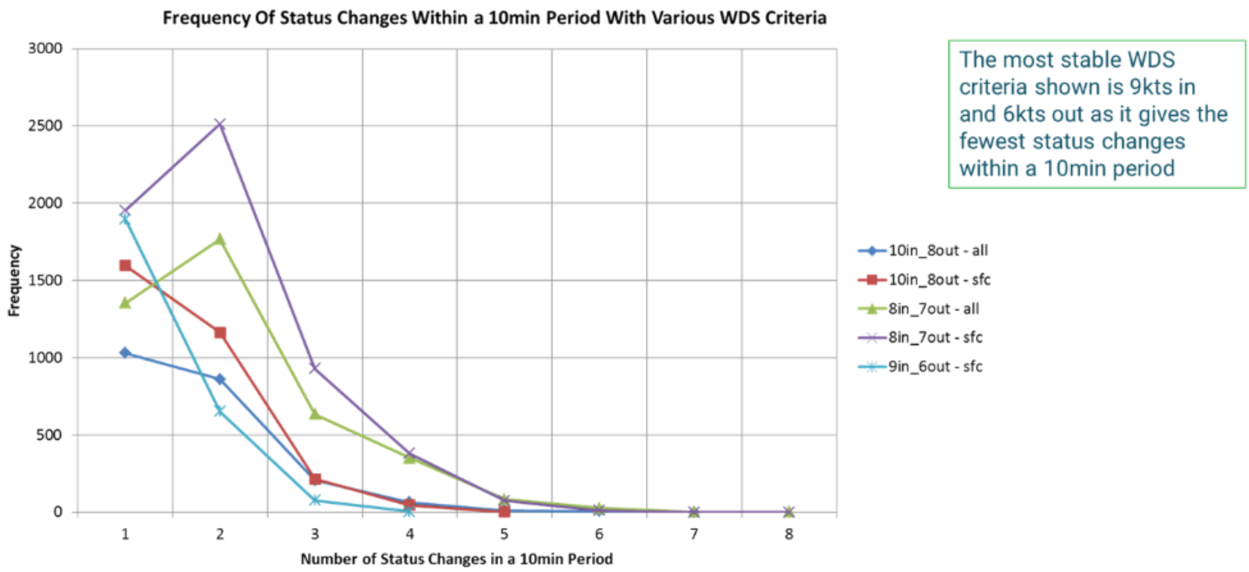


Figure 64: Frequency of Supervisor NOGO/GO Change Within a 10 Minute Period

K.3.4 Prevalence of Crosswind Conditions

There is a need to assess the prevalence of the crosswind conditions at the runway surface and over the straight-out initial departure path.

Initial analysis was conducted using recorded Heathrow runway anemometer data of the 2 minutes average wind speed and wind direction fields over the period of January to December 2016.

