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SESAR Solution 02.08 SPR-INTEROP/OSED for V3 - Part II - Safety Assessment Report

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EARTH

PJ.02.08 - TRAFFIC OPTIMISATION ON SINGLE AND MULTIPLE RUNWAY AIRPORTS

This SPR/INTEROP-OSED Safety Assessment Report is part of a project that 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 Project PJ02-Solution 08 (EARTH) by the project members during the V3 validation exercises.

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

The report presents the assurance that the Safety Requirements for the V3 phases are sufficient to reach the Safety Objectives (SO) and related Safety Criteria (SAC).

This document is used as the basis for assessing and establishing operational, safety, performance and interoperability requirements to deliver the following Operational Improvements:

Concept 1: Optimised integration of arrival and departure traffic flows with the use of a trajectory based Integrated Runway Sequence. TS-0301 "Integrated Arrival Departure Management for full traffic optimisation on the runway";

Concept 2: Optimised use of RWY capacity for multiple runway airports with the combined use of an Integrated Runway Sequence and RMAN. TS-0313 "Optimized use of runway capacity for multiple runway airports";

Concept 3: The Minimum Radar Separation (MRS) is reduced for low runway occupancy time medium aircraft. The analysis of historical ground radar data allows for characterization of ROT per aircraft type and per runway. AO-0337 "Increased Runway Throughput based on local ROT characterization (ROCAT)".

Concept 4: Optimised ROT and exit taxiway enables more efficient handling of peak traffic on medium airports with high peak runway utilisation. AO-0338 "Increased Runway Throughput based on AROT optimisation".

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1 Executive Summary

1.1 General

This Safety Assessment Report (SAR) contains the Specimen Safety Assessment for a typical application of Project PJ02-Solution 08 (Traffic Optimisation on Single and Multiple Runway Airports).

The solution 02-08 encompasses of the following concepts;

- **Concept 1** Optimised integration of arrival and departure traffic flows with the use of a Trajectory based Integrated Runway Sequence (TS-0301)
- **Concept 2** Optimised use of Runway Configuration for multiple runway airports with the combined use of Integrated Runway Sequence function and RMAN (TS-0313).
    - As the difference between Concept 1 and Concept 2 is only the combination of the use of an Integrated Runway Sequence and an RMAN, the use of the Integrated Runway Sequence is assessed in the frame of Concept 1 and it is considered that no specific safety assessment is required for Concept 2.
- **Concept 3** The Minimum Radar Separation (MRS) is reduced for low runway occupancy time medium aircraft. The analysis of historical ground radar data allows for characterization of ROT per aircraft type and per runway. AO-0337 “Increased Runway Throughput based on local ROT characterization (ROCAT)”.
- **Concept 4** Optimised ROT and exit taxiway enables more efficient handling of peak traffic on medium airports with high peak runway utilisation. This concept uses Increased Runway Throughput based on AROT optimisation (AO-0338).

The report presents the assurance that the Safety Requirements for the V3 phase are complete, correct and realistic, thereby providing all material to adequately inform the PJ02-08 Solution OSED/SPR/INTEROP.

This Safety Assessment Report (SAR) is contributing to the Operational Service and Environment Definition (OSED)/Safety and Performance Requirements (SPR)/Interoperability (INTEROP). As such it is not a self-contained document. It requires to have at hand the referenced documents.

1.2 Main results

1.2.1 Main results for Concept 1 and 2

Within the limitation of the simulations and considering the Concept 1 use cases included in V3 all four Safety Criteria are realistically achievable:

Reference	Safety Criteria
SAC#1	With the use of Integrated RWY Sequence integrated sequence, the number of planned tactical conflicts shall not increase.
SAC#2	With the use of Integrated RWY Sequence integrated sequence, the number of imminent runway incursions shall not increase.
SAC#3	With the use of Integrated RWY Sequence integrated sequence, the number of planned pre-tactical taxiway conflicts shall not increase.
SAC#4	With the use of Integrated RWY Sequence integrated sequence, the number of separation minima infringements shall not increase.

Table 1: Summary of Safety Criteria applicable to the Solution PJ02-08 Concept 1 and 2

1.2.2 Main results for Concept 3

Within the limitation of the simulations and considering the Concept 3 use cases included in V3 all Safety Criteria are realistically achievable. Results on Concept 3 are described in Appendix B.

The following safety criteria are realistically achievable:

Reference	Safety Criteria
SAC#1	The probability per approach of runway conflict resulting from Conflicting ATC Clearances, when correctly applying ROCAT, shall not be higher than the probability for a reference aircraft type pair in current operations
SAC#2	The probability per approach of runway conflict resulting from Conflicting ATC Clearances due to the incorrect application of ROCAT shall not be greater compared to current operations
SAC#3	The probability per approach of Imminent infringement during interception & final approach shall not be greater in operations with ROCAT compared to current operations
SAC#4	The probability per approach of Imminent infringement (wake) of wake constrained pairs during Interception & final approach shall be no greater in operations with ROCAT compared to current operations

Table 2: Summary of Safety Criteria applicable to the Solution PJ02-08 Concept 3

1.2.3 Main results for Concept 4

Within the limitation of the simulations and considering the Concept 4 use cases included in V3 all Safety Criteria are realistically achievable. The validation of the safety case for Concept 4 was performed during PANSA RTS 4. This exercise was executed on a contingency platform resulting in limitations in traffic realism (approach and landing performance was not variable enough) and necessity to display advisory on a HMI separate from EFS system. Both issues were critical for proper safety assessment. Due to the aforementioned shortcomings of underlying RTS validation and very limited staff available for safety assessment process we consider the confidence level for this result as low.

Reference	Safety Criteria
SAC-4-11	With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of planned tactical taxiway conflicts shall not increase.
SAC-4-12	With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of runway separation infringements shall not increase.
SAC-4-21	With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of imminent inappropriate landings shall not increase.

Table 3: Summary of Safety Criteria applicable to the Solution PJ02-08 Concept 4

2 Introduction

2.1 Background

Background is described for Concept 1 and 2 and separately for Concept 3 and Concept 4.

2.1.1 Background Concept 1 and 2

The rationale for the change, including a very high-level description, is extracted from the SESAR 2020 Solution 02-08 SPR INTEROP OSED Part I [5]. Concept 1 and 2 will integrate different concepts operating in both Execution and Planning Phases (Short and Medium term) and support both Tower Controllers and Supervisors in monitoring and optimising runway system usage.

PJ02.08 Concept 1 and 2 aim at providing ATC with an integrated support tool to improve single and multiple runway airport operations by:

- increasing the predictability of runway capacity,
- optimising runway configuration,
- optimising arrival / departure spacing,
- optimising arrival / departure balancing,
- optimising use of runway capacity

The solution also addresses the improvement of safety and situational awareness through the sharing of integrated arrival/departure sequence between the different actors.

This Safety Assessment Report (SAR) is addressing Project 02 Solution 08 (PJ02-08) Integrated Runway Sequence Function in the frame of SESAR2020.

PJ02-08 encompasses the following operational improvements:

<table>
<tr><th>OI Step code</th><th>OI Step title</th><th>OI Step coverage</th></tr>
<tr><td>TS-0301</td><td>Integrated Arrival Departure Management for Full Traffic Optimisation on the Runway</td><td>Fully</td></tr>
<tr><td colspan="3">A full integration of arrival and departure management processes provides dynamic assistance to the Tower controllers to optimize runway throughput. Additionally, to runway throughput optimization, making best use of variable taxi time, minimum separations and runway occupancy time could optimize arrival/departure spacing.</td></tr>
<tr><th>OI Step code</th><th>OI Step title</th><th>OI Step coverage</th></tr>
<tr><td>TS-0313</td><td>Optimized Use of Runway Configuration for Multiple Runway Airports</td><td>Fully</td></tr>
<tr><td colspan="3">The controller of a multiple runway airport is provided with decision support tools enhanced to allow runway configuration optimization from planning phase throughout the day of operations, improving predictability on airport operations.</td></tr>
</table>

Table 4: SESAR Solution PJ02-08 Concept 1 and 2 Scope and related OI steps

The solution integrates different concepts operating in both Execution and Planning Phases (Short and Medium term) to support both APP Controllers, Tower Controllers and Supervisors in monitoring and optimising runway system usage:

- **Concept 1:** Optimised integration of arrival and departure traffic flows with the use of a trajectory based Integrated Runway Sequence (TS-0301). This concept applies namely to execution phase and addresses mainly TWR and TMA ATCOs.
- **Concept 2:** Optimised use of RWY configuration for multiple runway airports with the combined use of an Integrated Runway Sequence and RMAN (TS-0313).

Their common point is the focus on RWY throughput, optimisation of arrival/departure spacing, predictability of runway capacity and provision of decision-making support tools to the relevant stakeholders in order to improve airport operations.

However, each concept works with elements (Integrated RWY Sequence and RMAN) that address different aspects of the runway operations, work on different time horizons with different data accuracy and provide support tools for different end users. While RMAN uses forecasted data of traffic demand, capacity constraints and target KPIs to provide TWR Supervisor with decision support tools to achieve an optimum use of runway capacity namely in planning phase, Integrated RWY Sequence uses accurate arrival and departure trajectories, focuses on the execution phase and supports TWR and TMA ATCOs to increase runway throughput and predictability by proposing an optimised runway sequence to be applied.

The figure hereafter illustrates the different time horizons for the application of the two concepts of the solution. The time values for are dependent on local environment, the presented values being provided as examples.

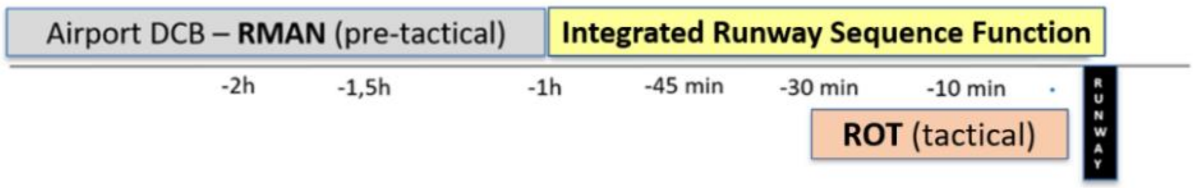


Figure 1: Time horizon application for the PJ02-08 solution concepts

The figure hereafter illustrates the arrival and departure processes with events and systems linked to the timeline. The time values are dependent on local environment, the presented values being provided as examples. There are a number of layers Inserted into the image.

- Arrival process is described above the timeline with Extended AMAN horizon, Top of decent, Time to lose and Time to gain and finally the Target Landing Time.
- Departure process is described below the timeline with push back (including start-up) and taxi out time to the runway (EXOT).
- Business Trajectory describing the progress of Scheduled and Reference Business Trajectory with final update by Airspace Users revised RBT.

One hour before estimated arrival/departure time, the Coupling function provides an integrated runway sequence with setting of Target landing times and Target take-off times.

Fine tuning of A/D sequence. In a certain stable time-horizon before estimated arrival/departure time there will be a fine tuning of spacing value between arrival flights and also an option for final update of the departure sequence. The result of this fine-tuning phase are updates of Target landing times and Target take-off times.

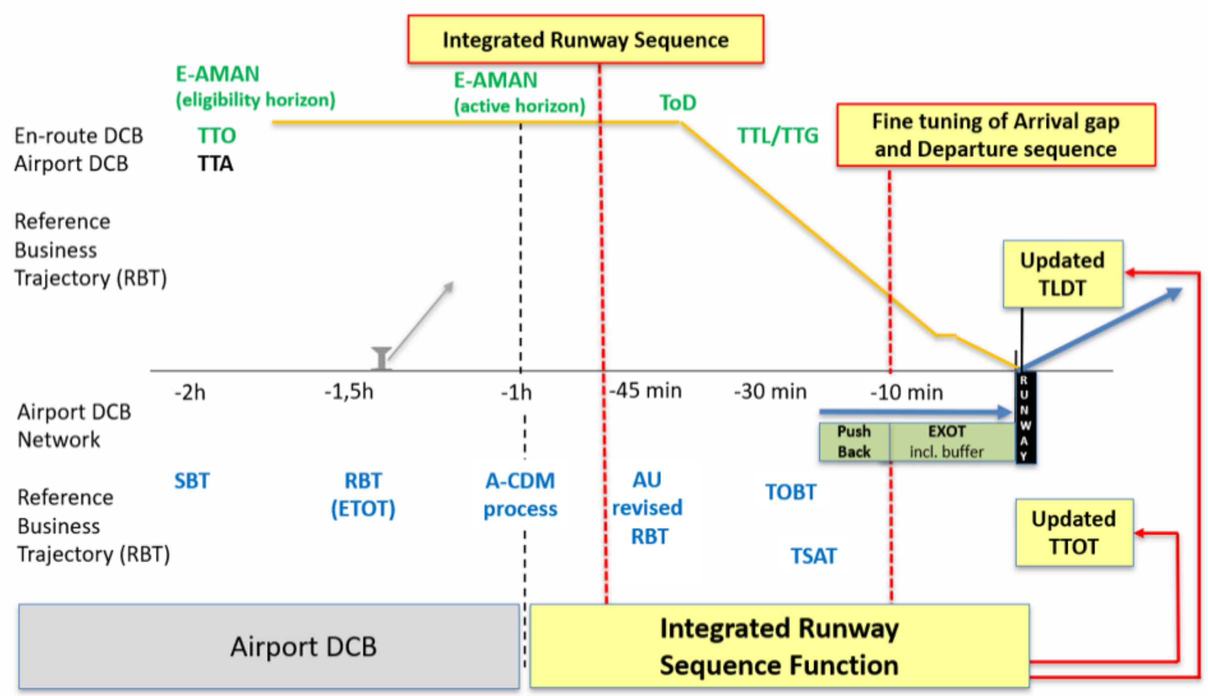


Figure 2: Integrated RWY Sequence

The figure hereafter illustrates the relationship between Integrated RWY Sequence function and RMAN. The time values are dependent on local environment, the presented values being provided as examples.

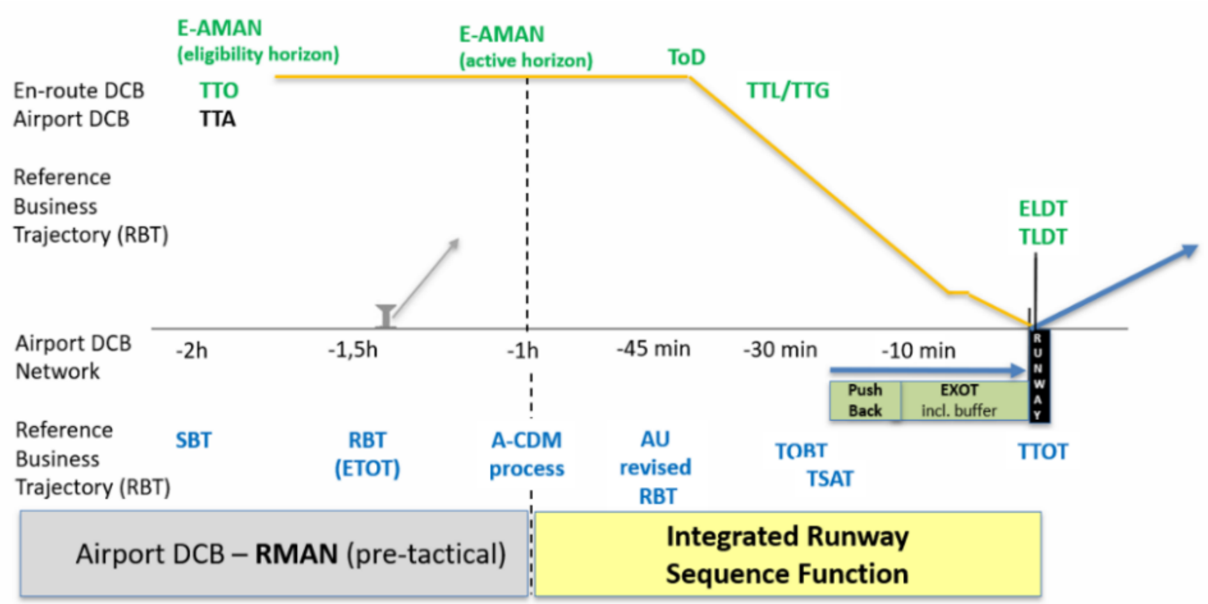


Figure 3: Integrated RWY Sequence and RMAN

2.1.2 Background Concept 3

The rationale for the change, including a very high-level description, is extracted from the SESAR 2020 Solution 02-08 SPR INTEROP OSED Part I [5].

PJ02.08 Concept 3 aim at providing ATC with Increased Runway Throughput based on local ROT characterization (ROCAT), that is based on static models to improve prediction of the arrival runway occupancy time.

PJ02-08 Concept 3 encompasses the following operational improvements:

<table>
<tr><th>OI Step code</th><th>OI Step title</th><th>OI Step coverage</th></tr>
<tr><td>AO-0337</td><td>Increased Runway Throughput based on local ROT characterization (ROCAT)</td><td>Fully</td></tr>
<tr><td colspan="3">The Minimum Radar Separation (MRS as defined in ICAO 4444 section 8.7.3) is reduced for low runway occupancy time medium aircraft. The analysis of historical ground radar data allows for characterization of ROT per aircraft type and per runway. Based on these results, the Medium aircraft can be grouped into 2 categories:

- one for aircraft with short ROT,

- one for aircraft with long ROT

A separation of either 2.0 NM (for aircraft presenting average ROT below 40s), 2.5 NM (for aircraft presenting average ROT below 50s) or 3.0 NM (for aircraft presenting average ROT above 50s) is associated to each ROT category.

Expected benefits is on capacity by increasing runway throughput (ranging between 5 and 10% increased throughput as a function of the proportion of Medium aircraft moved into the low-ROT categories allowing MRS reduction).</td></tr>
</table>

Table 5: SESAR Solution PJ02-08 Concept 3 Scope and related OI steps

2.1.3 Background Concept 4

The rationale for the change, including a very high-level description, is extracted from the SESAR 2020 Solution 02-08 SPR INTEROP OSED Part I [5].

PJ02.08 Concept 4 aim at providing ATC with – prediction of optimised exit taxiway and effective ROT for each arriving flight. As such it is an advisory tool helping in tactical decision making. Concept 4 (also called Enhanced AROT Predictor) is based on a dynamical model taking into account multitude of factors in order to provide optimised estimate of exit. The more in depth description is available in SESAR 2020 Solution 02-08 SPR INTEROP OSED Part I [5].

As AO-0338 has been defined very late in the project lifecycle the independent Safety assessment has been limited to a very short timeframe forcing the safety workshop to be replaced by PANSA RTS extended debriefings. Other elements of safety methodology have also been simplified (as Concept 4 operational implementation is very simple) but additional safety assessment would be recommended to fully justify V3 maturity.

PJ02-08 Concept 4 encompasses the following operational improvements:

OI Step code	OI Step title	OI Step coverage
AO-0338	Increased Runway Throughput based on AROT optimisation	Fully
The tower runway controller of a medium single runway airport is provided with an additional information in CWP that consists of predicted ROT and recommended exit TWY allowing for optimisation in RWY use in peak hours.		

Table 6: SESAR Solution PJ02-08 Concept 4 Scope and related OI steps

2.2 General Approach to Safety Assessment

2.2.1 General

This safety assessment started by the identification of Safety Criteria (SAC) describing what is acceptably safe for the Integrated RWY Sequence. 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 report presents the assurance that the identified Safety Requirements for the V3 phase are complete, correct and realistic.

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 at the end of this joint process to the identification of common and consistent Safety and Human Performance requirements and recommendations.

2.2.2 Specificities

The safety assessment approach chosen for the SESAR 2020 Solution 02-08, is two folded.

In a first step the safety requirements stemming from SESAR 1, that contains the set of minimum positive, and maximum negative, safety contributions for the solution, have been assessed in the context of the evolved solution. The assessment aimed at aligning the existing requirements. Multiple duplications existed between the Functional, HMI, Performance, Interoperability and Safety requirements. As a rule, requirements have been classified as a priority as Functional, HMI, Performance, and Interoperability. The remaining requirement where kept as safety requirements. The requirements list contained in the SESAR 2020 Solution 02-08 SPR INTEROP OSED for V3 Part I, paragraph 4.3 "Safety and Performance Requirements (SPR)" [5].

In a second step, based on the validation experience, additional safety requirements have been included in the list of requirements contained in the SESAR 2020 Solution 02-08 SPR INTEROP OSED for V3 Part I, paragraph 4.3 "The PJ02-08 Solution SPR-level Model" [5].

2.2.3 Safety Specification at the OSED Level

This is defined as what the Integrated RWY Sequence have to achieve at the Air Traffic Management (ATM) operational level in order to satisfy the requirements of the concerned parties - i.e. it takes a “black-box” view of the new method of operations and includes what is “shared” between the Air Traffic Service units.

From a safety perspective, the concerned parties' 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 have been derived in SESAR 1 and also in the SESAR2020 PJ02-08 V2 phase.

2.2.4 Safe Design at the SPR Level

This describes what the operations with the Integrated RWY Sequence tools with AMAN and DMAN 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 concerned parties' requirements. Design is essentially an internal, or "white-box", view of the operations supported by the Integrated RWY Sequence. This is more generally called the SPR-level Model for the Integrated RWY Sequence 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 and V3 phases of the development lifecycle. The purpose here is to feed the SPR/INTEROP/OSED with a complete and correct set of safety requirements. Furthermore, if relevant, interact with the validation exercises so as to include additional validation objectives and obtain validation feedback regarding certain proposed safety requirements.

2.3 Scope of the Safety Assessment

The safety assessment output are the safety requirements, safety objectives and safety criteria related to the generic solutions that need to be considered for the future implementation in the specific operational environment. The set of requirement has to be completed by the execution of a PSSA in the operational environment subject to the implementation of the solution.

2.4 Layout of the Document

The layout of this Safety Assessment report is as follows:

Section 1 presents the executive summary of the document.

Section 2 provides background information regarding the definition, design and validation addressed in the PJ02-08 Concepts, the principles for safety assessment in SESAR Programme and the scope of this safety assessment

Section 3 addresses the Concept 1, 2 and also Concept 4 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 Concept 1, 2 and also Concept 4 safe design at SPR level, through the derivation of Safety Requirements (SR) and link to validation results.

Appendix A presents the consolidated Concept 1 and 2 list of Safety Objectives and Safety Requirements

Appendix B presents the consolidated Concept 3 Safety Results

3 Safety specifications at the OSED Level

3.1 Scope

The scope includes the validation of the safety requirements included in the SESAR 2020 Solution 02-08 SPR INTEROP OSED Part I [5], paragraph 4.3 "Safety and Performance Requirements (SPR)".

This section addresses the following activities:

- Description of the key properties of the Operational Environment that are relevant to the safety assessment.
- 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 Solution.
- Setting of the SAfety Criteria.
- Comprehensive determination of the operational services that are provided by the Solution 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.
- Assessment of the adequacy of the operational services provided by the Solution under abnormal conditions of the Operational Environment.
- Assessment of the adequacy of the operational services provided by the Solution in the case of internal failures and mitigation of the System-generated hazards (derivation of Safety Objectives (failure approach)).
- Achievability of the SAfety Criteria.
- Validation & verification of the safety specification.

3.2 Safety specifications for Concept 1 and 2

3.2.1 Baseline: Independent AMAN and DMAN

For the Traffic Optimisation on single and multiple runway airports concept, the previous operating method considered is the current situation where AMAN and DMAN work separately or with a slight integration, the Runway Configuration is established by the supervisor based on the experience and the ROT is a fixed parameter. In some cases, like single runway in mixed mode operations, fixed patterns to take into account departures within an arrival sequence are considered by AMAN, but in general terms there is little or no integration between the 2 sequences.

The procedures used are the following:

- The Tower Runway Controller uses the arrival and departure sequences calculated by the AMAN and DMAN as support in order to maximise runway throughput. The integration of both sequences and the use of the runway occupancy time per flight is done in the ATCOs head and not shared via HMI with the other stakeholders.
- The Tower Ground Controller manages the traffic taking into account the arrival and departure sequences calculated by the AMAN and DMAN. The Tower Ground Controller mostly manages the departure sequence calculated by the DMAN taking into account the arrival sequence calculated by the AMAN.
- The Apron Controller manages the traffic in order to permit the Tower Ground Controller to manage the departure sequence calculated by the DMAN.
- The Executive TMA controller manages the traffic taking into account the arrival and departure sequences calculated by the AMAN and DMAN. The Executive TMA controller mostly manages the arrival sequence calculated by the AMAN taking into account the departure sequence calculated by the DMAN.
- The Airport Tower Supervisor decides a Runway Configuration based on experience and information about the planned demand without any decision support tool.
- The Sequence Manager manages the arrival sequence by planning, setting and adjusting runway landing rates according to changes, by monitoring the arrival sequence and by introducing on it the necessary manual changes when required.

In this situation, consistency between tools are only maintained by coordination between TWR Supervisor and TWR ATCOs. Changes in RWY conditions need to be reported from Tower Supervisor to the Tower Controllers in order to ensure consistency from the planning to the execution phase.

3.2.2 Operational Environment and Key Properties

The Operational Environment relevant for the solution 02-08 for V3 is described in the OSED/SPR/INTEROP Part 1 [5]. It describes the new operating method to achieve the Traffic Optimisation on single and multiple runway airport. It first describes the main features of the Integrated RWY Sequence function, the expected link with other parts of the concept and then provides a description of them together with their most relevant characteristics.

3.2.3 Integrated Runway Sequence Function

The main goal for the Integrated Runway Sequence function is to establish an integrated arrival and departure sequence by providing accurate TTOTs and TLDTs, including dynamic balancing of arrivals and departures while optimising the runway throughput.

The integrated sequence issued by the Integrated RWY Sequence function is calculated according to a look-ahead Time Horizon which value will range from firstly a time before arrival flights top of descent (e.g. 60 minutes before entry to runway) and updated in the tactical phase until a certain Stable Sequence Time Horizon. Then, TTOTs and TLDTs will be fine-tuned according to flight progress until a Frozen Sequence Time Horizon, from which TTOT/TLDT will be frozen.

The Figure 4 below gives a view of time horizons for arrivals from the right to middle (runway) and of departures from the left to middle (runway) including a highlight of the main working area for setting of the combined sequence. The look ahead Time Horizon is the time at which flights become eligible for the integrated sequence The Stable Sequence Time Horizon is the time horizon within which no automatic swapping of flights in the sequence will occur, but landing and departure time will still be updated. The Frozen Sequence Time Horizon is the time horizon within which no automatic swapping of flights in the sequence, and no update of landing /departure time will occur. The value of these time horizons is determined by the local implementation and they are not necessarily the same for arrivals and departures.

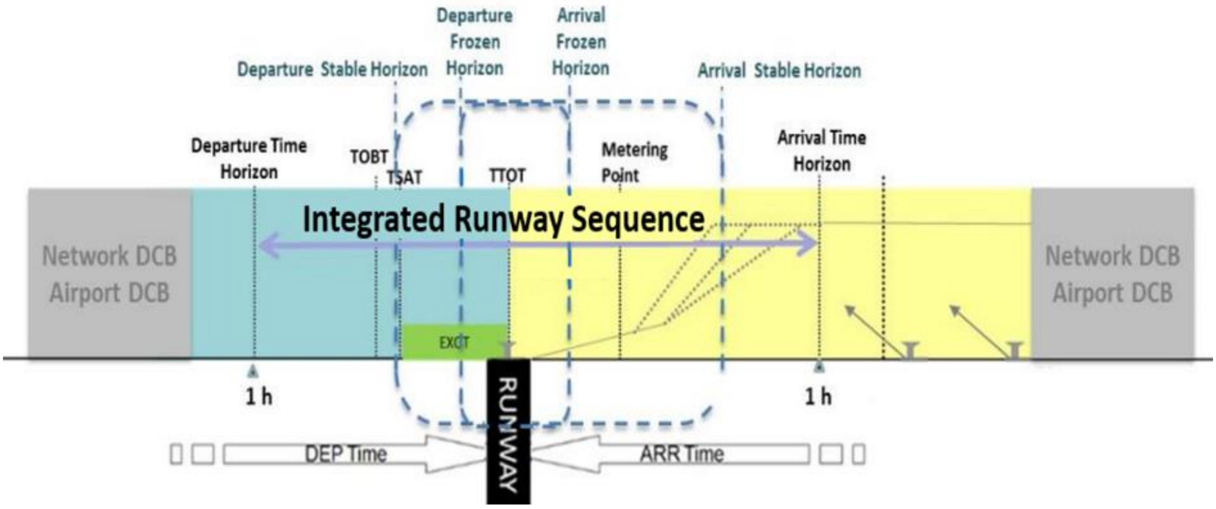


Figure 4: Time horizons for the new concept

The Integrated RWR Sequence function receives:

- The Flight data for arrivals including estimated and actual times involved in the arrival process
- The Flight data for departures including estimated and actual times involved in the departure process.
- Arrival/Departure ratio (option)
- The planned taxi time from each Stand to the Runway in Use provided by A-SMGCS (optional).

- The remaining taxi time from A-SMGCS will be used to update TTOT and thereby the sequence (optional).
- The Trajectory data including ETO, ATO for each point.

The following tasks will be performed by the Integrated RWR Sequence function:

- Calculation of an integrated arrival/departure sequence based on a dynamic balancing of arrival and departures, by using the estimated times at the runway;
- Assign TLDTs and TTOTs to arrivals and departures based on the best runway sequence which optimise the runway throughput;
- Update applicable parts of the sequence based on new information on arrival and departure flight progress.
- Provide a buffer of departing flights (predefined number) at the Runway hold to consider variability and delays depending on specific situation.
- Balancing of KPIs via parameters needs to be further investigated;
    - Runway Throughput
    - Fuel Efficiency
    - Predictability
        - Stability / Punctuality /Accuracy
        - Stability versus updates sequence

The integrated sequence optimisation of TTOT and TLDT is firstly calculated by the Coupling function in a look ahead Time Horizon balancing arrivals and departures according to demand, needs and configured parameters in order to achieve the best trade-off between efficiency, predictability and optimised throughput.

Target landing times (TLDT) will be set by the Coupling function to calculate constrains at Metering Fixes (MF). If TTL/TTG or CTA procedures are in place to implement the arrival sequence, the TLDTs from the Integrated RWY Sequence are converted to Time to Lose (TTL), Time to Gain (TTG) or Controlled Time of Arrival *(CTA)* and made available for ATCO and Flight Crew.

The TTOTs calculated from the Integrated RWY Sequence are converted to Target Start-Up Approval Times (TSAT) by the A-CDM platform and made available for ATCO, Flight Crew and relevant actors. TTOTs are also converted to DPIs according to the A-CDM concept and distributed to the network manager. The integrated sequence is built including departure aircraft that are not yet off-block (initial runway sequence) and an adjustment of the sequence (expected mainly for departures) will be made when the stability of flight progress is increased (update of runway sequence).

The Integrated RWY Sequence initial runway sequence:

- Integrated RWY Sequence function will adjust the number of arrivals and departures (dynamic ratio) to be in line with the planned runway capacity provided by A-DCB (optional).
- Coupled sequence planned for the runway is set a look ahead time before landing/take-off (e.g. 60 minutes);
- Integrated RWY Sequence function will distribute flights in the most optimal way taking into account a number of parameters e.g. wake vortex separations, SIDs etc. The integrated sequence will include time separation between pairs of aircraft, giving the minimum required spacing values for different wake vortex categories, wind conditions and weather.

- TLDTs and TTOTs are provided from the Integrated RWY Sequence function. Since departure times are more volatile than arrivals, the goal to be achieved with the optimization is to assign a combined runway sequence where TLDTs match the most likely TTOTs (sequences of departures to occur).

The Integrated RWY Sequence update of runway sequence:

- The Integrated RWY Sequence function will receive updated information on arrivals and departures including update of flight progress and will check
  - arrivals ability to meet TLDT;
  - departures ability to meet TTOT (adopt to late changes close to TSAT);
- Coupling function will update the runway sequence, at a latest time which is locally configurable based on progress information on arrivals and departures. New, updated TLDTs and TTOTs are provided from the Integrated RWY Sequence function. Based on the updated runway sequence a support function can present information to controllers on spacing advisory's and planned gap size between arrivals to accommodate planned departing flights.

To support ATC with an overview of the combined runway sequence a separate "Runway list" including the sequence order for both arrivals and departures can be presented. Support functions for ATC can be used to enhance awareness and increase controller ability to comply with a predefined combined runway sequence. The support functions will be used according to local preferences.
Example of ATC support functions are the provision of:

- Arrival sequence number;
- Departure sequence number;
- Speed instructions for arrivals;
- Integrated Runway sequence list;
- Spacing indicators for arrivals on final approach (distance based or time based).

These support functions can be used according to local ATC preferences.

In this operating method, the required time inserted between arrivals to allow departures is determined by the Integrated RWY Sequence and is no longer determined in advance by the Tower Runway Controller. The procedure for TWR is to respect and follow the departure sequence and TTOTs as closely as practical. The procedure for Approach is to respect the arrival sequence and follow advisories for gap size between arrivals to accommodate departing flights.

The following procedures are used:

- **Approach and Tower Supervisor**
  Will determine the runway configuration and distribution of demand according to capacity and local constraints entered in the system when utilizing only Integrated RWY Sequence If Integrated RWY Sequence is integrated with RMAN, the tool will take into account all the constraints entered in the system and will determine the runway configuration achieving.

- **Approach controllers**
  Will have to respect the arrival sequence and follow spacing advisories between arrivals to accommodate departing flights.

- **Clearance Delivery Controller**
  Will provide start-up approval based on TSAT (considering that TSAT is a predefined window of e.g. - 2/+3 minutes TBD) provided by the Integrated RWY Sequence. TSAT calculation will be based on TOBT and accurate estimated taxi times provided by routing and planning service.

- **Ground Controller (including Apron Manager)**
  Will provide push-back approval in line with TSAT window (- 2/+3 minutes TBD). Taxi-out clearance is arranged to meet the proposed departure sequence, updated in line with TTOTs as closely as practical. Handle deviations and possible updates based on remaining taxi-out time with update of departure sequence. Propose the use of runway intersections according to local procedures.

- **Tower Runway Controller**
  Will verify that the runway is clear and that the aircraft will meet arrival/departure separation requirements. He/she has to respect and follow the departure sequence and TTOTs as closely as practical. In coordination with Flight Crew use runway intersections according to local procedures to maintain runway throughput.

- **Sequence Manager**
  Will manage the integrated arrival/departure sequence by planning, setting and adjusting runway landing and departure rates according to changes, by monitoring the runway integrated sequence and by introducing on it the necessary manual changes when required.

3.2.3.1 Link to Airport DCB (RMAN)

When integrating arrival and departure sequences, the maximum flow to the runways must not exceed capacity.

Prediction of capacity on complex airports might be difficult for the controllers, since available capacity can be distributed over the runways in different ways according to the applicable dependencies.

Airport DCB, and in particular the Runway Manager (RMAN) will support Tower supervisors determining the optimal runway configuration and suggesting distribution of demand according to capacity and local constraints entered in the system by the Tower Supervisor during the time horizon prior Integrated RWY Sequence becomes active. For the time horizon in which Integrated RWY Sequence is active, the RMAN continuously monitors the planning in order to take appropriate actions for the following hours. The optimal runway configuration is assessed by calculating operational KPIs (delay, shortage and punctuality). From the active solution that yields the best weighted KPI result, the active RWY schedule, and the planned forecasted times per flight are provided to the Integrated RWY Sequence which will calculate its sequence taking into account these data.

3.2.4 Airspace Users Requirements

From a cockpit crew point of view the introduction of Integrated RWY Sequence is transparent. No airspace users' requirements are defined at the OSED level.

3.2.5 Relevant Pre-existing Hazards

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 provides 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 AIM models are relevant for the PJ02 Solution 8, this sub-section presents the relevant aviation hazards.

Concept 1 is contributing to approach and runways operations. Based on Guidance E.2 of [2] we have identified a list of pre-existing hazards relevant for Concept 1 functionality. The relevant pre-existing hazards are presented in

Pre-existing aviation Hazards [Hp]	**ATM-related accident type& AIM model**
Hp#1 "Situation in which the intended 4D trajectories of two or more aircraft are in conflict during interception& final approach"	Mid-Air Collision (MAC) during interception & final approach
Hp#2 "Situation leading to wake vortex encounter"	Wake Turbulence-induced Accident (WTA) on Final Approach (WAKE FAP)
Hp#3 **"**Situation leading to collision with another aircraft or a ground vehicle on RWY"	Collision on the runway (RWY Col)
Hp#4 **"**Situation leading to collision with an obstacle, ground vehicle, another aircraft"	Collision on the taxiway (TWY)
Hp#5 **"**Low runway-surface friction"	Low friction on runway with impact on runway occupancy time

Table 7.

Pre-existing aviation Hazards [Hp]	**ATM-related accident type& AIM model**
Hp#1 "Situation in which the intended 4D trajectories of two or more aircraft are in conflict during interception& final approach"	Mid-Air Collision (MAC) during interception & final approach
Hp#2 "Situation leading to wake vortex encounter"	Wake Turbulence-induced Accident (WTA) on Final Approach (WAKE FAP)
Hp#3 **"**Situation leading to collision with another aircraft or a ground vehicle on RWY"	Collision on the runway (RWY Col)
Hp#4 **"**Situation leading to collision with an obstacle, ground vehicle, another aircraft"	Collision on the taxiway (TWY)
Hp#5 **"**Low runway-surface friction"	Low friction on runway with impact on runway occupancy time

Table 7. Pre-existing hazards relevant for Integrated Runway Sequence

3.2.6 SAfety Criteria for Concept 1 and 2

3.2.6.1 General

The SAfety Criteria (SAC) are taken over of the Integrated Runway Sequence – S02V2 Final SPR of project P06.08.04.

SACs 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 and it needs to be consistent with the SESAR safety performance targets defined by PJ 19.04.