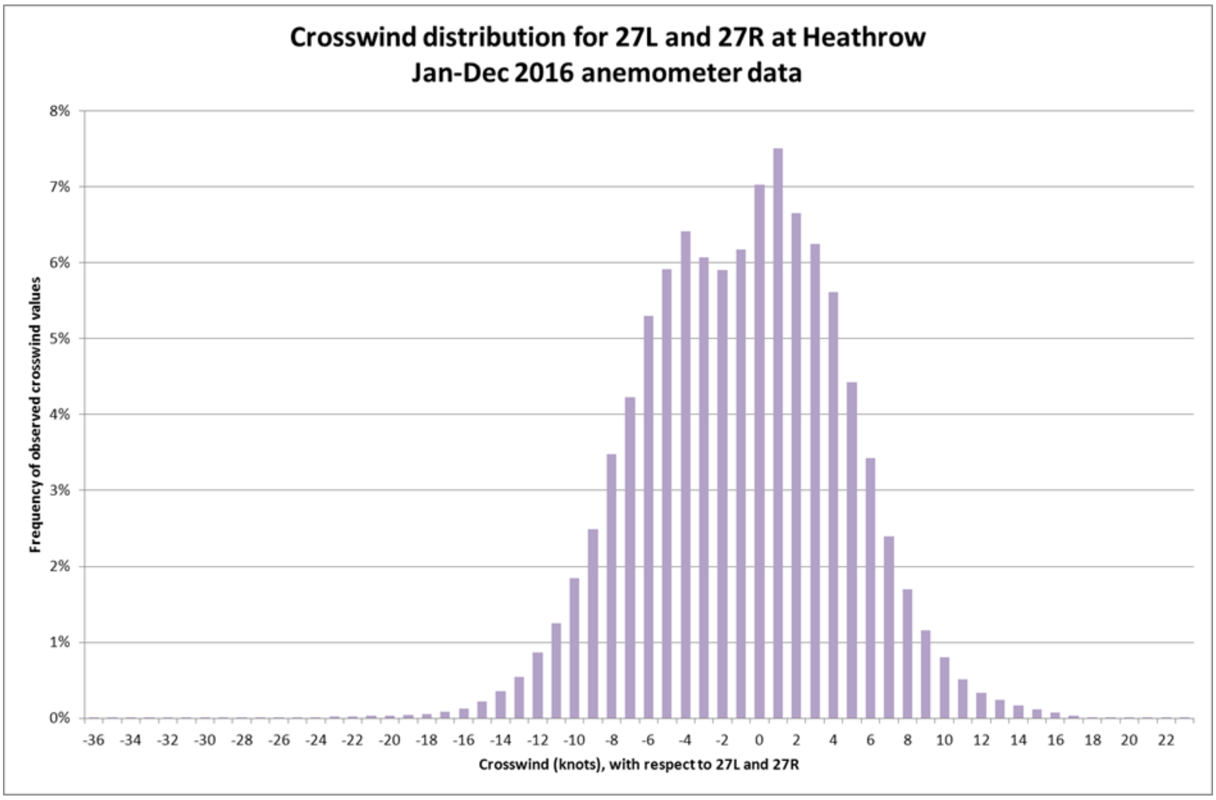


Figure 65: Crosswind Distribution for RWYs 27L & 27R at Heathrow, January to December 2016

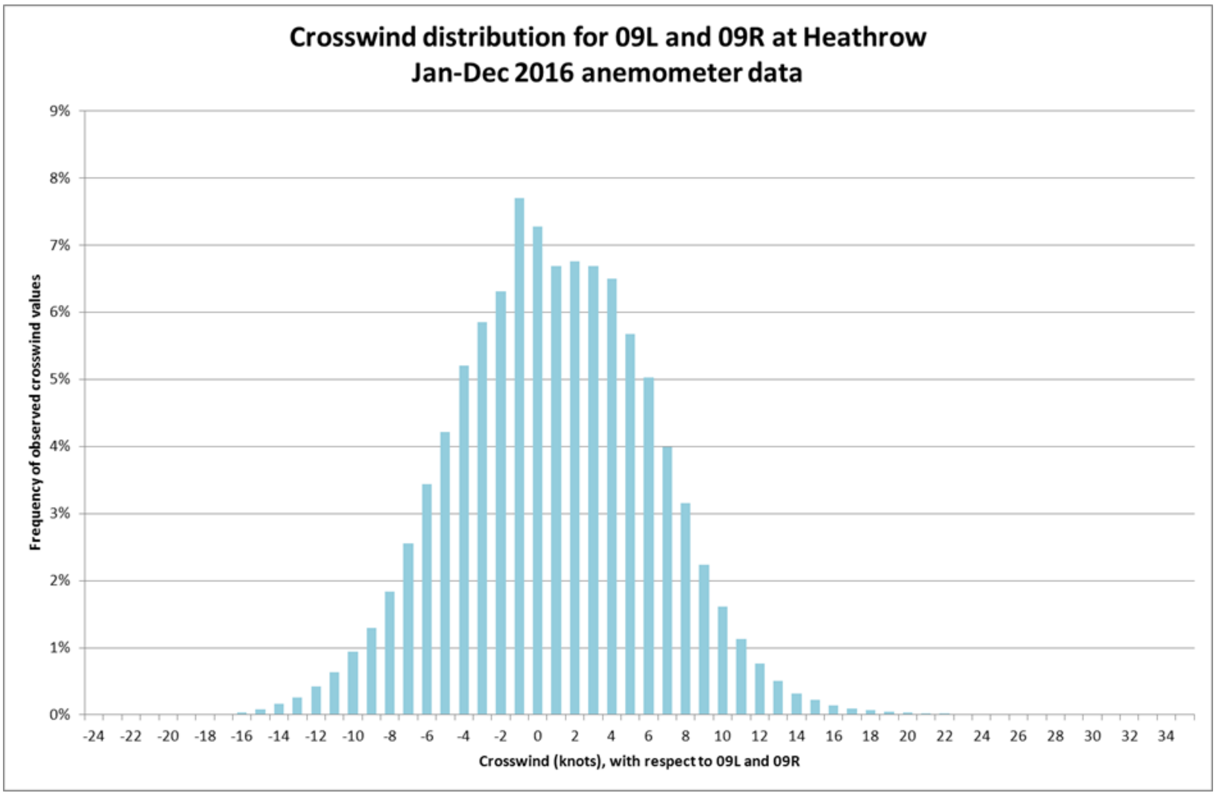


Figure 66: Crosswind Distributions for RWYs 09R & 09L at Heathrow, January to December 2016

Based on the crosswind values observed in the 2016 data, it can be established how often a crosswind of various strengths is observed, by employing a minimum threshold.

Crosswind minimum threshold - 27L and 27R	Proportion of time when crosswind meets the minimum threshold criteria
1 knot	93%
2 knots	79%
3 knots	67%
4 knots	54%
5 knots	42%
6 knots	32%
7 knots	23%
8 knots	17%
9 knots	12%
10 knots	8%
11 knots	5%
12 knots	3%
13 knots	2%
14 knots	1%
15 knots	1%

Table 117: Proportion of Time When the Crosswind Meets the Minimum Threshold Criteria for RWYs 27L & 27R at Heathrow

Crosswind minimum threshold - 09L and 09R	Proportion of time when crosswind meets the minimum threshold criteria
1 knot	93%
2 knots	78%
3 knots	65%
4 knots	53%
5 knots	41%
6 knots	31%
7 knots	23%
8 knots	16%
9 knots	11%
10 knots	8%
11 knots	5%
12 knots	3%
13 knots	2%
14 knots	1%
15 knots	1%

Table 118: Proportion of Time When the Crosswind Meets the Minimum Threshold Criteria for RWYs 09R & 09L at Heathrow

Please note that the analysis is currently based on the whole dataset, meaning that observed values have been taken for each 24 hours (night and day), for every day in the year. The analysis needs to be repeated for busy operational hours only.

K.4 WDS-D Crosswind Concept Rules

There is a need to establish the WDS-D crosswind concept rules such that the wake vortices generated by the lead aircraft are transported out of the path of the follower aircraft taking into account:

- There are a significant number of follower aircraft where the vertical difference in climb profile are at or below that of the lead aircraft
- There is some time separation evolution with some catch-up along the straight-out initial common departure path to the first SID turn
    - Of up to 5s behind Heavy (CAT B, C) lead aircraft
    - Of up to 5s at 2000m from the stop end of the runway behind Super lead aircraft; up to 9s by the first SID turn
- The extent of the lateral deviation along the straight-out initial departure path such the lead aircraft is upwind of the follower aircraft, and how this varies depending on the longitudinal distance from the stop end of the runway
- The headwind component transport of the wake vortices towards the follower aircraft
- Consideration of under-separation delivery provision

A simple model of crosswind transport was developed to take the above into account.