3.2.6.2 Relevant AIM Models for Concept 1 and 2

The introduction of Integrated RWY Sequence improves upon the uncoupled AMAN & DMAN functionalities present in current operations. The introduction of Integrated RWY Sequence affects functions in a number of the AIM models. The goal for the concept is for there to be no safety detriment resulting from its introduction. Therefore, where an impact on AIM has been identified in the AIM models, the corresponding accident pre-cursor has been listed. A SAC has then been derived for this accident pre-cursor of the form 'no worse than today'. These affected functions are listed in the table here-after, along with the related type of accident, the AIM Model used and the corresponding Safety Criteria (as explained in previous section):

SAC	AIM Model Used	Barrier	Pre-cursor	AIM Function affected
SAC#1 With the use of Integrated RWY Sequence integrated sequence, the number of planned tactical conflicts shall not increase.	MAC-TMA	B10 Traffic planning and synchronisation	Planned Conflict (MF5.1)	Inadequate AMAN information (MB10.2.1a)
				Inadequate synchronisation regarding arrivals (MB10.2.1b)
				Inadequate DMAN information (MB10.2.2.a)
				Inadequate synchronisation regarding departures (MB10.2.2b)

SAC	AIM Model Used	Barrier	Pre-cursor	AIM Function affected
SAC#2 With the use of Integrated RWY Sequence integrated sequence, the number of imminent runway incursions shall not increase.	RWC Col	B4 ATC Runway Entry Management	Imminent Runway Incursion (RP4)	Inadequate coordination between Tower and Approach (RB4.1.3.2)
		B9 Runway DCB	Potential Runway Use (RP9)	Mixed mode failure in managing sequence causes insufficient spacing (MB9.3.4)
SAC#3 With the use of Integrated RWY Sequence integrated sequence, the number of planned pre-tactical taxiway conflicts shall not increase.	TWC	B5 Pre-Tactical Ops Planning	Planned Pre-tactical Taxiway Conflict (TP4B)	Ineffective Demand Prediction (TB5.1.5)
SAC#4 With the use of Integrated RWY Sequence integrated sequence, the number of separation minima infringements shall not increase.	WAKE FAP	B7 Separation Management of ATC-induced Conflict	Separation Minima Infringement (WE5F)	Wake Vortex – no Planning Data (Bx.1.1.2.2)
			Under- separation not managed within safe margins (WE7F)	

Table 8: List of affected functions in AIM

3.2.6.3 Integrated RWY Sequence Related Safety Criteria

The following Safety Criteria were identified from Accident Incident Model for the Integrated RWY Sequence:

SAC#1: With the use of Integrated RWY Sequence integrated sequence, the number of planned tactical conflicts shall not increase.

This SAC is related to the barrier B10 of the Mid-Air Collision (TMA) Risk model.

Rationale:

Controllers might face high traffic density due to a corrupt sequence in terms of too much traffic that is planned. This can lead to an increased workload.

Controllers might expect a different situation due a corrupt sequence in terms of the order of flights is different to what the controller expects based on the current aircraft position

SAC#2: With the use of Integrated RWY Sequence integrated sequence, the number of imminent runway incursions shall not increase.

This SAC is related to the barrier B4 of the Runway Incursion Risk model.

Rationale:

The Tower Runway Controller might be provided with a sequence, which does not correctly consider the separation constraints.

SAC#3: With the use of Integrated RWY Sequence integrated sequence, the number of planned pre-tactical taxiway conflicts shall not increase.

This SAC is related to the barrier B5 Taxiway Collision Risk model.

Rationale:

Wrong taxi times provided by the Routing functionality might have an impact on the number of taxiing aircraft (too many aircraft taxiing at the same time) which could increase workload of Ground Controller.

SAC#4: With the use of Integrated RWY Sequence integrated sequence, the number of separation minima infringements shall not increase.

This SAC is related to the barrier B8 of the Wake-Induced Risk model and also related to MAC on FAP.

Rationale:

If wrong wake vortex separations or the wrong separation/spacing are considered in the planning this might lead to additional workload for the controller as he has to adjust his expectation when separating traffic.

3.2.7 Mitigation of the Pre-existing Risks – Normal Operations

3.2.7.1 Operational Services to Address the Impacted Function in AIM

This section describes the ATC services that are provided by the Integrated RWY Sequence in the relevant operational environment to address (all/some of) the SAC identified above.

Note that these services are the same as the ATC services provided in current operations.

ID	Service Objectives	Related AIM Functions

ID	Service Objectives	Related AIM Functions
CAD.ATC-01	Traffic planning Traffic synchronisation	Inadequate coordination between Tower and Approach (RB4.1.3.2) Mixed mode failure in managing sequence causes insufficient spacing (MB9.3.4)
CAD.ATC-02	Traffic monitoring Conflict resolution	Wake Vortex – no Planning Data (Bx.1.1.2.2) Wake Vortex – Incorrect planning Information (Bx.1.1.2.1)
CAD.ATC-03	Potential collision detection Collision avoidance	Wake Vortex – no Planning Data (Bx.1.1.2.2) Wake Vortex – Incorrect planning Information (Bx.1.1.2.1)
CAD.ATC-04	TWY Collision avoidance	Ineffective Demand Prediction (TB5.1.5)
CAD.ATC-05	Runway Entry/exit management Take-off Management Landing Management	Inadequate AMAN information (MB10.2.1a) Inadequate synchronisation regarding arrivals (MB10.2.1b) Inadequate DMAN information (MB10.2.2.a) Inadequate synchronisation regarding departures (MB10.2.2b)

Table 9: ATC services and related AIM Functions

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

This section provides the functionality Safety Objectives (concerning the success part of the assessment) for Integrated RWY Sequence providing the ATC services listed in the previous section. They have been defined based on the services presented in previous section, using the same sources mentioned in that section.

These safety objectives describe WHAT the Integrated RWY Sequence (CAD) system has to perform in order to provide the ATC services.

The HOW this is to be done will be described by the safety requirements, derived from those safety objectives, in terms of requirements on technical equipment (information to be provided and associated performance characteristics), controller competence/training, and procedures.

Ref	Phase of Flight / Operational Service	Related AIM Barrier	Achieved by / Safety Objective [SO xx]

Ref	Phase of Flight / Operational Service	Related AIM Barrier	Achieved by / Safety Objective [SO xx]
CAD.ATC-01	Take-off Land	ATC Runway Entry Management Barrier (B4 RWC Model) Runway DCB Barrier (B9 RWC Model)	SO-0001 SO-0002 SO-0003
CAD.ATC-02	Take-off Land	Separation Management of close-following traffic Barrier (B9 WAKE Model)	SO-0004
CAD.ATC-03	Take-off Land	Separation Management of close-following traffic Barrier (B9 WAKE Model)	SO-0004
CAD.ATC-04	Surface-in Surface-out (Apron/Taxi-in/Taxi-out)	Pre-Tactical Airport OPS Planning Barrier (B5 TWC Model)	SO-0005
CAD.ATC-05	Take-off Land	Traffic Planning and Synchronisation Barrier (B10 MAC-TMA Model)	SO-0006 SO-0007

Table 10: PJ 02-08 Solution Operational Services & Safety Objectives (success approach)

The following table describe the Safety Objectives referred above:

ID	Description
SO#1	Integrated RWY Sequence shall support coordination between TWR and Approach
SO#2	Integrated RWY Sequence shall support effective ATC runway management
SO#3	Integrated RWY Sequence shall support managing the sequence in mixed and dependent mode environment
SO#4	Integrated RWY Sequence shall be provided with accurate and correct MRS/wake vortex information
SO#5	Integrated RWY Sequence shall be provided with reliable demand prediction
SO#6	Integrated RWY Sequence needs to be provided with all relevant information for sequencing traffic

Table 11: List of Safety Objectives (success approach) for Normal Operations

Apart from the safety objectives listed above, the following assumptions are also to be considered in order to ensure the appropriate provision of the services described.

ID	Description
AO-01	The safety objectives that apply for a basic AMAN that is not coupled to DMAN still apply to the Integrated RWY Sequence
AO-02	The safety objectives that apply for a basic DMAN that is not coupled to AMAN still apply to the Integrated RWY Sequence

Table 12: List of operational assumptions under nominal conditions

3.2.8 Concept 1 and 2 Operations under Abnormal Conditions

The purpose of this section is to assess the ability of operations based on the Integrated RWY Sequence 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 that have not been covered in §3.7.2 or conditions external to the scope of the solutions PJ02-08. In the OSED these abnormal conditions are non-nominal use cases.

3.2.8.1 Identification of Abnormal Conditions

The following abnormal (non-nominal) conditions scenarios have been identified.

- Runway Closure (either planned or instant closure)
- Go-Around
- Instant Change of Runway in Use for a single flight (instant runway intent change)

The non-nominal conditions listed above are assessed in this section. The following assumption is made:

ID	Description
AO-03	The coupling of AMAN and DMAN does not introduce new abnormal conditions compared to the baseline uncoupled AMAN and DMAN.

Table 13: List of operational assumptions under non-nominal conditions

The potential operational effects of the non-nominal conditions and the potential mitigation of these effects are presented in the following table:

Ref	Non-nominal Conditions	Operational Effect	Mitigation of Effects

Ref	Non-nominal Conditions	Operational Effect	Mitigation of Effects
1	Runway Closure	Supervisor needs to re-plan traffic to remaining runway using parameters (runway forecasted re-opening time) provided by Integrated RWY Sequence. In one runway environment traffic needs to be put on hold or to be diverted.	Closure of runway needs to be displayed in Integrated RWY Sequence. Integrated RWY Sequence shall support re-planning of traffic to remaining runway(s), if any. Integrated RWY Sequence shall automatically reschedule traffic after expected runway opening.
2	Go-Around	Go-Around needs to be re-sequenced into arrival sequence.	Go-Around needs to be re-entered into the arrival sequence either manually or automatically by the Integrated RWY Sequence.
3	Instant Change of Runway in Use for a single flight	Flight will be managed to a new runway. Other flights will be updated with new sequence number.	Flight will be manually managed into the new runway and Integrated RWY Sequence shall automatically reschedule all traffic.

Table 14: Mitigation of non-nominal conditions

3.2.8.2 Derivation of Safety Objectives (Functionality & Performance – success approach) for Non-Nominal Operations

ID	Non-Nominal Conditions	Description
SO#7	Runway Closure, Go-Around and Instant Change of runway	For abnormal conditions the same safety objectives remain as for unintegrated RWY Sequence

Table 15: List of Safety Objectives related to non-nominal conditions

3.2.9 Mitigation of System-generated Risks (failure approach)

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 Integrated RWY Sequence 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 list of hazards for arrivals is based on the analysis which was previously done in project P06.08.04 in SESAR 1. These hazards have been refined further for this iteration.

The following table shows for each hazard:

- The corresponding hazard described at operational level

- The related safety objective from which the hazard is derived
- The assessed operational effects of the hazard accounting for the mitigation means identified
- The possible mitigations of the hazard consequences with a reference to existing functional and performance safety objectives (or assumptions) or to new ones.
- The assessed severity of the mitigated consequence determined used the risk classification schemes provided Accident Incident Model (AIM).

The following operational hazards and linked Safety Objectives are shown in the table below with assessed likelihood of occurrence.

Hazard ID	Description	SO ID	Operational Effects	Severity	SO calculation
H-01	The likelihood that the Integrated Runway Sequence function causes inadequate coordination between Tower and Approach should be no more than 0.0001 per flight hour	SO#1	An imminent runway Incursion could occur. A separation Minima Infringement could occur	RWY-SC5 (1e-2) MAC-SC4b	MTFoO / N x IM = 1e-2 / 50 x 1 for RWY-SC5 = 0.0002 for RWY-SC5 MTFoO / N x IM = 1e-2 (per fh) / 100 x 1 = 0.0001 for MAC-SC4b
H-02	The likelihood that the Integrated Runway Sequence function causes ineffective ATC Runway Management leading to insufficient spacing should be no more than 0.0002 per flight hour	SO#2	An imminent runway Incursion could occur.	RWY-SC5 (1e-2)	MTFoO / N x IM = 1e-2 / 50 x 1 for RWY-SC5 = 0.0002 for RWY-SC5

Hazard ID	Description	SO ID	Operational Effects	Severity	SO calculation
H-03	The likelihood that the Integrated Runway Sequence function causes mixed mode failure in managing sequence causes insufficient spacing should be no more than 0.0001 per flight hour	SO#3	A separation Minima Infringement could occur	MAC-SC4b	MTFoO / N x IM = 1e-2 (per fh) / 100 x 1 = 0.0001 for MAC-SC4b
H-04	The likelihood that the Integrated Runway Sequence function causes separation infringements due to inaccurate information for separation management (in Approach and Tower) should be no more than 0.0001 per flight hour	SO#4	A separation Minima Infringement could occur	RWY-SC5 MAC-SC4b	MTFoO / N x IM = 1e-2 / 50 x 1 for RWY-SC5 = 0.0002 for RWY-SC5 MTFoO / N x IM = 1e-2 (per fh) / 100 x 1 = 0.0001 for MAC-SC4b
H-05	The likelihood that the Integrated Runway Sequence function causes separation infringements	SO#4	A separation Minima Infringement could occur	WK-FA-SC3b Applies to departures as well, but there is no model for that	MTFoO / N x IM = 1E-02 (per approach) / 5 x 1 = 0.002

Hazard ID	Description	SO ID	Operational Effects	Severity	SO calculation
	due to no planning data on Wake Vortex should be no more than 0.002 per approach				
H-06	The likelihood that the Integrated Runway Sequence function causes separation infringements due to incorrect planning information on Wake Vortex should be no more than 0.002 per approach	SO#4	A separation Minima Infringement could occur	WK-FA-SC3b Applies to departures as well, but there is no model for that	MTFoO / N x IM = 1E-02 (per approach) / 5 x 1 = 0.002
H-07	The likelihood that the Integrated Runway Sequence function causes ineffective Demand Prediction should be no more than 0.02 per movement	SO#5	A pre-Tactical Taxiway Conflict could occur	TWY-SC5	MTFoO / N x IM = 1 (per movement) / 50 x 1 = 0.02
H-08	The likelihood that the Integrated Runway Sequence function causes inadequate	SO#6	A planned tactical conflict could occur	MAC-SC4.b (1e-2)	MTFoO / N x IM = 1e-2 (per fh) / 100 x 1 = 0.0001

Hazard ID	Description	SO ID	Operational Effects	Severity	SO calculation
	synchronisation regarding arrivals should be no more than 0.0001 per flight hour				
H-09	The likelihood that the Integrated Runway Sequence function causes inadequate AMAN information should be no more than 0.0001 per flight hour	SO#6	A planned tactical conflict could occur	MAC-SC4.b (1e-2)	MTFoO / N x IM = 1e-2 (per fh) / 100 x 1 = 0.0001
H-10	The likelihood that the Integrated Runway Sequence function causes inadequate synchronisation regarding departures should be no more than 0.0001 per flight hour	SO#6	A planned tactical conflict could occur	MAC-SC4.b (1e-2)	MTFoO / N x IM = 1e-2 (per fh) / 100 x 1 = 0.0001
H-11	The likelihood that the Integrated Runway Sequence function causes inadequate DMAN information	SO#6	A planned tactical conflict could occur	MAC-SC4.b (1e-2)	MTFoO / N x IM = 1e-2 (per fh) / 100 x 1 = 0.0001

Hazard ID	Description	SO ID	Operational Effects	Severity	SO calculation
	should be no more than 0.0001 per flight hour				

Table 16: Failure Case Safety Objectives

3.2.10 Impacts of Concept 1 and 2 operations on adjacent airspace or on neighbouring ATM Systems

The scope of the validation for the PJ02-08 Solution has been set in a manner to not impact adjacent airspace and neighbouring ATM Systems. Any part impacted has been included in the scope of the PJ02-08 Solutions.

3.2.11 Achievability of the SAfety Criteria

Safety Validation Objectives for Concept 1 used in the V3 exercises performed by LFV/COOPANS and SKYGUIDE.

OBJ-PJ02.08-V3-VALP-SA1

OBJ Description: To assess the impact of Integrated Arrival Departure management for full traffic optimisation on the RWY on safety in all potential context of application

Success criteria: CRT-PJ2.08-V3-VALP-SA1-001: The objective is fulfilled by making an initial Safety Assessment, i.e. identifying potential Safety Hazards with the introduction of the operational improvement.

Safety Objectives, listed in the table below, are used in the V3 validations;

Safety Objective	Description
SO#1	Integrated RWY Sequence shall support coordination between TWR and Approach
SO#2	Integrated RWY Sequence shall support effective ATC runway management
SO#3	Integrated RWY Sequence shall support managing the sequence in mixed mode environment
SO#4	Integrated RWY Sequence shall be provided with accurate and correct wake vortex information

Safety Objective	Description
SO#5	Integrated RWY Sequence shall be provide with reliable demand prediction
SO#6	Integrated RWY Sequence needs to be provided with all relevant information for sequencing
SO#7	The degraded modes of the Integrated RWY Sequence should not be worse than the current one with de-coupled AMAN and DMAN

Table 17: Concept 1 Safety Objectives

3.2.11.1 Safety Criteria and linked Safety Objectives

This paragraph lays down the allocation of the Safety Objectives, defined in the paragraphs 3.2.7.2 and 3.2.8.2, to the Safety Criteria defined in the paragraph 3.2.6.3.

The table below shows the allocation of SO to each SAC:

Safety Criteria	Related Safety Objective
SAC#1 The number of tactical conflicts shall not increase	**SO#1** Integrated RWY Sequence shall support coordination between TWR and Approach
	SO#3 Integrated RWY Sequence shall support managing the sequence in mixed and dependent mode environment
	SO#6 Integrated RWY Sequence needs to be provided with all relevant information for sequencing
SAC#2 The number of runway incursions shall not increase	**SO#1** Integrated RWY Sequence shall support coordination between TWR and Approach
	SO#2 Integrated RWY Sequence shall support effective ATC runway management
	SO#3 Integrated RWY Sequence shall support managing the sequence in mixed and dependent mode environment

Safety Criteria	Related Safety Objective
SAC#3 The number of taxiway conflicts shall not increase	**SO#5** Integrated RWY Sequence shall be provide with reliable demand prediction
SAC#4 The number of separation minima infringements shall not increase	**SO#4** Integrated RWY Sequence shall be provided with accurate and correct wake vortex information

Table 18**: Allocation of Safety Objectives to each Safety Criteria**

3.2.12 Validation & Verification of the Safety Specification

The current safety assessment report takes on board the relevant results from SESAR 1 PJ06.08.04, namely D30 - Integrated RWY Sequence - S02V2 Final SPR [4].

The results of SESAR 1 has then been reviews in a SAF/HP workshop, organised in June 2018 , with the support of operational people, which addressed the un-coupled AMAN & DMAN operations and the Integrated RWY Sequence operations with use cases in nominal and non-nominal conditions (output from this SAF/HP workshop included directly into this report).

In the V3 phase dedicated Safety areas for Concept 1 has been addressed as a part of RTS activities in December 2018 and January 2019, included into the Validation Exercise Reports. Also see Concept 1 SAF Results in Annex C.

In the framework of SESAR 2020 PJ02-08, the PJ02-08 Validation Plan has been developed that considers the Safety Criteria and the different Safety objectives by identifying safety validation objectives. Satisfaction of these safety validation objectives is shown in the PJ02-08 Validation Report.

3.3 Safety specifications for Concept 3

3.3.1 Operational Environment, Key Properties and Airspace User Requirements

Please look into the SPR-INTEROP/OSED Part I [5] for the operational environment, key properties and Airspace User Requirements.