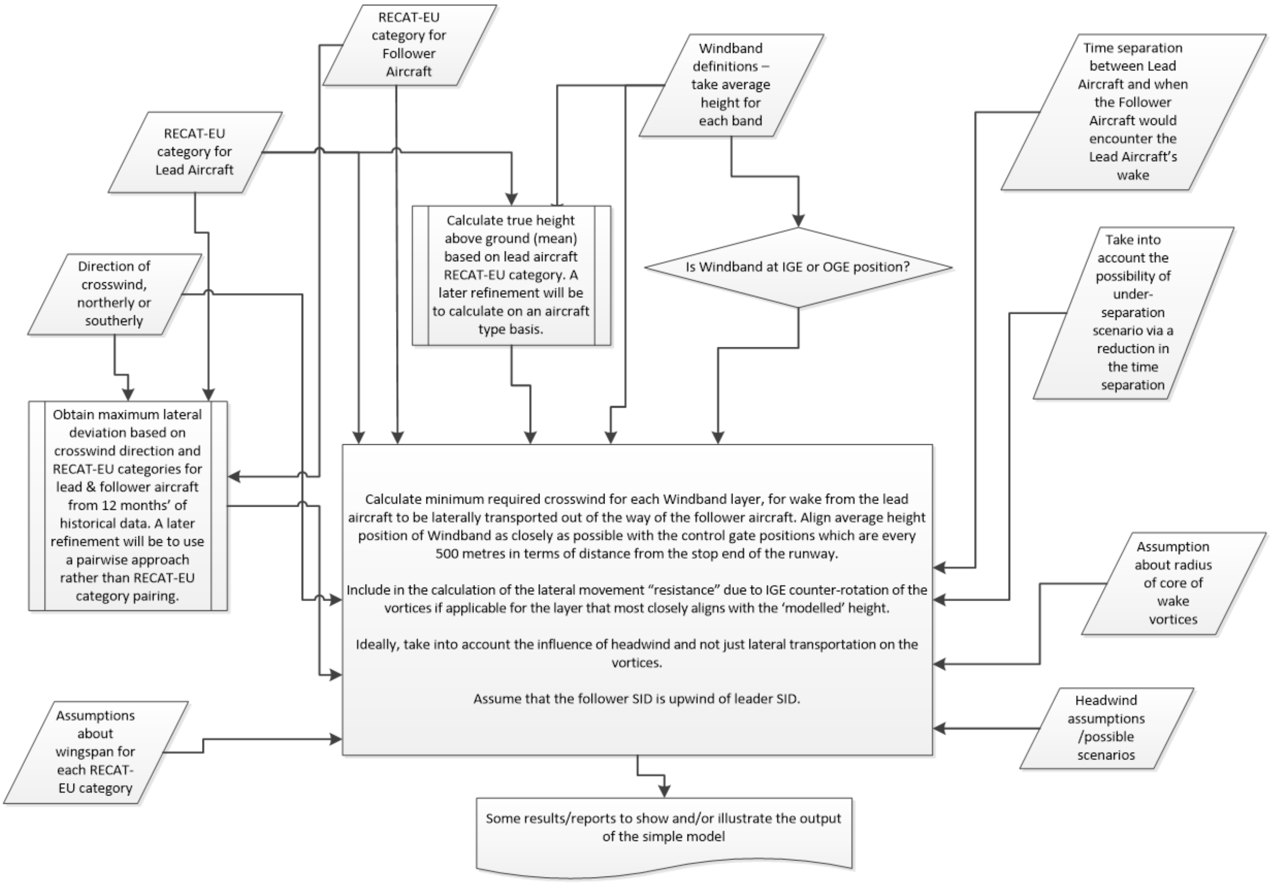


Figure 67: Simple Model of Crosswind Transport

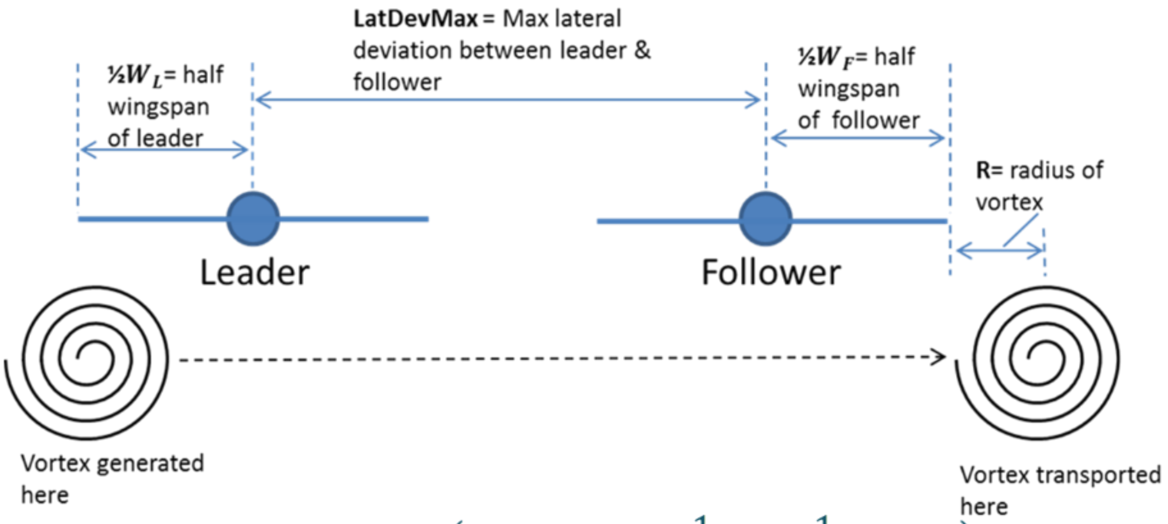
The 'worst case' lateral deviation is assumed from the analysis based on the 12 months of data for 27L.

At the surface and for the first winds aloft layer an additional 3 knots has been added to take into account the counter transport effect of the upwind wake vortex due to the in-ground-effect interaction of the rotating wake vortex with the ground.

Basic assumptions have been made on the maximum wing span in each wake category.

The model was run using two different assumptions about the size of the vortex radius to be avoided; 5m and half the wing span. The results for 5m are presented in more detail, and summary results are shown for both. The minimum crosswind speed results are referred to as min_speed1 and min_speed2 respectively.

$$\text{minimum lateral distance} = \text{LatDevMax} + \frac{1}{2}W_L + \frac{1}{2}W_F + R$$



$$\text{mincrosswind} = \frac{\left(\text{LatDevMax} + \frac{1}{2}W_L + \frac{1}{2}W_F + R\right)}{\text{time}_{sep}}$$

Figure 68: Model of Minimum Lateral Transportation Distance and Minimum Crosswind

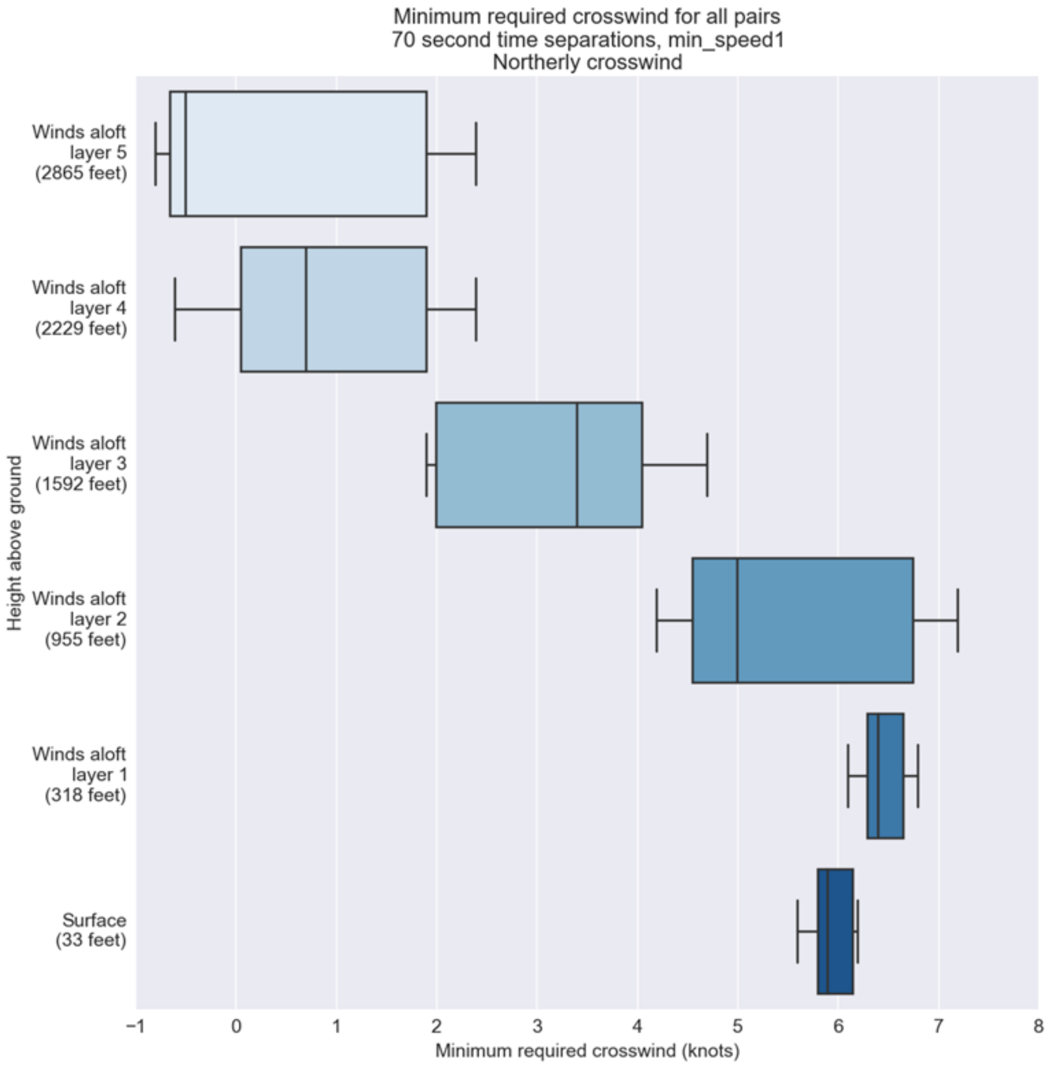


Figure 69: Initial Results from the Simple Model of Crosswind Transport for 70s Time Separation for Northerly Crosswind