3.3.2 Relevant Pre-existing Hazards

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] provides 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 the PJ02.08 Increased Runway Throughput based on local ROT characterization (ROCAT) (Concepts 3), this sub-section presents the relevant aviation hazards (that pre-exist in the operational environment before any form of de-confliction has taken place).

The safety-relevant impact of the change brought in by the Enhanced ROT Concept 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 19.

Pre-existing Hazards [Hp]	ATM-related accident type & AIM model
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
Hp#3 "The preceding landing aircraft are not clear of the runway-in-use"	Runway Collision (RC) & associated AIM

Table 19: Pre-existing hazards relevant for the PJ02-08 ROCAT Concept

3.3.3 SAfety Criteria

This section defines the set of SAfety Criteria applicable to the operational scenarios for the Enhanced Prediction of ROT based on aircraft type Concept.

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 3.3.2) and it needs to be consistent with the SESAR safety performance targets defined by PJ 19.04.

Two sets of safety criteria are formulated:

- A first one aimed at ensuring an appropriate Spacing minima design i.e. the computation of ROT values, which if correctly applied, guarantee safe operations on final approach segment and initial common approach path respectively; (this is can be done by means such as data collection, statistical analysis and methods based on theoretical model such as machine learning techniques used for concept 3 RTS)
- A second one aimed at ensuring correct Spacing and Separation delivery i.e. that the ROCAT is correctly applied by ATC.

Note that this safety assessment considers the use case where ROCAT is applied with a Separation Delivery Tool (due to the high number of ROT spacing values to be applied), as this is the use case where there is a change compared to today's operations. The use case where the Enhanced ROT is used to define different MRS values in the ICAO or RECAT-EU schema (or any other schemas with up to six WT categories) where there is no need for the Separation Delivery Tool, is considered no different from today's operations and hence it will not be treated in this safety assessment.

SPACING MINIMA DESIGN

Regarding the design of ROCAT:

- on risk of Runway Conflict when ATCO correctly applies a wrongly computed ROT (see RP2.4 in RWY Col model):

R-SAC#1: The probability per approach of runway conflict resulting from Conflicting ATC Clearances when correctly applying ROCAT shall not be higher than the probability for a reference aircraft type pair in current operations

The strategy intended for meeting the above **R-SAC#1** will rely upon data collection, statistical analysis and methods based on a theoretical modelling.

SPACING AND SEPARATION DELIVERY

RWY Collision accident:

A SAC is defined in order to cap the safety risk for the case where ROCAT is not correctly applied, with potential risk of runway conflict.

- on risk of runway conflict resulting from Conflicting ATC Clearances (see RP2.4 in RWY Col model which might be caused by e.g. spacing management by APP ATCO without considering ROT constraint and which outcome is mitigated by B3A: Runway Monitoring involving e.g. a Go Around instructed by TWR ATCO):

R-SAC#F1: The probability per approach of runway conflict resulting from Conflicting ATC Clearances due to the incorrect application of ROCAT shall not be greater compared to current operations

Safety assurance strategy for R-SAC#F1:

The strategy intended for meeting the R-SAC#F1 relies upon qualitatively showing that the use of the Separation Delivery Tool will significantly reduce the frequency of the wrong application of ROCAT.

MAC and WAKE FAP accident:

Regarding the **potential side effect** of applying ROCAT (applied to non-wake and non-MRS constrained pairs) **on the separation delivery of the wake and MRS constrained pairs**, via impact on ATCOs workload or Situation Awareness, the following need to be considered:

- on risk of Imminent infringement of the radar separation minima during interception and final approach path (see in AIM MAC FAP model MF5.1 & MF5.2):

M-SAC#F1: The probability per approach of Imminent infringement during interception & final approach shall be no greater in operations with Enhanced ROT spacing minima compared to current operations

- on risk of Imminent infringement (wake) during interception and final approach (related to wake constrained aircraft pairs) (see in AIM WT model WE 8):

W-SAC#F1: The probability per approach of Imminent infringement (wake) of wake constrained pairs during Interception & final approach shall be no greater in operations with ROCAT compared to current operations

Safety assurance strategy for M-SAC#F1 and W-SAC#F1:

- recording the MRS/Wake separation infringements in the solution scenario and comparing it with the number of MRS/Wake separation infringements in Baseline (from RTS, acknowledging the limited statistical relevance in relation to the rare occurrences);
- expert-based analysis of failure causes, risk assessment and mitigation.

3.3.4 Mitigation of the Pre-existing Risks – Normal Operations

3.3.4.1 Operational Services to Address the Pre-existing Hazards

The concept under assessment is applicable to the final approach operations from interception until the aircraft has vacated the runway. Therefore, both Approach Control Service and Aerodrome Control Service are impacted. The Air Traffic Management / Air Navigation (ATM/ANS) services listed in Table 200 below have been considered relevant for these concepts:

ID	Air Navigation Service Objective	Pre existing Hazard
Approach and Landing		
SP1a	Maintain spacing/separation between aircraft during interception of the final approach path	**Hp#2a** (MAC risk)
SP1b	Maintain spacing/separation between aircraft on the same final approach path	**Hp#2a** (MAC risk)
SP2	Maintain aircraft separation between successive arrivals	**Hp#3** (Rwy collision risk)

	on the Runway Protected Area (RPA)	

Table 20: Relevant ATM/ANS and Pre-existing Hazards

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

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 we need to interpret, from a safety perspective, the OSED Operational Concept specification (i.e. how the PJ02-08 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 PJ02-08 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 Enhanced ROT concept as a series of continuous processes described through the Use Cases. That 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.

Table 21 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 provided with a Separation Delivery Tool in order to be able to apply ROCAT concept (based on aircraft type and runway) at interception and on the final approach segment	*"Increased RWY Throughput based on local ROT characterization (ROCAT)"*	SP1a SP1b	M-SAC#F1 W-SAC#F1 R-SAC#F1
	When applying ROCAT, ATC shall provide correct spacing from final approach path acquisition until landing such that to ensure the correct spacing minima delivery based on correctly computed separation indicators	As above	SP1a SP1b SP2	M-SAC#F1 W-SAC#F1 R-SAC#1
	The Target Distance Indicators shall be calculated and displayed to correctly and accurately represent the greatest constraint out of wake separation minima, MRS, leader aircraft ROT	As above	SP1a SP1b SP2	M-SAC#F1 W-SAC#F1 R-SAC#1
	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	As above	SP1a	M-SAC#F1 W-SAC#F1
	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	As above	SP1b SP2	M-SAC#F1 M-SAC#F2 R-SAC#1

Table 21: Safety Objectives (success approach) Normal Conditions

3.3.5 Concept 3 Operations under Abnormal Conditions

The purpose of this section is to assess the ability of operations based on the new Enhanced ROT minima 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 the ROCAT use cas or conditions external to the scope of the new System which are not under control).

3.3.5.1 Identification of Abnormal Conditions

The following abnormal conditions have been identified in PJ02.01 and are also relevant for this solution concept :

ID	Abnormal Scenario
1	Change of Aircraft landing runway intent (with the Separation Delivery Tool)
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 ITD computation
6	Flight Crew Notification of Aircraft Speed non-conformance
7	Late change of landing runway (not planned)
8	Scenario specific spacing requests (e.g. unforeseen need for RWY inspection)

Table 22: Abnormal scenario

1/ CHANGE OF AIRCRAFT LANDING RUNWAY INTENT

No change introduced by this solution compared to PJ02.01.

Mitigation SO 103 also applies to concept 3. (see next section for Mitigation)

2/ ABNORMAL PROCEDURAL AIRCRAFT AIRSPEED AND/OR ABNORMAL STABILIZED APPROACH SPEED

No change introduced by this solution compared to PJ02.01.

Mitigation SO 102 also applies to concept 3. (see next section for Mitigation)

3/ LEAD AIRCRAFT GO-AROUND

No change introduced by this solution compared to PJ02.01.

Mitigation SO 102 also applies to concept 3. (see next section for Mitigation)

4/ DELEGATION OF SEPARATION TO FLIGHT CREW

No change introduced by this solution compared to PJ02.01. No mitigation derived as there is no change introduced by the concept compared to today's operations.

5/ ACTUAL WIND ON FINAL APPROACH DIFFERENT FROM THE WIND USED FOR FTD/ITD COMPUTATION

No change introduced by this solution compared to PJ02.01.

Note the impact on the computed/displayed FTD only applies to concept 3 if the ROCAT is applied in combination with a TB-mode. The impact on the computed/displayed ITD applies for all pairs.

Mitigation: SO 101. (see next section for Mitigation)

6/ FLIGHT CREW NOTIFICATION OF AIRCRAFT SPEED NON-CONFORMANCE

No change introduced by this solution compared to PJ02.01.

Mitigation SO 104 also applies to concept 3. (see next section for Mitigation)

7/ LATE CHANGE OF LANDING RUNWAY - NOT PLANNED

No change introduced by this solution compared to PJ02.01.

Mitigation SO 105 also applies to concept 3. (see next section for Mitigation).

8/SCENARIO SPECIFIC SPACING REQUESTS (E.G. UNFORESEEN NEED FOR RWY INSPECTION)

No change introduced by this solution compared to PJ02.01.

Mitigation SO 105 also applies to concept 3. (see next section for Mitigation).

3.3.5.2 Potential Mitigations of Abnormal Conditions

The following Safety Objectives considering the abnormal conditions identified above have been derived for arrivals, applicable only with the separation delivery tool:

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).	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	7 and 8

Table 23: List of Safety Objectives (success approach) for Abnormal Operations for the PJ02-01 Arrivals Concepts Solutions

3.3.6 Mitigation of System-generated Risks (failure approach)

3.3.6.1 Identification and Analysis of System-generated Hazards

The following is the hazards related to concept 3:

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
SHz#1	Runway Conflict due to landing clearance in conflict with another landing (ROT not respected)	SO-1	the situation when an arrival aircraft is landing on a runway which is being used by a previous landing, the two aircraft being thus in conflict, but where the situation is solved by the corrective action of the TWR ATCO	Tower ATCO initiating go-around	RWY-C SC3

Table 21: System-Generated Hazards and Analysis

3.3.6.2 Derivation of Safety Objectives (integrity/reliability)

ID	Safety Objectives
SHz#1	The frequency of occurrence of a runway conflict due to landing clearance in conflict with another landing (ROT not respected) shall not be greater than 1E-5 per movement.

Table 22: Safety Objectives (integrity/reliability)

3.3.7 Achievability of the Safety Criteria

The exercise safety validation objectives and the related success criteria are summarized in Table 25 below, for all the safety relevant exercises performed in the frame of PJ02.08. The last column indicates the Safety Criteria that are covered by each validation exercise or other validation methods.

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage
VAL-EXE 02-08.V3.005: RTS conducted by EUROCONTROL to assess the operational feasibility and acceptability of the AO-0337 "Increased Runway Throughput based on local ROT characterization (ROCAT) concept when combined with the ORD tool (EUROCONTROL LORD tool with FTD and ITD) (AO-0306) and TB PWS-A separation scheme (AO-0328) under segregated runway operations to optimise runway throughput capacity.	**OBJ-PJ2.08-V3-VALP-SA3** To assess the impact on operational safety of applying ROCAT.	**CRT-PJ02.08-V3-VALP-SA1-001** There is evidence that the level of operational safety is maintained and not negatively impacted when ROCAT is applied compared to the current operations.	**R-SAC#1**
		CRT-PJ02.08-V3-VALP-SA1-002 There is evidence that the level of operational safety is maintained and not negatively impacted when ROCAT is applied compared to the current operations.	**R-SAC#F1**
		CRT-PJ02.08-V3-VALP-SA1-003 There is evidence that ROCAT does not increase the likelihood of go around compared to the current operations.	**M-SAC#F1** **W-SAC#F1**

Table 235: validation objectives and related success criterias

3.3.8 Validation & Verification of the Safety Specification

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 have been derived based on information collected during the HP&SAF Scoping & Change assessment workshop, which took place on the 23th of November 2017. The workshop gathered significant participation of the PJ02.03 and PJ02.08 operational and technical experts. During that workhop in addition to the solution 3 gathered information, questions related to ROT and the use of the runway were raised and allowed to formulate the safety criteria for concept 3.

Furthermore, a HAZID identification & safety requirements validation workshop was organised on March 29th 2019 at Heathrow Airport premises in order to address the concept covered to date for solution 3 but allowed also to cover some major aspects of solution 8 concept 3. The workshop was facilitated by SAF and HP experts from EURCONTROL 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 **Fel! Hittar inte referenskälla.**.

3.4 Safety specifications for Concept 4

3.4.1 Operational Environment and Key Properties

Concept 4 and a relevant Operational Environment are described in SESAR 2020 Solution 02-08 SPR INTEROP OSED Part I [5]. However, in order to maintain clarity, the main highlight of the Enhanced ROT Predictor and its Operational Environment will be outlined here.

Enhanced ROT Predictor is an advisory tool that is situated in the Tower Runway Controller CWP. This tool provides ATCO with optimal ROT and exit taxiway estimate a fixed time before arrival. This estimate is communicated to the Flight Crew and used for tactical planning purpose by the ATCO.

This concept is the simplest operational use of the dynamic ROT prediction. As such it is intended for **medium airports with very high peak runway utilisation** (usually airports with very significant seasonal traffic variability). Enhanced ROT Predictor is currently not designed to function on an airport where two or more runways are dependent. Therefore, it can be configured for environments with either single runway or multiple independent runways (in practice ECAC medium airports have at most two runways that can be utilised by commercial traffic).

As a result of PANSA FTS exercise (EXE.02-08.V3.008, see Pj.02-08 Validation Report) it has been established that the necessary conditions for Concept 4 to bring operational benefit are the following:

1. Mixed mode traffic, separation on approach at most 4.75 NM
2. Segregated mode, separation on approach at most 2.25 NM

Since the latter is not considered operationally feasible at the moment only the mixed mode case is considered further in the present document.

The traffic intensity must be very high for an extended period of time (at least 1 uninterrupted hour intense peak hour) and such conditions will be considered here.

3.4.2 Airspace Users Requirements

For the airspace users the solution is not expected to bring neither significant benefits nor operational consequences. The main performance gain – increase of peak hour traffic intensity – is mostly aimed at aerodrome and local ANSP – see SESAR 2020 Solution 02-08 SPR INTEROP OSED Part I [5].

3.4.3 Relevant Pre-existing Hazards

Concept 4 is contributing to operations during final approach and landing roll. Therefore, based on Guidance E.2 of [2] we have identified a list of pre-existing hazards relevant to Concept 4 functionality in those flight phases.

Hz#1 situation leading to collision with another aircraft or a ground vehicle on RWY

Hz#3 situation leading to collision with an obstacle, ground vehicle, another aircraft on apron or TWY (e.g. situation in which the intended 3-D[1] route of a taxiing aircraft would lead to collision with an obstacle, a ground vehicle or another aircraft on apron or TWY) ground or close to ground on landing / take-off

Hz#4 adverse weather conditions like violent wind effects (thunderstorm, windshear) affecting aircraft vertical speed or tailwind or severe crosswind on landing / take-off

Hz#5 low runway-surface friction

3.4.4 SAfety Criteria

As increasing safety is not the primary objective of Solution PJ.02-08 Concept 4 we have appointed the following Safety Criteria that express the ambition to maintain the level of operational safety while introducing Enhanced ROT Predictor into operations. The Safety Criteria are associated with few AIM perspectives. For each SAC the relevant AIM perspective is specified.

SAC-4-11 With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of planned tactical taxiway conflicts shall not increase.

Associated AIM and barrier: Taxiway Collision B4

Associated AIM precursor: TP3B Planned "Taxiway Conflict"

Potentially impacted AIM functions: TB4.1.1 GC creates conflict with other a/c and TB4.1.3 GC creates conflict with vehicle

Rationale:

In case system prediction is wrong the impacted aircraft diverges from previously planned conflict free taxi route. This may potentially negatively impact ground movement management.

SAC-4-12 With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of imminent runway incursions shall not increase.

Associated AIM and barrier: Runway Collision B4 and B8

Associated AIM precursor: RP4A Imminent Inappropriate Runway Entry (ATC); RP4D Imminent Inappropriate Take-off

Potentially impacted AIM functions: RB4.1.2.2 Misjudges separation with other users of the runway, RB8.1.1.2 Misjudgement of Runway Separation.

Rationale:

In case system prediction is wrong the impacted aircraft may take different exit and take longer to exit runway. This can cause additional mental load and be detrimental to situational awareness leading to mistakes in runway entry management.

[1] In the horizontal dimensions and time

SAC-4-21 With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of imminent inappropriate landings shall not increase.

Associated AIM and barrier: Runway Collision B7

Associated AIM precursor: RP4C Imminent Inappropriate Landing

Potentially impacted AIM functions: RB7.1.1 Insufficient spacing between landings, RB7.1.2 Landing Clearance error by ATCO.

Rationale:

In case system prediction is wrong the assumed final approach spacing may not be enough as a consequence of longer ROT. This may lead either to a go around or subsequently to RP3C (Premature Landing Incursion). In both cases the mental load and procedural demands on ATCO are significantly increased.

This criterion also covers cases where runway friction is degraded and the system does not take this properly into account. However, AIM model for Runway Excursion is not finalised allowing only for partial usage in present Safety analysis.

3.4.5 Mitigation of the Pre-existing Risks – Normal Operations

3.4.5.1 Operational Services to Address the Pre-existing Hazards

All hazards identified in Section 3.4.3 can be considered addressed by Concept 4 Enhanced AROT Predictor. The corresponding Operational Services have been designated: AETP – AROT and Exit Taxiway Provision, ERSI - Evaluation of Runway Surface Influence, MIFA - MET Influence on Final Approach.

Designations used for accidents/incidents in the table below are as follows: RWYCol – Runway Collision, TWYCol – Taxiway Collision, RE – Runway Excursion.

ID	Service Objective	Pre-existing Hazards [Hp xx]
AETP	Provide ATCO reliable and achievable exit taxiway and ROT forecast for arriving flights.	**Hz#1** (RWYCol risk) **Hz#3** (TWYCol ris)
ERSI	This service takes into account runway surface condition and reflects this in its predictions.	**Hz#5** (RE risk)
MIFA	This service takes into account the MET situation on the final approach and surface providing ROT and Exit TWY recommendations.	**Hz#4** (RE risk)

Table 24: ATM and Pre-existing Hazards

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

We use three AIM models for barrier designation (the abbreviations are corresponding to the ones used in previous section. Each barrier will be designated with: [AIM model] / [Barrier Reference]. The barrier references are corresponding to those defined in [8] and [2].

Ref	Phase of Flight / Operational Service	Related AIM Barrier	Achieved by / Safety Objective [SO xx]
	Final Approach / AETP	TWYCol / B4 RWYCol / B4 RWYCol / B7 RWYCol / B8	SO-1 SO-2 SO-3
	Final Approach / ESRI	RE / REB4	SO-4
	Final Approach / MIFA	RE / REB5	SO-5

Table 25: Concept 4 Operational Services & Safety Objectives (success approach)

ID	Description
	Predicted exit taxiway shall be achievable by the arriving aircraft.
	Predicted ROT shall not be underestimated.
	ROT and exit taxiway prediction shall be repeatedly verified and updated according to approach execution and weather conditions.
	Enhanced ROT Predictor shall be provided the most up to date runway surface condition information.
	Enhanced ROT Predictor shall be provided up to date aerodrome MET data.

Table 26: List of Safety Objectives (success approach) for Normal Operations

3.4.5.3 Analysis of the Concept for a Typical Flight

Due to simplicity of Solution PJ.02-08 Concept 4 and the fact that it addresses only Final Approach and ATCO Take-off Management this analysis has been omitted in the present safety assessment.

3.4.6 Concept 4 Operations under Abnormal Conditions

3.4.6.1 Identification of Abnormal Conditions

The following abnormal conditions have been deemed relevant for Enhanced ROT Predictor:

Abn#1 Sudden change of weather conditions along approach trajectory

Abn#2 Approaching aircraft performance is different than normal

Abn#3 Approach execution irregularities

Abn#4 Missed approach.

Abn#5 Surveillance data connection is lost or data is erroneous

Abn#6 MET data connection is lost or data is erroneous

3.4.6.2 Potential Mitigations of Abnormal Conditions

Ref	Abnormal Conditions	Operational Effect	Mitigation of Effects / [SO xx]
	Abn#1	Approach execution may change significantly leading to inability to reach predicted exit taxiway.	The prediction should be updated repeatedly based on approach execution (SO-3)
	Abn#2	Approach and landing roll execution may be different from what is expected from the aircraft of a given type.	This is partly mitigated via updates of prediction based on approach execution (SO-3). However, if the performance degradation is significant and affects landing roll exclusively (e.g. braking device malfunction) this cannot be mitigated on the system level. System may give incorrect prediction.
	Abn#3	Approach is executed in a way that is not expected or different than prescribed.	The prediction should be updated repeatedly based on approach execution (SO-3)
4	Abn#4	Approach is interrupted, missed approach procedure is executed.	Proper and safe missed approach procedure definition and execution – not relevant for Concept 4.
5	Abn#5 Abn#6	V3 PANSA FTS 8 exercise [7] has demonstrated that system has low resilience to random	In case of any input for which the system was configured is missing the system should cease function and

		missing inputs and the prediction quality drops significantly.	generate appropriate message (SO-6). In case of erroneous data some QC procedures can be applied (SO-7) but certain types of errors in inputs cannot be mitigated at the system level resulting in possibly erroneous predictions.

Table 27: Additional Safety Objectives (success approach) for Abnormal Conditions

ID	Description
	In case any input for which the system was configured is missing or found erroneous Enhanced AROT Predictor shall cease function and display appropriate error message until issue is resolved.
	Enhanced AROT Predictor shall run quality check on its input data.

Table 28: List of Safety Objectives (success approach) for Abnormal Operations

3.4.7 Mitigation of System-generated Risks (failure approach)

3.4.7.1 Identification and Analysis of System-generated Hazards

The analysis summarised below is a result of safety related debriefings during PANSA RTS 4 exercise [7] as well as off-line consultation with domain safety experts. The severity AIM model designations are in as in section 3.4.5, the severity designations correspond to Guidance G.3 in [2].

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
SHz#1	Predicted exit taxiway/ROT is not achievable by the aircraft.	SO-1 SO-2 SO-4	ATCO planned exit is not met. ROT is greater than predicted. This may result in a go-around	ATCO vigilance – lack of runway entry or landing	RWYCol / RP6 – Imminent failure to exit (non-ATC) [RWY-

		SO-5	instruction for a follower aircraft.	clearance for the following aircraft.	SC4] Also may result in TWYCol / TP3 – Taxiway Conflict [TWY-SC5]
SHz#2	Predicted ROT and exit taxiway are not in agreement with the execution of final approach.	SO-3 SO-6 SO-7	As for SHz#1	As for SHz#1	As for SHz#1

Table 29: System-Generated Hazards and Analysis

3.4.7.2 Derivation of Safety Objectives (integrity/reliability)

For setting the following Safety Objectives the methodology presented in Guidance G of Reference [2] was used. Few details need to be given for the calculations leading to formulating the failure approach Safety Objectives. As the setting of IM (impact Modification factor) is left to discretion of the safety assessment teams we have chosen to set IM=3 for our Safety Objectives. The reasoning was as follows:

- Safety analysis for Concept 4 usually indicates participation of two aircraft in hazardous situation (IM=10 according to guidance [2]).
- However, operational expert judgement is that related safety barriers are not readily broken as a result of Enhanced AROT Predictor errors (IM<1 according to guidance [2]) as Concept 4 is just a tactical advisory system.
- As a result we have chosen to multiply two impact factors ($IM=IM_{A/C}*IM_{barrier}$). Setting $IM_{barrier}$=0.3 results in IM=3.

N for severity class TWY-SC5 has been set to 300 (lacking in guidance [2]).

ID	Safety Objectives
SHz#1	(SO-8) The likelihood that incorrect prediction of exit taxiway or ROT will result in failure to timely exiting the runway shall be less than 1.1E-6 per movement.
SHz#1	(SO-9) The likelihood that incorrect prediction of exit taxiway or ROT will result in taxiway conflict shall be less than 1.1E-3 per movement.
SHz#2	(SO-10) The likelihood prediction of exit taxiway or ROT being invalid due to execution of final approach will result in failure to timely exiting the runway shall be less than 1.1E-6 per movement.
SHz#2	(SO-11) The likelihood prediction of exit taxiway or ROT being invalid due to execution

	of final approach will result in taxiway conflict shall be less than 1.1E-3 per movement.

Table 30: Safety Objectives (integrity/reliability)

3.4.8 Impacts of Concept 4 operations on adjacent airspace or on neighbouring ATM Systems

No significant impact on adjacent airspace has been identified as a result of safety assessment of PJ.02-08 Concept 4.

3.4.9 Achievability of the Safety Criteria

There were two exercises that were validating Concept 4: EXE.02-08.V3.004 (PANSA RTS) and EXE.02-08.V3.008 (PANSA FTS) [7]. Of these two the RTS exercise was tasked with validating the following safety related objective:

OBJ-PJ02.08-V3-VALP-SA3 To assess the impact of Enhanced Prediction of ROT on operational safety compared to current ROT prediction scheme.

With associated Success Criteria:

CRT-PJ2.08-V3-VALP-SA3-001: There is evidence that the level of operational safety is maintained and not negatively impacted when Enhanced Prediction of ROT is applied compared to the current operations.

The safety implications related to this criterion were measured via questionnaires and debriefings (see [7]).

CRT-PJ2.08-V3-VALP-SA3-002: There is evidence that Enhanced Prediction of ROT does not increase the likelihood of go around compared to the current operations.

The mapping between SAC and the success criteria of OBJ-PJ02.08-V3-VALP-SA3 is as follows:

SAC	Validation Success Objective ID / Validation Success Criterion ID
SAC-4-11	OBJ-PJ02.08-V3-VALP-SA3 / CRT-PJ2.08-V3-VALP-SA3-001
SAC-4-12	OBJ-PJ02.08-V3-VALP-SA3 / CRT-PJ2.08-V3-VALP-SA3-001
SAC-4-21	OBJ-PJ02.08-V3-VALP-SA3 / CRT-PJ2.08-V3-VALP-SA3-002

Table 31 Mapping between SAC and Concept 4 Validation Objectives

3.4.10. Validation & Verification of the Safety Specification

Independent safety process for Concept 4 has been initiated very late in the project lifecycle allowing only for very rudimentary implementation of SESAR SRM [1]. This has been mostly achieved via series of PANSA RTS 4 debriefings being enriched with extended safety discussions. Except for the debriefings only off-line expert judgement has been used to assist in the present analysis. According to SESAR Ethics regulations we are not at liberty to disclose personality of operational experts involved in the process as they were also the validators for PANSA RTS 4 exercise. The remaining staff involved in safety process for Concept 4 is named in Table 32.

Name / Company	Role or expertise
Jacek Kopeć / UNIWARSAW / PANSA (B4)	Safety Task Leader for PJ.02-08 Concept 4, Validation Leader for PJ.02-08 Concept 4
Mateusz Sokołowski / PANSA (B4)	PANSA PJ.02-08 PoC
Nicolas Giraudon / EGIS	Safety Expert

Table 33: Personnel engaged in Concept 4 safety assessment (except for operational experts)

4 Safe Design at SPR Level

4.1 Scope

This section addresses the following activities:

- Safe Design at SPR Level for Concept 1 and 2 in section 4.2 including;
  - Functional and SPR-level model
  - Analysis of the SPR-level model
  - Design Analysis
  - Achievability of the Safety Criteria
  - Realism of the SPR-level design Safe Design
  - Validation and Verification of the Safe Design at SPR Level

- Safe Design at SPR Level for Concept 4 in section 4.3 including;
  - Functional and SPR-level model
  - Analysis of the SPR-level model
  - Design Analysis
  - Achievability of the Safety Criteria
  - Realism of the SPR-level design Safe Design
  - Validation and Verification of the Safe Design at SPR Level

4.2 Concept 1 and 2 Safe Design at SPR Level

4.2.1 The Concept 1 and 2 Functional Model

This section contains a global functional model updated according to the basis of the information found in the OSED.

A functional model is a structured flow-representation of the main functions of a system (application) with the aim to define the relationships between the related inputs and outputs. The functions broadly translate into processes that transform input to output. Therefore, the functional model is sometimes referred to as a process model.

It provides an efficient baseline for functional assessment (safety and performance assessment) because it decomposes the system (application) into structured subsystems and processes and hereby visualises the critical transactions. Therefore, the functional model will be used as a baseline for a systematic assessment of a system (application).

As regards the Operational Performance Assessment, the functional model will be used as a support to develop the OPA. The different interactions between R&P functionalities and input/output information will be analysed, thus leading to the identification of causes underpinning potential performance issues. The approach assumes that the Integrated Runway Sequence functionalities operate as expected under nominal conditions and assesses potential drops on performance levels caused by incorrect or non-existent input/output parameters. One of the expected benefits will be related to the number of movements on the runway (take-off and landing) realized in a given period. The solution reflects the scenario based on a tightly integrated and collaborative configuration.

4.2.1.1 Description of the Functional Model

In order to identify the concept of the Integrated Runway Sequence function, as well as its inputs, outputs, internal processes and interaction with external agents (Routing and Planning Function, ATC) in a visual way, a block diagram was defined based on the functional description provided in the final OSED [5]. Afterwards, the different performance issues identified will be referred to the different unique functions of this diagram.

Generally speaking, the Integrated Runway Sequence function will be in charge of internally calculating the arrival sequence.

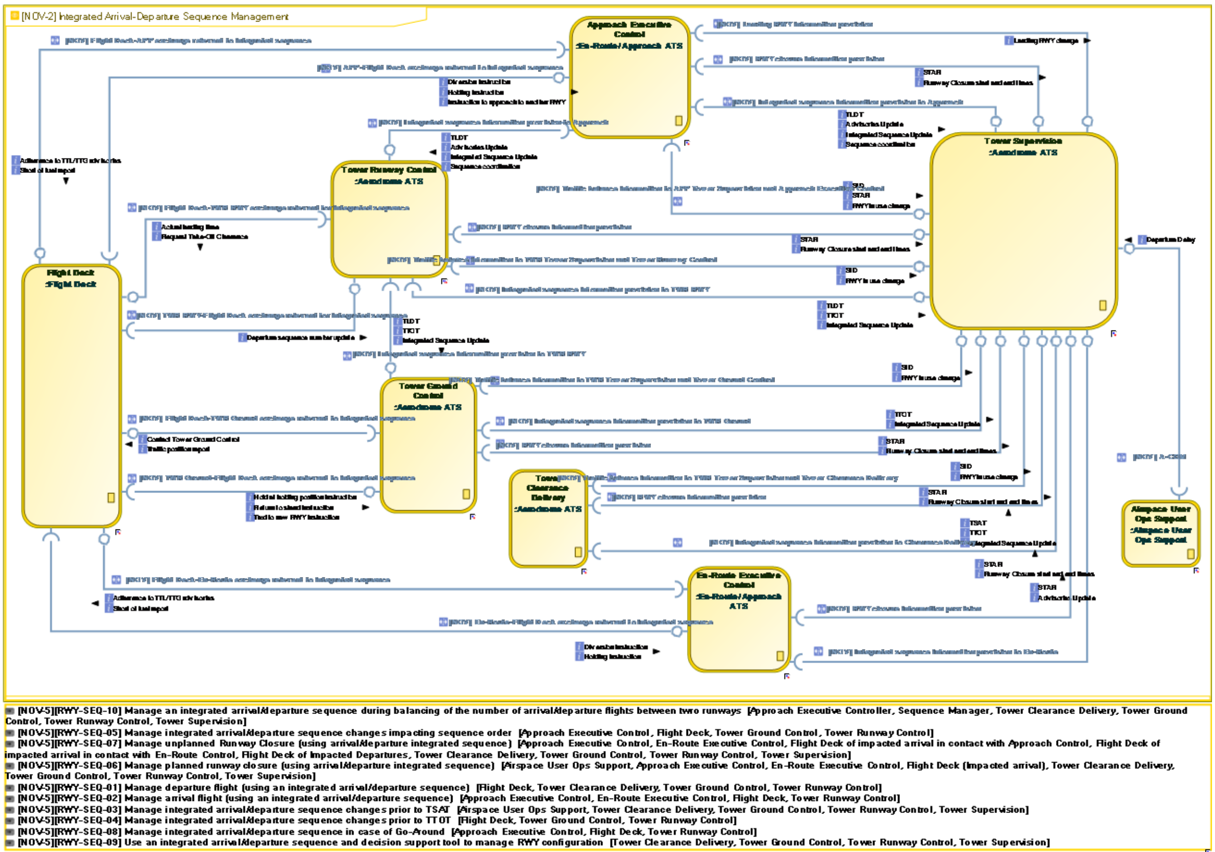


Figure 5: Functional model for the integrated arrival and departure flow management

The final OSED [5] provides all details related to the above functional model as well as for each functional model dedicated to the use cases.

4.2.2 Concept 1 and 2 SPR-level Model

The SPR-level Model in this context is a high-level architectural representation of the Solution System design that 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.

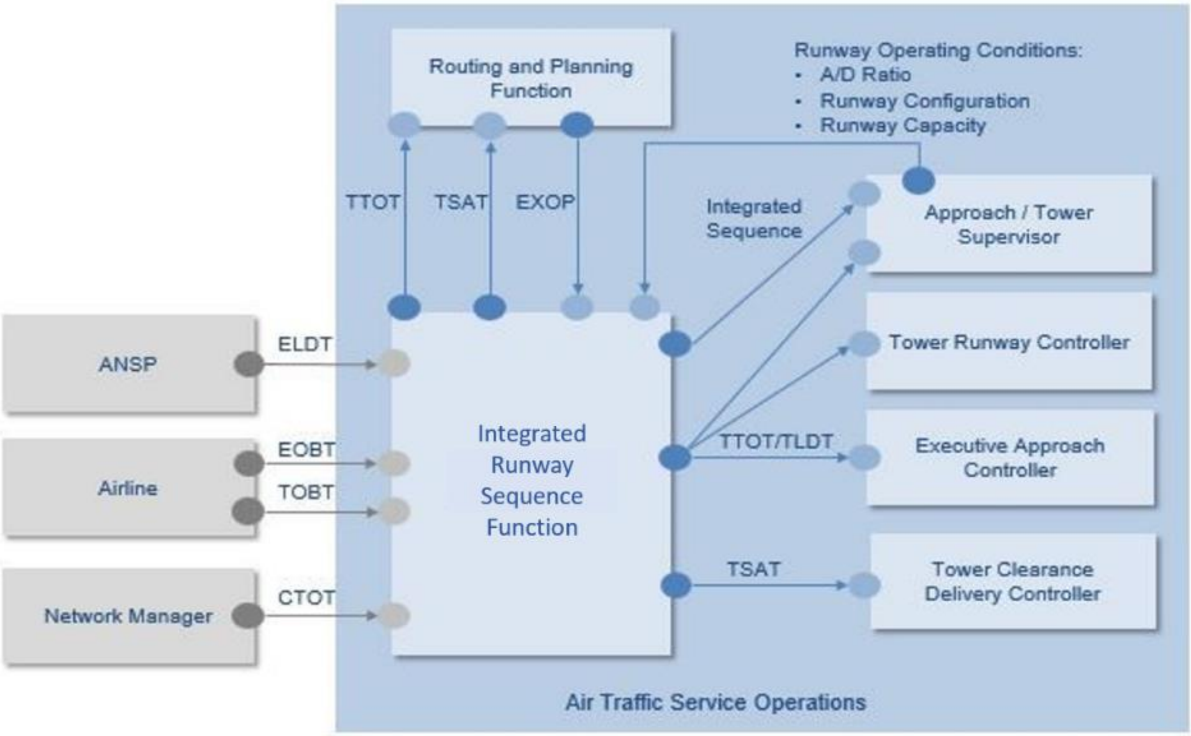


Figure 6: PJ02-08 overview of Integrated Runway Sequence

The NSV4 diagrams below for Concept 1 and 2 (also available in MEGA with a better resolution), describe how the Runway Sequence Flow Management (RSFM) receives as input the arrival sequence provided by AMAN and the departure sequence provided by DMAN

The AMAN arrival sequence (resp. DMAN departure sequence) is built taking into account the current airport/runway configuration and the current arrival/departure integrated sequence to manage room in the sequence for the departure (resp. arrival) traffic in case of mixed mode runway.

Based on the received information, RSFM calculates the arrival/departure integrated sequence over the runways, optimising the runway usage and provides target times (TLDTs, TTOTs and also TSATs in pre-departure phase).