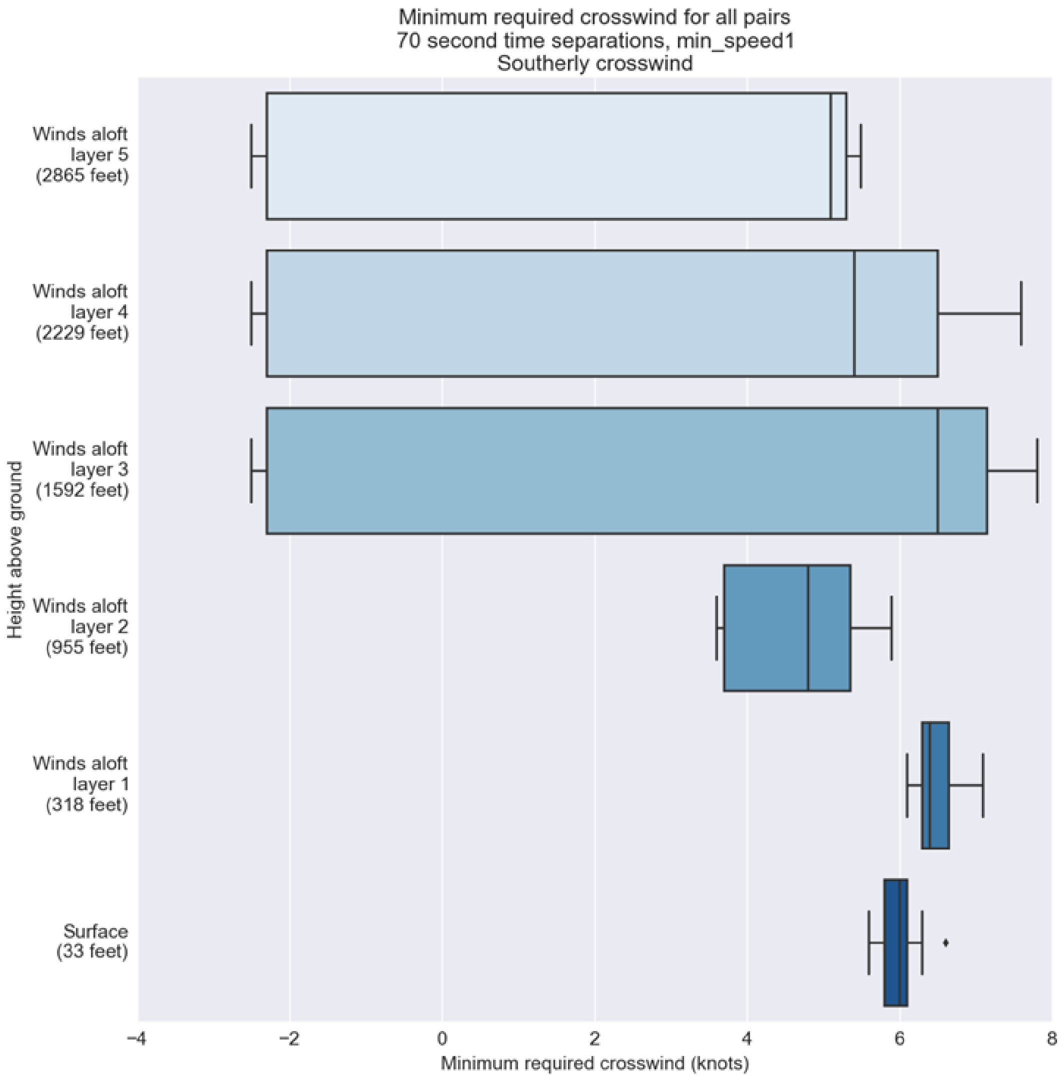


Figure 70: Initial Results from the Simple Model of Crosswind Transport for 70s Time Separation for Southerly Crosswind

From the initial results above the largest value of minimum required crosswind speed across all scenarios for a 70s transport time for the runway surface and each wind layer aloft have been established.

	Maximum of the min_speed1 values by windband (knots)	Maximum of the min_speed2 values by windband (knots)
Surface	6.6	7.5
Winds aloft 1	7.1	8.1
Winds aloft 2	7.2	8.2
Winds aloft 3	7.8	8.6
Winds aloft 4	7.6	8.1
Winds aloft 5	5.5	6.2

Table 119: Initial Summary Results for Minimum Crosswind Speed for 70s Wind Transport

Analysis has also been conducted to establish the largest value of minimum required crosswind speed for a 90s transport time for the runway surface and each wind layer aloft.

	Maximum of the min_speed1 values by windband (knots)	Maximum of the min_speed2 values by windband (knots)
Surface	5.8	6.5
Winds aloft 1	6.2	6.9
Winds aloft 2	5.6	6.4
Winds aloft 3	6.1	6.7
Winds aloft 4	5.9	6.3
Winds aloft 5	4.3	4.9

Table 120: Initial Summary Results for Minimum Crosswind Speed for 90s Wind Transport

For a WDS-D reduced wake separation of 90s there is a need to factor in the time separation evolution, headwind transport and the provision for under separation delivery when considering the amount of time for wake transport

- These may reduce the time separation for wake transport towards 70s

For a 70s time separation for wake transport, depending on the core size of the wake vortices (5m or ½ wing span modelled) the minimum time for wake transport appears to be 7 knots or 8 knots at the runway surface and 8 knots or 9 knots aloft.

When allowing for the provision for the wind conditions changing of 2 knots this results in a GO to NOGO transition of 9 knots or 10 knots at the runway surface and 10 knots or 11 knots aloft.

When allowing for provision for some instability of the wind conditions to provide for a stable NOGO to GO transition of either 2 knots or 3 knots this results in a NOGO to GO transition of 11/12 knots or 12/13 knots at the runway surface and 12/13 knots or 13/14 knots aloft.

Crosswind conditions above 10 knots only occurred 8% of the time and above 12 knots only occurred 3% of the time at the runway surface at Heathrow during 2016. There is a need to reduce the crosswind criteria towards 7 knots for the proportion of the time to increase to above 20%. This will mean assessing the necessity for outlier behaviour to be mitigated by the crosswind transport.

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