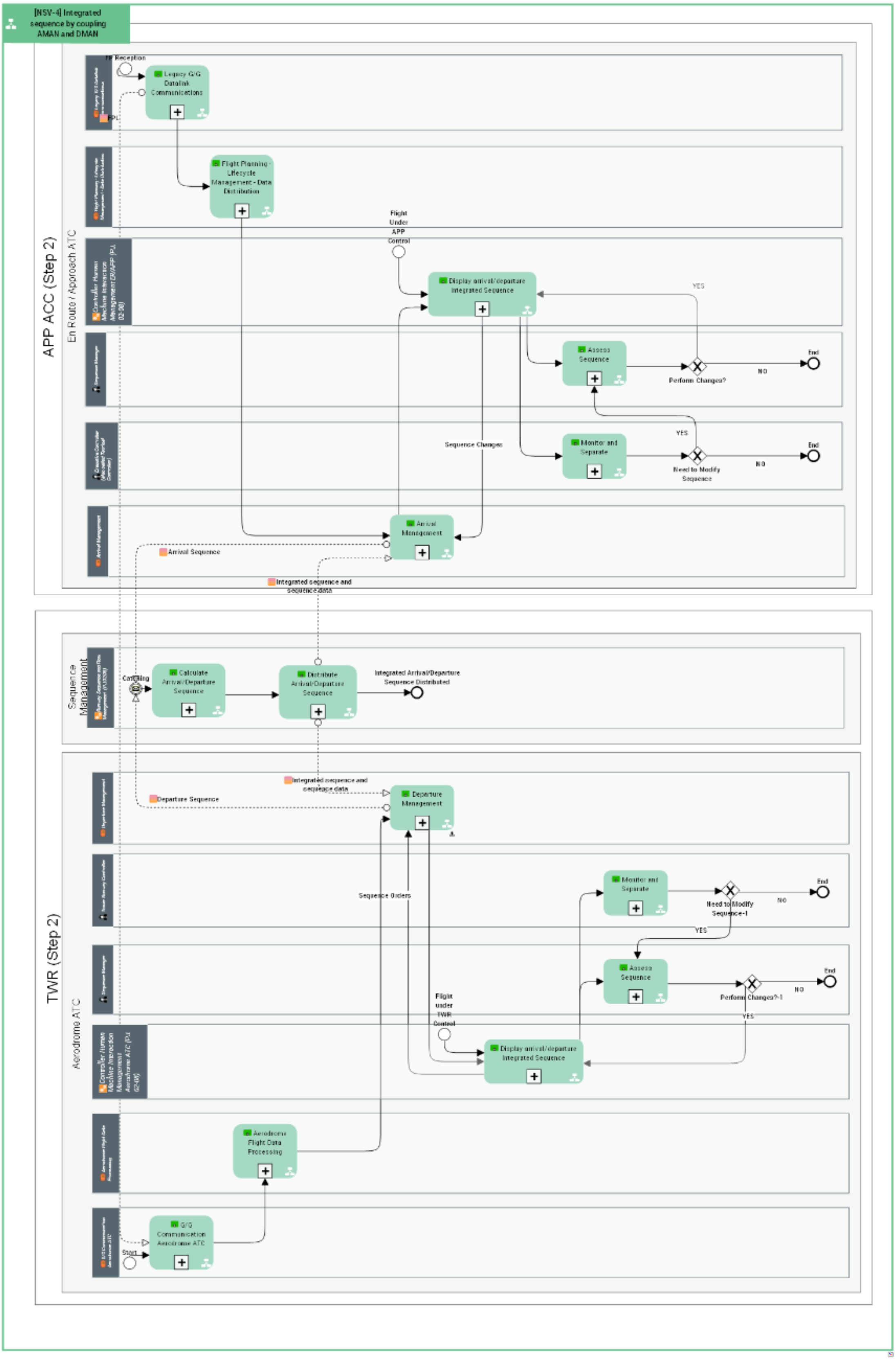


Figure 7: NSV-4 diagram for PJ.02-08 Concept 1 (AMAN, DMAN and RSFM)

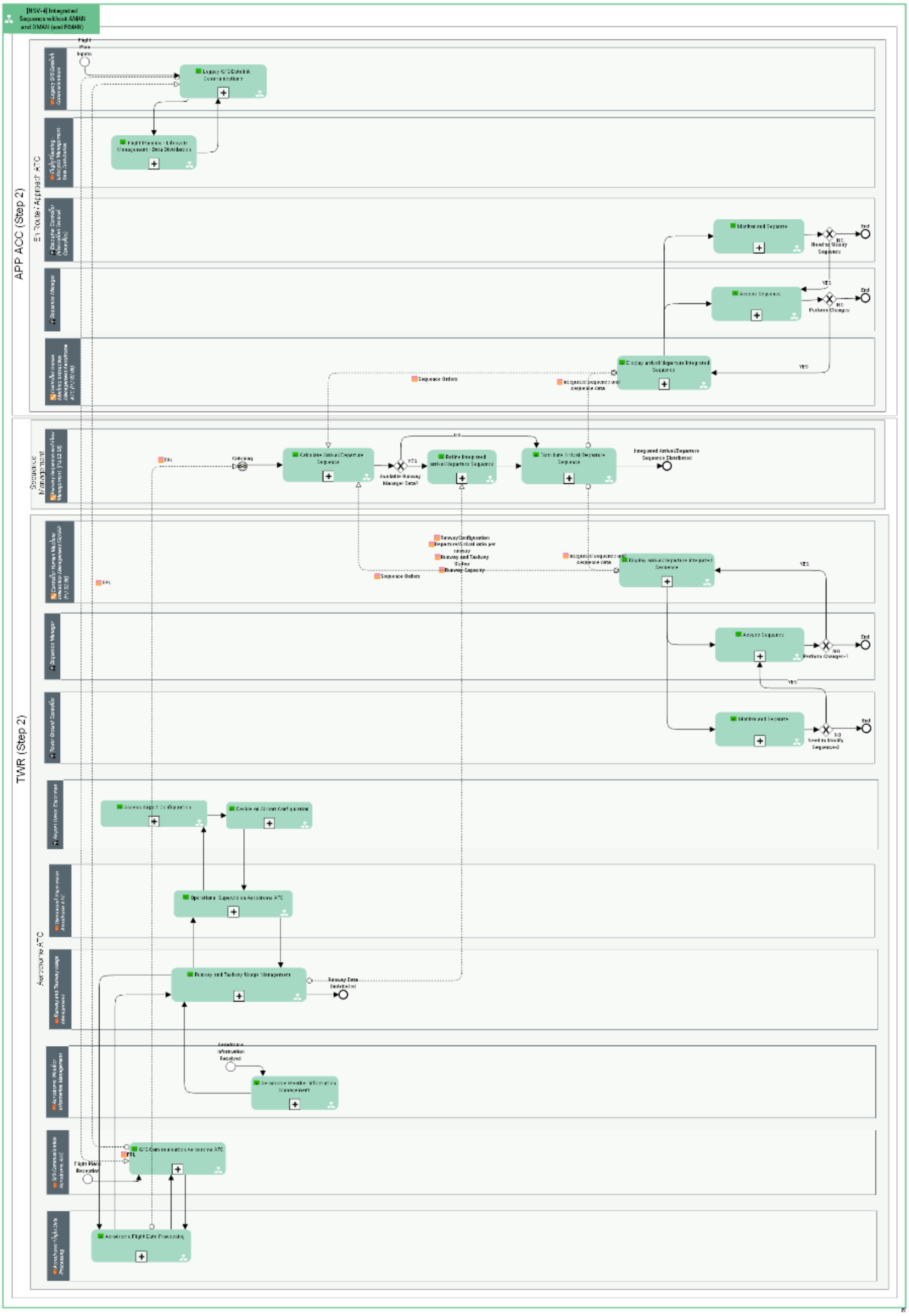


Figure 8: NSV-4 diagram for PJ.02-08 Concept 2 (RSFM+RTUM)

4.2.2.1 Description of SPR-level Model

4.2.2.1.1 Aircraft Elements

There are no new Aircraft Elements in the Integrated Runway Sequence function.

4.2.2.1.2 Ground Elements

The Ground Element Introduced is the Integrated Runway Sequence function which calculates an integrated sequence using dynamic Arrival Free Interval and optimizing wake vortex separation of arriving traffic.

4.2.2.1.3 External Entities

The External Entities do not change compared to standalone AMAN and standalone DMAN.

4.2.2.1.4 Task Analysis

The task analysis shows that the tasks for all controllers remain the same regarding their interaction with airspace users as they are with the standalone AMAN and standalone DMAN; the main difference is that controllers has to follow as much as possible the sequence provided by the Integrated Runway Sequence function.

- **Approach Supervisor**
  - Decides on nominal Arrival capacity in terms of separation values,
  - Coordinates with the APOC or with the Tower Supervisor and ACC regarding the measures related to Demand Capacity Balancing,
  - Coordinates with Tower Supervisor on the capacity depending on the current and future weather situation (used in the Integrated Runway Sequence function),
  - Coordinates with ACC the flow admitted into TMA based on arrival capacity.

- **Tower Supervisor**
  - Decides on runway(s) for landing and take-off in co-operation with all concerned partners
  - Decides on nominal Departure Capacity in terms of separations,
  - Coordinates with APOC or with the Approach Supervisor regarding the measures related to Demand Capacity Balancing and traffic smoothing measures,
  - Coordinates with the Approach Supervisor on the runway configuration and associated capacity depending on the current and future weather situation (used in the Integrated Runway Sequence function),
  - Maintains close liaison with the Airport Operator with respect to the daily inspection of the movement area, the aerodrome lighting system, the marking of obstructions, snow clearance etc…,
  - Implements and discontinues limited visibility operations (CAT II or CAT III) after liaison with Airport Operator and Approach Supervisor.

- **Approach Executive Controller**
  - Sequence arrivals (clearances) to conform with the separations provided by the Integrated Runway Sequence function proposals
  - Ensures sufficient spacing between successive arrivals upon their turn onto final and departures according to the spacing proposed by the Integrated Runway Sequence function.

- **Tower Clearance Delivery Controller**
  - In the Integrated Runway Sequence function context, his role and responsibility are concentrated on the Start-Up approval according to the TSAT and sequence provided by the Integrated Runway Sequence function.

- **Tower Ground Controller**
  - Issue clearances, instructions and permission to aircraft, vehicles and persons operating on the manoeuvring area as required for the safe and efficient flow of traffic, especially he/she:
  - Provides taxi instructions to arriving and departing flights,
  - Follows and complies as much as possible with TSAT sequence for departure flights, in order to perform the TTOT sequence,
  - Provides push-back and start engines clearance in accordance with the Integrated Runway Sequence function proposals,
  - Informs on de-icing procedures.

- **Tower Runway Controller**
  - Sequences departures as much as possible according to the TTOT sequence provided by the Integrated Runway Sequence function.
  - Ensures sufficient spacing between successive arrivals and departures,
  - Issues runway entry and take-off clearance to departing flights in accordance with the TTOT,
  - Manages integration of departures in the arrival sequence in mixed-mode operations according to the Integrated Runway Sequence function proposals,
  - Issues landing clearances to arrival flights
  - If possible, fine tunes sequence for throughput improvement,
  - If necessary, adjusts the sequence for safety.

- **En-route Executive Controller**
  - Depending on the Integrated Runway Sequence function horizon, the En-route Controller has to follow the Target Metering Times and arrival sequence (order and time).

- **Flight Crew**
  - Requests a departure clearance by voice (R/T) or by datalink communications as in previous operations.

4.2.2.2 Derivation of Safety Requirements (Functionality and Performance – success approach)

Table below shows how the Safety Objectives (Functionality and Performance) derived in section 3 map on to the related elements of the SPR-level Model by identifying 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 Integrated Runway Sequence function concepts.

Safety Objectives (Functionality and Performance from success approach)	Mapping to Functional Model Elements	
	Requirement	**Maps on**
SO#1 Integrated Runway Sequence Function N shall support coordination between TWR and Approach	REQ-02.08-SPRINTEROP-FUN1.0001	Integrated Runway Sequence function
	REQ-02.08-SPRINTEROP-FUN1.0002	
	REQ-02.08-SPRINTEROP-FUN1.0013	
	REQ-02.08-SPRINTEROP-FUN1.0015	
	REQ-02.08-SPRINTEROP-HMI1.0001	
	REQ-02.08-SPRINTEROP-HMI1.0002	
	REQ-02.08-SPRINTEROP-HMI1.0003	
	REQ-02.08-SPRINTEROP-HMI1.0004	
	REQ-02.08-SPRINTEROP-SAF1.0001	
SO#2 Integrated Runway Sequence function shall support effective ATC runway management	REQ-02.08-SPRINTEROP-FUN1.0001	Integrated Runway Sequence function
	REQ-02.08-SPRINTEROP-FUN1.0007	
	REQ-02.08-SPRINTEROP-FUN1.0008	
	REQ-02.08-SPRINTEROP-FUN1.0010	
	REQ-02.08-SPRINTEROP-FUN1.0012	
	REQ-02.08-SPRINTEROP-FUN1.0014	
	REQ-02.08-SPRINTEROP-FUN1.0016	
	REQ-02.08-SPRINTEROP-FUN1.0017	
	REQ-02.08-SPRINTEROP-HMI1.0005	
	REQ-02.08-SPRINTEROP-HMI1.0008	
	REQ-02.08-SPRINTEROP-PRF1.0004	
	REQ-02.08-SPRINTEROP-PRF1.0005	
	REQ-02.08-SPRINTEROP-PRF1.0006	
	REQ-02.08-SPRINTEROP-PRF1.0007	
	REQ-02.08-SPRINTEROP-PRF1.0008	

SO#3 Integrated Runway Sequence function shall support managing the sequence in mixed and dependent mode environment	REQ-02.08-SPRINTEROP-FUN1.0001	Integrated Runway Sequence function
	REQ-02.08-SPRINTEROP-FUN1.0007	
	REQ-02.08-SPRINTEROP-FUN1.0010	
	REQ-02.08-SPRINTEROP-FUN1.0012	
	REQ-02.08-SPRINTEROP-FUN1.0017	
	REQ-02.08-SPRINTEROP-HMI1.0008	
	REQ-02.08-SPRINTEROP-PRF1.0004	
	REQ-02.08-SPRINTEROP-PRF1.0005	
	REQ-02.08-SPRINTEROP-PRF1.0007	
	REQ-02.08-SPRINTEROP-PRF1.0006	
SO#4 Integrated Runway Sequence function shall be provided with accurate and correct wake vortex information	REQ-02.08-SPRINTEROP-FUN1.0001	ATC Services
SO#5 Integrated Runway Sequence function shall be provided with reliable demand prediction	REQ-02.08-SPRINTEROP-FUN1.0001	ATC Services
	REQ-02.08-SPRINTEROP-SAF1.0008	
SO#6 Integrated Runway Sequence function needs to be provided with all relevant information for sequencing traffic	REQ-02.08-SPRINTEROP-FUN1.0001	ATC Services
	REQ-02.08-SPRINTEROP-FUN1.0007	
	REQ-02.08-SPRINTEROP-FUN1.0010	
	REQ-02.08-SPRINTEROP-FUN1.0016	
	REQ-02.08-SPRINTEROP-HMI1.0002	
	REQ-02.08-SPRINTEROP-HMI1.0003	
	REQ-02.08-SPRINTEROP-HMI1.0004	

Table 34: Mapping of Safety Objectives to SPR-level Model Elements

ID	Assumptions

AO-01	The safety objectives that apply for a basic AMAN that is not coupled to DMAN still apply to the Integrated Runway Sequence function
AO-02	The safety objectives that apply for a basic DMAN that is not coupled to AMAN still apply to the Integrated Runway Sequence function

Table 35: Assumptions made in deriving the above Safety Requirements

4.2.3 Analysis of the SPR-level Model – Normal Operational Conditions

4.2.3.1 Scenarios for Normal Operations

The use cases are extracted from the OSED [5].

ID	Scenario
[NOV-5][RWY-SEQ-01]	Manage departure flight (using an integrated arrival/departure sequence)
[NOV-5][RWY-SEQ -02]	Manage departure flight (using an integrated arrival/departure sequence)
[NOV-5][RWY-SEQ -03]	Manage integrated arrival/departure sequence changes prior to TSAT
[NOV-5][RWY-SEQ -04]	Manage integrated arrival/departure sequence changes prior to TTOT
[NOV-5][RWY-SEQ -05]	Manage integrated arrival/departure sequence changes impacting sequence order
[NOV-5][RWY-SEQ -06]	Manage planned runway closure (using arrival/departure integrated sequence)
[NOV-5][RWY-SEQ -07]	Manage unplanned Runway Closure (using arrival/departure integrated sequence)
[NOV-5][RWY-SEQ -08]	Manage integrated arrival/departure sequence in case of Go-Around
[NOV-5][RWY-SEQ -09]	Use an integrated arrival/departure sequence and decision support tool to manage RWY configuration
[NOV-5][RWY-SEQ -10]	Manage integrated arrival/departure sequences during balancing of the number of arrival/departure flights between the two runways

Table 36: Operational Scenarios – Normal Conditions

In all the use cases listed in table above the Integrated Runway Sequence function will support managing the traffic in order to avoid traffic overloads. If a traffic overload occurs none the less, controllers will stack the traffic in order to avoid an overload in workload.

4.2.3.2 Thread Analysis of the SPR-level Model – Normal Operations

For all Scenarios described for normal operations, Integrated Runway Sequence function is designed to optimise for predictability and runway throughput and to avoid traffic overload and thus prevent an overload in workload. No new safety objectives are derived from the normal operations scenarios.

The process is the same for all Use cases (compare SPR-level Model):

- Tower Clearance Delivery
  will follow TSAT as in current operations
- Tower Runway Controller
  will follow as closely as possible the TTOT (so according to Integrated Runway Sequence function plan)
- Approach Controllers
  will deliver sequencing and spacing according to AMAN as in current operations

4.2.3.3 Effects on Safety Nets – Normal Operational Conditions

As Integrated Runway Sequence Function does not introduce any new procedures, the current safety nets will also work as in current operations – that applies for ground as for airborne safety nets (e.g. TCAS and STCA). No new safety requirement can be derived.

4.2.4 Analysis of the SPR-level Model – Non-nominal Operational Conditions

4.2.4.1 Scenarios for Non-nominal Conditions

ID	Scenario	Rationale for the Choice
[NOV-5][RWY-SEQ -06]	Manage planned runway closure (using arrival/departure integrated sequence)	Additional workload induced
[NOV-5][RWY-SEQ -07]	Manage unplanned Runway Closure (using arrival/departure integrated sequence)	Additional workload induced
[NOV-5][RWY-SEQ -08]	Manage integrated arrival/departure sequence in case of Go-Around	Additional workload induced
[NOV-5][RWY-SEQ -09]	Use an integrated arrival/departure sequence and decision support tool to manage RWY configuration	Additional workload induced
[NOV-5][RWY-SEQ -10]	Manage integrated arrival/departure sequences during balancing of the number of arrival/departure flights between the two runways	Additional workload induced

Table 37: Operational Scenarios – Abnormal Conditions

4.2.4.2 Derivation of Safety Requirements (Functionality and Performance) for Non-nominal Conditions

Ref	Abnormal Conditions / SO (*Functionality and Performance*)	Mitigations (SR 0xx and/or A 0xx)
1	**SO#1** Integrated Runway Sequence function shall support coordination between TWR and Approach	REQ-02.08-SPRINTEROP-FUN1.0013
2	**SO#2** Integrated Runway Sequence function shall support effective ATC runway management	REQ-02.08-SPRINTEROP-FUN1.0007
		REQ-02.08-SPRINTEROP-FUN1.0012
		REQ-02.08-SPRINTEROP-HMI1.0008
3	**SO#3** Integrated Runway Sequence function shall support managing the sequence in mixed and dependent mode environment	REQ-02.08-SPRINTEROP-FUN1.0007
		REQ-02.08-SPRINTEROP-FUN1.0012
		REQ-02.08-SPRINTEROP-HMI1.0008
4	**SO#7** Degraded mode depends on the local implementation	REQ-02.08-SPRINTEROP-HMI1.0009
		REQ-02.08-SPRINTEROP-SAF1.0003
		REQ-02.08-SPRINTEROP-SAF1.0004

Table 38: Safety Requirements or Assumptions to mitigate abnormal conditions

4.2.4.3 Thread Analysis of the SPR-level Model - Abnormal Conditions

For all Scenarios described for normal operations, the Integrated Runway Sequence function is designed to optimise for predictability and runway throughput and to avoid traffic overload and thus prevent an overload in workload. No new safety objectives are derived from the normal operations scenarios.

The process is the same for all Use cases (compare SPR-level Model):

- Tower Clearance Delivery will follow TSAT as in current operations
- Tower Runway Controller will follow as closely as possible the TTOT (so according to Integrated Runway Sequence function plan
- Approach Controllers will deliver sequencing and spacing according to AMAN as in current operations

4.2.4.4 Effects on Safety Nets – Abnormal Operational Conditions

In the abnormal Scenarios safety will even be improved as the parameters for any constraints like runway inspection may be entered only once into the system and the same information will be available for Tower as for Approach controllers.

4.2.4.5 Additional Safety Requirements – Abnormal Operational Conditions

ID	Description	Mitigations (SR 0xx and/or A 0xx)
1	The Integrated Runway Sequence function shall integrate a Go-Around into the sequence again (automatically or manually by the controller).	AO-03 The Integrated Runway Sequence function does not introduce new abnormal conditions compared to the baseline uncoupled AMAN and DMAN.
2	The Integrated Runway Sequence function shall be able to enter a temporary runway closure and re-plan traffic accordingly (e.g. after Take-Off Abortion.)	AO-03 The Integrated Runway Sequence function does not introduce new abnormal conditions compared to the baseline uncoupled AMAN and DMAN.
3	The Integrated Runway Sequence function shall be able to provide gaps on the runway for a runway inspection and re-plan traffic accordingly.	AO-03 The Integrated Runway Sequence function does not introduce new abnormal conditions compared to the baseline uncoupled AMAN and DMAN.
4	The Integrated Runway Sequence function shall be able to enter a manual change in the sequence and re-plan traffic accordingly	AO-03 The Integrated Runway Sequence function does not introduce new abnormal conditions compared to the baseline uncoupled AMAN and DMAN.

Table 39: Additional Safety Requirements from Thread Analysis – Abnormal Operational Conditions

4.2.5 Design Analysis – Case of Internal System Failures

The objective of this analysis consists in determining how the system architecture (encompassing people, procedures, equipment) designed for the Integrated Runway Sequence function concept 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 4.2.2.2 and 4.2.4.2 during the design analysis in normal and abnormal conditions.

Quantitative Safety Requirements are the means to express Safety Requirements for elements/parts of the system that will be subject to more in-depth safety assessment in further lifecycle steps.

The validity of the quantitative Safety Requirements is conditioned upon the validity of the Safety Objectives and on the accuracy of probabilistic data input to the fault trees.

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).

4.2.5.1 Causal Analysis

A top-down identification of internal system failures leading to hazards has been conducted in SESAR 1, identifying each of these causes and linking them to the possible hazards they could lead to, which are identified and listed in paragraph 3.2.5. Identification and Analysis of System-generated Hazards. The table below lists the causes identified for the Integrated Runway Sequence concept and relates them to these hazards.

Cause	Cause Description	Related OH
1	Corruption of 4D trajectories of two or more aircraft	Hp#1
2	Corrupted MRS/wake vortex data	Hp#2
3	Situation leading to collision with another aircraft or a ground vehicle on RWY	Hp#3
4	Situation leading to collision with an obstacle, ground vehicle, another aircraft	Hp#4
5	Low runway-surface friction	Hp#5
6	Total loss of Integrated Runway Sequence function	Linked to HP#1 and Hp#2
7	Corruption of Integrated Runway Sequence function	Linked to HP#1 and Hp#2

Table 40: List of causes leading to operational hazards

As part of the top-down identification of internal system failures that could lead to a hazard, the causal analysis includes a description of these system failures supported by fault trees including the basic causes of such failures. Additionally, Safety Objectives have been included associated to the hazard causes where applicable.

4.2.5.1.1 Total Loss of Integrated Runway Sequence function

Total loss of Integrated Runway Sequence function describes a situation where a total unavailability of AMAN/DMAN function occurs.

Two barriers have been considered to mitigate the effects of the hazard:

1. An alert is sent to the ATCO HMIs in order to allow the detection of the failure.

REQ-02.08-SPRINTEROP-SAF1.0003: A failure (partial or total loss) of the Integrated Runway Sequence function shall be properly notified on approach and Tower Controller and Supervisor HMI.

2. In case the alert has not been sent, the ATCO can always detect on the HMI that the aircraft sequence has not been calculated.

   REQ-02.08-SPRINTEROP-SAF1.0003: The ATCO has to compare the planned arrival sequence with the actual aircraft position in order to detect any inconsistencies.

In both cases, ATCO can contact the technical personnel to communicate the failure and can revert to the today procedures used in case of failure of AMAN or DMAN. Both cases should envisage just a slight impairment of working conditions due to an increase of ATCOs workload as in current operations. The increase in ATCO workload in turn will be compensated by reduced traffic throughput.

Regarding the identification of the basic causes, fault tree analysis has led to the following outcomes:

BC1. – No aircraft sequence is calculated due to failure of Integrated Runway Sequence function Server.

No specific Safety Requirement has been developed for this degraded mode. The rational lays in the fact that not all local implementations are identical. Some have already an AMAN and a DMAN whereas other not. The Solution PJ02-08 has to remain at a sufficient level to cope with all local infrastructures.

BC2. – Aircraft sequence is calculated but ATCO cannot be able to see it due to failure of controller HMI.

REQ-02.08-SPRINTEROP-SAF1.0004: Controllers shall be properly trained in the back up procedures for loss of Integrated Runway Sequence functionality.

For each Cause the hazards with mitigation and related safety requirements are listed in the table below;

Cause	Hazard	Mitigation	Related SAF requirements
1	Hp#1 Situation in which the intended 4D trajectories of two or more aircraft are in conflict during interception& final approach	The alert will be useful to notify the failure of the Integrated Runway Sequence function to the controller/supervisor who has to apply the foreseen backup procedures.	REQ-02.08-SPRINTEROP-SAF1.0003 An alert on the HMI shall warn the Controller and Supervisor in case of a failure (partial or total loss) of the Integrated Runway Sequence function.

Cause	Hazard	Mitigation	Related SAF requirements
2	Hp#2 Situation leading to wake vortex/MRS encounter	The alert will be useful to notify the failure of the Integrated Runway Sequence function to the controller/supervisor who has to apply the foreseen backup procedures.	REQ-02.08-SPRINTEROP-SAF1.0003 An alert on the HMI shall warn the Controller and Supervisor in case of a failure (partial or total loss) of the Integrated Runway Sequence function.
3	Hp#3 Situation leading to collision with another aircraft or a ground vehicle on RWY	TWR ATCO trained to maintain situation awareness, option to revert to manual procedures (Integrated Runways Sequence function is a planning tool).	Procedures and training defined in the local environment.
4	Hp#4 Situation leading to collision with an obstacle, ground vehicle, another aircraft	TWR ATCO trained to maintain situation awareness, option to revert to manual procedures (Integrated Runways Sequence function is a planning tool).	Procedures and training defined in the local environment.
5	Hp#5 Low runway-surface friction	Part of normal operations when runway braking action is reduced for all or parts of the runway. Tower Supervisor can provide an update (extend by %) into pre-set ROT values	Procedures and training defined in the local environment.
6	Hp#1 Situation in which the intended 4D trajectories of two or more aircraft are in conflict during interception& final approach Hp#2 Situation leading to wake vortex/MRS encounter	The alert will be useful to notify the failure of the Integrated Runway Sequence function to the controller/supervisor who has to apply the foreseen backup procedures. As for any function that includes automation, when the ATCOs gets used to it, their unavailability might have an impact in human performance and a proper training in backup procedures can mitigate this impact and prevents that it leads to an unsafe situation.	REQ-02.08-SPRINTEROP-SAF1.0003 An alert on the HMI shall warn the Controller and Supervisor in case of a failure (partial or total loss) of the Integrated Runway Sequence function. REQ-02.08-SPRINTEROP-SAF1.0004 The responsible units shall ensure that Controllers are properly trained in the back up procedures for failures (partial or total loss) of Integrated Runway Sequence function

Cause	Hazard	Mitigation	Related SAF requirements
7	Hp#1 Situation in which the intended 4D trajectories of two or more aircraft are in conflict during interception& final approach Hp#2 Situation leading to wake vortex/MRS encounter	The alert will be useful to notify the failure of the Integrated Runway Sequence function to the controller/supervisor who has to apply the foreseen backup procedures. As for any function that includes automation, when the ATCOs gets used to it, their unavailability might have an impact in human performance and a proper training in backup procedures can mitigate this impact and prevents that it leads to an unsafe situation.	REQ-02.08-SPRINTEROP-SAF1.0003 An alert on the HMI shall warn the Controller and Supervisor in case of a failure (partial or total loss) of the Integrated Runway Sequence function. REQ-02.08-SPRINTEROP-SAF1.0004 The responsible units shall ensure that Controllers are properly trained in the back up procedures for failures (partial or total loss) of Integrated Runway Sequence function

Table 41: List of causes with mitigation of hazards and linked SAF requirements

4.2.5.1.2 Corruption of Integrated Runway Sequence function

The same external mitigation as for total loss of Integrated Runway Sequence function is considered.

For corruption of Integrated Runway Sequence function, all basic causes have been identified by means of Fault Tree Analysis.

Regarding the identification of the basic causes, fault tree analysis has led to the following outcomes:

BC1/BC2: Corrupted aircraft sequence is generated due to a wrong or missing data provided from AMAN as input to Integrated Runway Sequence function.

BC3: Corrupted aircraft sequence is generated due to algorithm malfunction. It means that the inputs are correct but the system doesn't produce the right output.

4.2.6 Common Cause Analysis

Operational Hazards which can cause situation with multiple hazards are addressed in this section. Partial or total loss of the Integrated Runway Sequence function (planning tool impact on operational efficiency) will have to be addressed when defining/updating the local operational procedures;

- As for any function that includes automation, when the ATCOs gets used to it, their unavailability might have an impact in human performance and a proper training in backup procedures can mitigate this impact and prevents that it leads to an unsafe situation.
- Mitigation and prevention of multiple hazards when implementing new or refined planning tools should be part of the ATCO training.

4.2.7 Safety Requirements (integrity/reliability)

No specific integrity/reliability requirements have been identified.

In the below table the Safety Requirements from OSED/SPR-INTEROP Part I are listed.

Safety Requirement ID	Safety Requirement Description
REQ-02.08-SPRINTEROP-SAF1.0001	The Integrated Runway Sequence function shall support shared situation awareness between TWR and Approach by providing the relevant information (based on local implementation needs) of the up-to-date integrated arrival/departure sequence.
REQ-02.08-SPRINTEROP-SAF1.0003	An alert on the HMI shall warn the Controller and Supervisor in case of a failure (partial or total loss) of the Integrated Runway Sequence function.
REQ-02.08-SPRINTEROP-SAF1.0004	The responsible units shall ensure that Controllers are properly trained in the back up procedures for failures (partial or total loss) of Integrated Runway Sequence function
REQ-02.08-SPRINTEROP-SAF1.0008	The Integrated Runway Sequence function shall never override a manual update of the Integrated Runway Sequence with an automatic update.

Table 42: Safety Requirements

4.2.8 Achievability of the SAfety Criteria

No quantitative evidence on the achievability of the safety criteria through the specification of the safety objectives have been collected for the Integrated Runway Sequence function.

Taking into account that RTS cannot provide relevant data to make statistics on probability of separation infringement, the main criteria we can use to provide evidence that safety is not impaired is the subjective assessment of ATCOs. After V3 validations including safety assessment in two RTS, following main results can be summarised on safety;

- ATCOs participating to V3 RTS consider that the use of an Integrated Runway Sequence do not introduce new hazards compared to the situation of using a standalone AMAN with a standalone DMAN.
- ATCOs participating to V3 RTS consider that the implemented safety requirements are sufficient and efficient barriers to mitigate all the possible hazards.

However, in section 3.2.11 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 all four Safety Criteria, results of the validation exercises (debriefing and post simulation surveys) 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 SACs are met by the design of the Integrated Runway Sequence concept 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 (See section 3.2.7), for abnormal conditions (See section 3.28) and for failure aspects (See section 3.2.9). 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 Safety Criteria. Traceability between Safety Requirements and Safety Objectives are in section 4.2.2.2 (nominal) and 4.2.4.2 (non-nominal).

4.2.9 Realism of the SPR-level Design

4.2.9.1 Achievability of Safety Requirements / Assumptions

All of the Safety Requirements have been demonstrated as capable of being satisfied in a typical implementation because they have either been implemented and tested in the solutions or exercised during validation exercises with a positive outcome or because their achievability has been confirmed with controllers during meetings, SAF/HP workshop or debriefing sessions.

4.2.9.1.1 Achievement of SR & Associated Evidences

For the verification of the achievability of the (Safety) Requirements the following list of ten use cases has been made use of:

Use cases for PJ02-08 Concept 1 and Concept 2
[NOV-5] [RWY-SEQ-01] Manage departure flight (using an integrated arrival/departure sequence) → defined as nominal (normal) condition.
[NOV-5] [RWY-SEQ -02] Manage arrival flight (using an integrated arrival/departure sequence) → defined as nominal (normal) condition.
[NOV-5] [RWY-SEQ -03] Manage integrated arrival/departure sequence changes prior to TSAT → defined as nominal (normal) condition.
[NOV-5] [RWY-SEQ -04] Manage integrated arrival/departure sequence changes prior to TTOT → defined as nominal (normal) condition.
[NOV-5] [RWY-SEQ -05] Manage integrated arrival/departure sequence changes impacting sequence order → defined as nominal (normal) condition.
[NOV-5] [RWY-SEQ -06] Manage planned runway closure (using arrival/departure integrated sequence) → defined as non-nominal (abnormal) condition.
[NOV-5] [RWY-SEQ -07] Manage unplanned Runway Closure (using arrival/departure integrated sequence) → defined as non-nominal (abnormal) condition.

[NOV-5] [RWY-SEQ -08] Manage integrated arrival/departure sequence in case of Go-Around → defined as non-nominal (abnormal) condition.
[NOV-5] [RWY-SEQ -09] Use an integrated arrival/departure sequence and decision support tool to manage RWY configuration → defined as non-nominal (abnormal) condition.
[NOV-5] [RWY-SEQ -10] Manage integrated arrival/departure sequences during balancing of the number of arrival/departure flights between the two runways → defined as non-nominal (abnormal) condition.

Table 43: SESAR Solution PJ02-08 use cases for Concept 1 and Concept 2

Each requirement has been verified either in the nominal use cases ([NOV-5] [RWY-SEQ-01] to UCH-[NOV-5] [RWY-SEQ -05]) and/or the non-nominal use cases ([NOV-5] [RWY-SEQ -06] to [NOV-5] [RWY-SEQ -10]).

All the above Use Cases are further defined in the SESAR 2020 Solution 02-08 OSED [5].

The table below shows for each requirement, the uses cases that supported the verification, the validity of the Safety Requirement to achieve the Safety Objectives defined in the paragraphs 3.2.7.2 and 3.2.8.2 and the associated source of evidence.

Requirement	Verified in UCs	Valid	Supporting Evidence
REQ-02.08-SPRINTEROP-FUN1.0001	All	YES	Solution Design
REQ-02.08-SPRINTEROP-FUN1.0002	All	YES	Solution Design
REQ-02.08-SPRINTEROP-FUN1.0007	None	YES	Survey data
REQ-02.08-SPRINTEROP-FUN1.0008	All	YES	Survey data
REQ-02.08-SPRINTEROP-FUN1.0010	All	YES	Survey data
REQ-02.08-SPRINTEROP-FUN1.0012	Non-nominal	YES	Survey data
REQ-02.08-SPRINTEROP-FUN1.0013	Non-nominal	YES	Survey data
REQ-02.08-SPRINTEROP-FUN1.0014	All	YES	Survey data
REQ-02.08-SPRINTEROP-FUN1.0015	All	YES	Survey data
REQ-02.08-SPRINTEROP-FUN1.0016	All	YES	Solution Design
REQ-02.08-SPRINTEROP-HMI1.0001	Nominal	YES	Solution Design
REQ-02.08-SPRINTEROP-HMI1.0002	All	YES	Survey data
REQ-02.08-SPRINTEROP-HMI1.0003	All	YES	Survey data
REQ-02.08-SPRINTEROP-HMI1.0004	All	YES	Survey data
REQ-02.08-SPRINTEROP-HMI1.0005	All	YES	Survey data

Requirement	Verified in UCs	Valid	Supporting Evidence
REQ-02.08-SPRINTEROP-HMI1.0008	Non-nominal	YES	Survey data
REQ-02.08-SPRINTEROP-SAF1.0001	All	YES	Survey data
REQ-02.08-SPRINTEROP-SAF1.0003	NO	YES	Warning on degraded mode depends on the local implementation
REQ-02.08-SPRINTEROP-SAF1.0004	NO	YES	Survey data
REQ-02.08-SPRINTEROP-SAF1.0008	All	YES	Survey data
REQ-02.08-SPRINTEROP-PRF1.0002	All	YES	Solution Design
REQ-02.08-SPRINTEROP-PRF1.0003	All	YES	Survey data
REQ-02.08-SPRINTEROP-PRF1.0004	All	YES	Survey data
REQ-02.08-SPRINTEROP-PRF1.0005	All	YES	Survey data
REQ-02.08-SPRINTEROP-PRF1.0006	All	YES	Solution Design

Table 44: Achievement and evidences for Safety Requirements

4.2.9.1.2 Achievement of SO & Associated Evidences

The verification of the achievability of the Safety Objective is based, on the one hand, on the verification of the Safety Requirement, and on the other hand, with addition (direct) evidences.

The table below shows for each Safety Objective, defined in paragraphs 3.2.7.2 and 3.2.8.2, the achievability of the Safety Requirement allocated to the Safety Objectives and direct supporting evidence of the achievability of the Safety Objective.

SO	Direct Supporting Evidence		Supporting Requirements Achievement	
	YES/NO	Type	Requirement	YES/NO
SO#1	YES	Survey data	REQ-02.08-SPRINTEROP-FUN1.0001	YES
			REQ-02.08-SPRINTEROP-FUN1.0002	YES
			REQ-02.08-SPRINTEROP-FUN1.0013	YES
			REQ-02.08-SPRINTEROP-FUN1.0015	YES
			REQ-02.08-SPRINTEROP-HMI1.0001	YES
			REQ-02.08-SPRINTEROP-HMI1.0002	YES
			REQ-02.08-SPRINTEROP-HMI1.0003	YES

SO	Direct Supporting Evidence		Supporting Requirements Achievement	
	YES/NO	Type	Requirement	YES/NO
			REQ-02.08-SPRINTEROP-HMI1.0004	YES
			REQ-02.08-SPRINTEROP-SAF1.0001	YES
SO#2	YES	Survey data	REQ-02.08-SPRINTEROP-FUN1.0001	YES
			REQ-02.08-SPRINTEROP-FUN1.0007	NO
			REQ-02.08-SPRINTEROP-FUN1.0008	YES
			REQ-02.08-SPRINTEROP-FUN1.0010	YES
			REQ-02.08-SPRINTEROP-FUN1.0012	YES
			REQ-02.08-SPRINTEROP-FUN1.0014	YES
			REQ-02.08-SPRINTEROP-FUN1.0016	YES
			REQ-02.08-SPRINTEROP-FUN1.0017	YES
			REQ-02.08-SPRINTEROP-HMI1.0005	YES
			REQ-02.08-SPRINTEROP-HMI1.0008	YES
			REQ-02.08-SPRINTEROP-PRF1.0004	YES
			REQ-02.08-SPRINTEROP-PRF1.0005	YES
			REQ-02.08-SPRINTEROP-PRF1.0006	YES
			REQ-02.08-SPRINTEROP-PRF1.0007	YES
			REQ-02.08-SPRINTEROP-PRF1.0008	YES
SO#3	YES	Survey data	REQ-02.08-SPRINTEROP-FUN1.0001	YES
			REQ-02.08-SPRINTEROP-FUN1.0007	NO
			REQ-02.08-SPRINTEROP-FUN1.0010	YES
			REQ-02.08-SPRINTEROP-FUN1.0012	YES
			REQ-02.08-SPRINTEROP-FUN1.0017	YES
			REQ-02.08-SPRINTEROP-HMI1.0008	YES
			REQ-02.08-SPRINTEROP-PRF1.0004	YES
			REQ-02.08-SPRINTEROP-PRF1.0005	YES

SO	Direct Supporting Evidence		Supporting Requirements Achievement	
	YES/NO	Type	Requirement	YES/NO
			REQ-02.08-SPRINTEROP-PRF1.0006	YES
			REQ-02.08-SPRINTEROP-PRF1.0007	YES
SO#4	YES	Solution design	REQ-02.08-SPRINTEROP-FUN1.0001	YES
SO#5	YES	Survey data	REQ-02.08-SPRINTEROP-FUN1.0001	YES
			REQ-02.08-SPRINTEROP-SAF1.0008	YES
SO#6	YES	Solution design	REQ-02.08-SPRINTEROP-FUN1.0001	YES
			REQ-02.08-SPRINTEROP-FUN1.0007	NO
			REQ-02.08-SPRINTEROP-FUN1.0010	YES
			REQ-02.08-SPRINTEROP-FUN1.0016	YES
			REQ-02.08-SPRINTEROP-HMI1.0002	YES
			REQ-02.08-SPRINTEROP-HMI1.0003	YES
			REQ-02.08-SPRINTEROP-HMI1.0004	YES
			REQ-02.08-SPRINTEROP-SAF1.0003	NO
			REQ-02.08-SPRINTEROP-SAF1.0004	NO
			REQ-02.08-SPRINTEROP-PRF1.0002	YES
			REQ-02.08-SPRINTEROP-PRF1.0003	YES

Table 45: Achievement and evidences for Safety Objectives

4.2.9.1.3 Achievement of SAC & Associated Evidences

The verification of the achievability of the Safety Criteria is based, on the one hand, on the verification of the achievability of the allocated Safety Objectives, and on the other hand, with addition (direct) evidences.

The table below shows for each Safety Criteria, defined in paragraph 3.2.6.3, the achievability of the Safety Objectives allocated to the Safety Criteria and direct supporting evidence of the achievability of the Safety Criteria.

SAC	Direct Supporting Evidence	Supporting Objective Achievability	Achievability of SAC

	YES/NO	Type	SO ID	YES/NO	
SAC#1	YES	Survey data	SO#1	YES	The simulation and the related survey provide the sufficient evidence that the SAC#1 will be achieved (no trend could be derived during RTS one hour runs).
			SO#3	YES	
			SO#6	YES	
			SO#7	YES	
SAC#2	YES	Survey data	SO#1	YES	The simulation and the related survey provide the sufficient evidence that the SAC#2 will be achieved (no trend could be derived during RTS one hour runs).
			SO#2	YES	
			SO#3	YES	
SAC#3	YES	Per design	SO#5	YES	The simulation and the related survey provide the sufficient evidence that the SAC#3 will be achieved (no trend could be derived during RTS one hour runs).
SAC#4	YES	Survey data	SO#4	YES	The simulation and the related survey provide the sufficient evidence that the SAC#4 will be achieved (no trend could be derived during RTS one hour runs).
			SO#7	YES	

Table 46: Achievement and evidences for Safety Criteria

4.2.9.2 "Testability" of Safety Requirements

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, ATM information, etc.

For some safety requirements, verification should rely on appropriate assurance process to be implemented.

4.2.10Validation & Verification of the Safe Design at SPR Level

A safety team encompassing controllers, engineers, Safety and Human Performance specialists have supported this safety assessment.

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 Appendix A of this document. In addition to the SAF/HP workshop, several meetings were organised to consolidate the list of safety requirements in particular to obtain consistent Functional, HMI, Safety and Performance requirements.

4.3 Concept 3 Safe Design at SPR Level

4.3.1 The Concept 3 Functional Model

Only SPR level model has been developed for the present safety assessment of Concept 3.

4.3.2 The Concept 3 SPR-level Model

Instead of separately developed SPR-level model we will use existing NSV-4 diagram from V3 TS/IRS [9].

4.3.2.1 Description of SPR-level Model

In depth description of NSV-4 elements is available in SESAR 2020 Solution PJ.02-08 TS/IRS [9]. Below we will only list elements of the model broken down into airborne/ground and human/machine categories.

4.3.2.1.1 Aircraft Elements

- Flight Crew

No particular machine aircraft elements are relevant for ROCAT. The concept doesn't impact the aircraft element.

4.3.2.1.2 Ground Elements

- ORD Tool
- Approach Controller CWP
- Approach Controller
- Tower Runway Controller CWP
- Tower Runway Controller

4.3.2.1.3 External Entities

- Data sources (ground): MET, surveillance and runway surface condition.

4.3.2.2 Derivation of Safety Requirements (Functionality and Performance – success approach)

Safety Objectives (Functionality and Performance from success approach)	Requirement (forward reference)	Maps on to

	SR-1	APP Controller
	SR-2	ORD Tool
	SR-3	APP Controller CWP/Tower Controller CWP
	SR-4	ORD Tool
	SR-5	ORD Tool/APP Controller CWP/Tower Controller CWP

Table 47: Mapping of Safety Objectives to SPR-level Model Elements

ORD tool requirements are described in solution 1, to avoid duplication, only specific ROCAT requirements are provided

Safety Requirement (functionality & performance) [SPR-level Model Element]	Requirement	Derived from Table 21
	The Initial Approach Controller shall ensure that the aircraft type and wake category is correct in the system flight plan data and it is propagated through the approach arrival sequence display.	
	An ORD tool shall be available in support of the ATC, capable of calculating and displaying at least a Final Target Distance (FTD) indicator.	
	An indicator shall be displayed by the ORD tool to indicate the minimum required separation applicable between each pair of aircraft on final approach, depending on the most constraining factor (e.g. wake turbulence separation, MRS, ROT) to be applied at the separation delivery point	
	The ORD tool shall take into account an intervention buffer that ATCO uses to prevent aircraft to go bellow minimum radar separation	
	A catch-up alert shall be triggered if there is a predefined difference (to be determined based on the specific safety case) between the calculated speed of the ITD and the speed of the follower aircraft, whenever the lead aircraft has not passed the deceleration point	

Table 48: Derivation of Safety Requirements (functionality and performance) from Safety Objectives

4.3.3 Analysis of the SPR-level Model – Normal Operational Conditions

This section is concerned with ensuring that the SPR-level design is complete, correct and internally coherent with respect to Scenarios for Normal Operations

PJ.02-08 SPR-INTEROP/OSED [5] introduces only one use case related to Concept 3. This use case is treated as a normal operations scenario.

ID	Scenario	Rationale for the Choice
1	ROCAT	Use case from SPR-INTEROP OSED

Table 49: Operational Scenarios – Normal Conditions

4.3.3.1 Thread Analysis of the SPR-level Model – Normal Operations

The ROCAT use case follows the flow presented in the NSV-4 model. the analysis of the flow shows that there is no need for additional Safety Requirements.

4.3.3.2 Effects on Safety Nets – Normal Operational Conditions

No effect of the Concept 3 on the safety nets has been found in the course of the present safety assessment.

4.3.3.3 Additional Safety Requirements (functionality and performance) – Normal Operational Conditions

Addition safety requirements can be found in the PJ02-01 and PJ02-03 related to the use of the ORD tool.

4.3.4 Analysis of the SPR-level Model – Abnormal Operational Conditions

4.3.4.1 Scenarios for Abnormal Conditions

Table below recalls the different scenarios relative to the abnormal conditions identified in Section 3.3.5 and for which new Safety Objectives have been derived, analyses the causal factors or possible influences and presents the risk mitigation.

Ref	Abnormal Conditions / SO (*Functionality and Performance*)	Possible influences or causal factors	Mitigations (SR 0xx and/or A 0xx)
1	Change of Aircraft landing runway intent.	No change from Sol 01. Same mitigations as in Sol 01 apply	No change from Sol 01. Same mitigations as in Sol 01 apply

2	Abnormal procedural aircraft airspeed and/or abnormal stabilized approach speed.	Pilot basic airmanship not respected. Aircraft problem.	Detect abnormal airspeed (through alerting) and manage compression manually.
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.	No change from Sol 01. Same mitigations as in Sol 01 apply	No change from Sol 01. Same mitigations as in Sol 01 apply
5	Actual Wind on final approach different from the wind used for FTD/ITD computation.	No change from Sol 01. Same mitigations as in Sol 01 apply	No change from Sol 01. Same mitigations as in Sol 01 apply
6	Flight Crew Notification of Aircraft Speed non-conformance.	No change from Sol 01. Same mitigations as in Sol 01 apply	No change from Sol 01. Same mitigations as in Sol 01 apply
7	Unexpected drop of reference wind below safe threshold.	No change from Sol 01. Same mitigations as in Sol 01 apply	No change from Sol 01. Same mitigations as in Sol 01 apply
8	Late change of landing runway (not planned).	No change from Sol 01. Same mitigations as in Sol 01 apply	No change from Sol 01. Same mitigations as in Sol 01 apply

Table 50: Safety Requirements or Assumptions to mitigate abnormal conditions

4.3.4.2 Derivation of Safety Requirements (Functionality and Performance) for Abnormal Conditions

The table below, uses the outcome of the previous sub-section and the Safety Objectives to derive the corresponding Safety Requirements (Functionality and Performance) by considering the SPR level Model.

Safety Objectives for abnormal conditions	Safety Requirements (functionality and performance) for abnormal conditions	Map on to
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 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 wind monitoring function about a significant difference between actual glideslope headwind profile and the glideslope headwind 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.	
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	The following requirements from PJ02.01 apply: REQ-02.01-SPRINTEROP-ARR0.1500 REQ-02.01-SPRINTEROP-ARR0.1510 REQ-02.01-SPRINTEROP-ARR0.1700 REQ-02.01-SPRINTEROP-ARR0.1710	
	A generic wake risk assessment shall be performed for the non-wake pairs in the specific case when the leader is performing a break-off/go-around and the follower, separated at or close to the separation minima, continues its descent crossing the leader's descending wake	
	The following requirements from PJ02.01 also apply: REQ-02.01-SPRINTEROP-ARR0.0440 REQ-02.01-SPRINTEROP-ARR0.0441 REQ-02.01-SPRINTEROP-ARR0.0960 REQ-02.01-SPRINTEROP-ARR0.0560 REQ-02.01-SPRINTEROP-ARR0.0550 REQ-02.01-SPRINTEROP-ARR0.0910 REQ-02.01-SPRINTEROP-ARR0.0561 REQ-02.01-SPRINTEROP-ARR0.0950	

	REQ-02.01-SPRINTEROP-ARR0.0540
	The following requirements from PJ02.01 apply: REQ-02.01-SPRINTEROP-ARR0.1360 REQ-02.01-SPRINTEROP-ARR0.1370
	The following requirements from PJ02.01 apply: REQ-02.01-SPRINTEROP-ARR0.0560 REQ-02.01-SPRINTEROP-ARR0.0550 REQ-02.01-SPRINTEROP-ARR0.0910 REQ-02.01-SPRINTEROP-ARR0.0561 REQ-02.01-SPRINTEROP-ARR0.0950 REQ-02.01-SPRINTEROP-ARR0.0540

Table 51: Operational Scenarios – Abnormal Conditions

4.3.5 Design Analysis – Case of Internal System Failures

Section 3.3.6.1 above identifies the relevant system generated hazard:

- **SHz#1** Runway Conflict due to landing clearance in conflict with another landing (ROT not respected).

4.3.5.1 Causal Analysis

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.

Note, as mentioned previously, hazards have been previously identified in Sol 01. Even though they are all relevant to Sol 08, ROCAT concept does not introduce changes in all of them. Therefore, in order to avoid clutter, fault trees will be developed only for the hazard in which a change is introduced by ROCAT. The fault trees (together with their mitigations) for which there is no change compared to Sol 01, will be referenced to Sol 01.

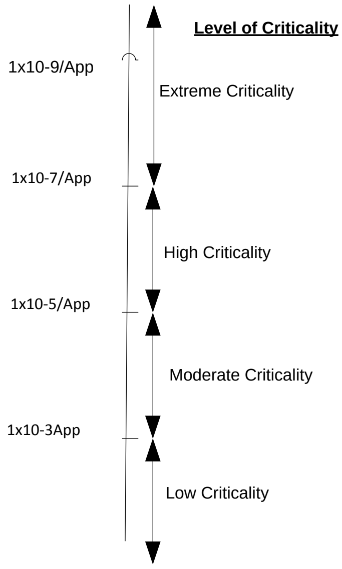
Fault trees are elaborated by detailing the hazard in a combination of failures (i.e. Basic Causes and failure of mitigations) linked by different gates, i.e. "AND" and "OR" gates. The “AND” and “OR” gates will serve in the quantification process later on during the concept lifecycle.

Existing mitigations (i.e. already captured as safety) 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.

INFORMATION RELATIVE TO THE QUALITATIVE/QUANTITATIVE REQUIREMENTS ALLOCATION PROCESS USED IN THE DIFFERENT FAULT TREES

The first step of this process is to allocate a level of criticality to the top level event of the Fault Tree based on the associated safety objectives in accordance with the following allocation principle depicted in the diagram below

- Principle 1:



Then the next step is to "cascade" the level of criticality to the subsequent Fault Tree branches until a human error is isolated in a branch of an "AND" gate, e.g. Human Error is isolated as basic event.

The "cascade" process is applied using the following rules:

- For an OR gate: the criticality of all "child" events is the same as the one of parent event.
- For an AND gate: the level of criticality of the parent event can be degraded one level at child level, provided the child events are independent and degradation is duly justified

The following principles are applied to human mitigations implied in the FT branch:

- Principle 2: For human task/action which permits a downgrading of the Level of Criticality. This downgrading should be justified by field experience/observation/expert judgement. Qualitative Safety requirements shall be derived accordingly. These events are noted "P2" in the Fault Trees.

Principle 3: No mitigation possible by human action/task. These human tasks/actions are represented in the Fault Trees for information but they are not effective enough to be considered as mitigation considering the operational situation. These events are noted "P3" in the Fault Trees.

4.3.5.1.1 Hz#1 The frequency of occurrence of a runway conflict due to landing clearance in conflict with another landing (ROT not respected) shall not be greater than 10-5/movement

This hazard occurs during the execution phase due to an erroneous management of the separation mode

Basic causes for such failures have been captured in the Hz#01 Fault Tree in the following figure:

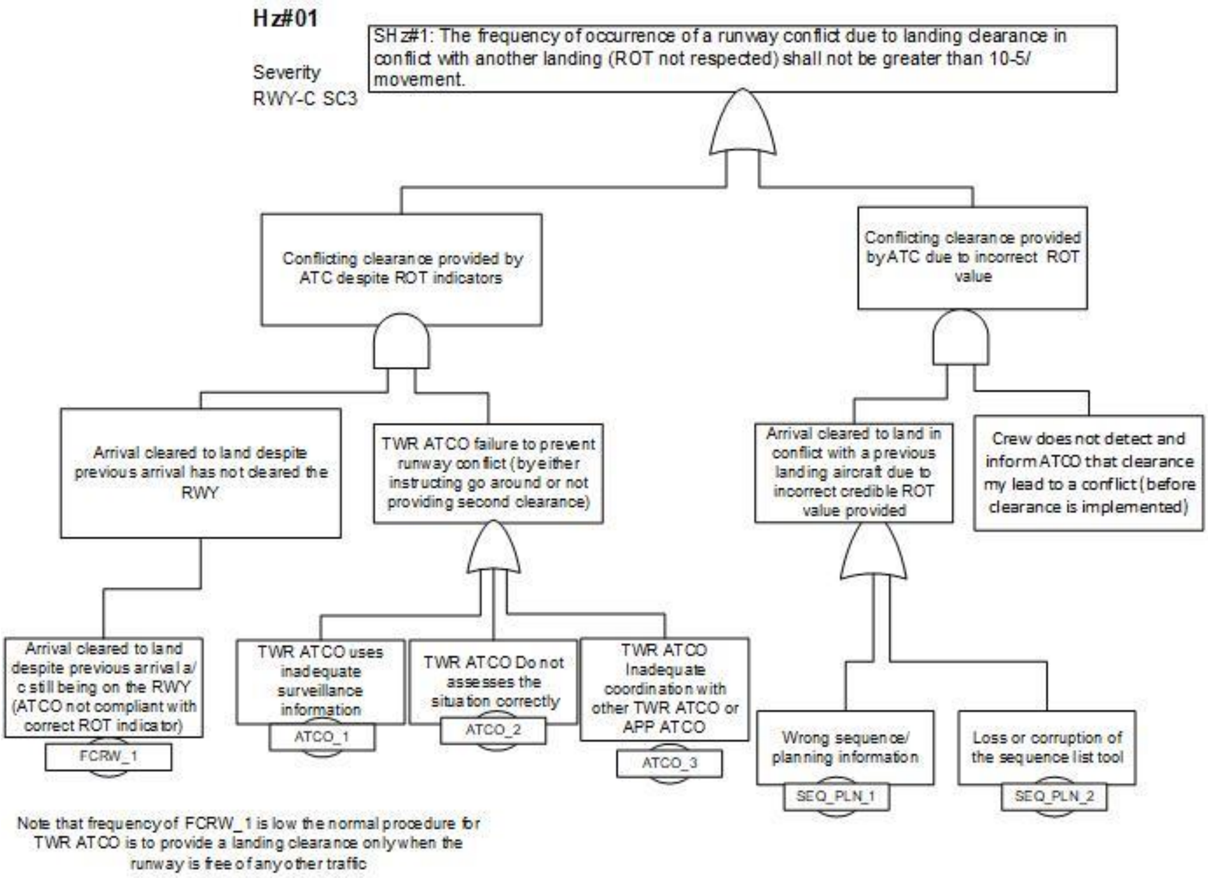


Figure 9: ROCAT Hazard Fault Tree

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Conflicting clearance provided by ATC despite correct ROT indicators			
Arrival cleared to land despite previous arrival a/c still being on the RWY (ATCO not compliant with correct ROT indicator)	FCRW_1	ATCO is not compliant with the ROT indicator	**SR1**
TWR ATCO uses inadequate surveillance information	ATCO_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.
TWR ATCO do not assesses the situation correctly	ATCO_2	misjudgement	This is not changed compared to current operations.

TWR ATCO inadequate coordination with other ATCOs	ATCO_3	Lack of communication between ATCOs	This is not changed compared to current operations.
Conflicting clearance provided by ATC due to incorrect ROT value			
Wrong sequence/planning information	SEQ_PLN_1		**SR6:** 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. **SR7:** 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: **SR8:** 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

Table 51: Derivation of Mitigation/Safety Requirements for Hazard Hz#01 for the concept 3

4.3.5.2 Common Cause Analysis

The main common causes have been identified through an initial causal analysis of the successive WTA AIM barriers. 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 in solution 1 and 3 of PJ related to the ORD tool

4.3.6 Achievability of the SAfety Criteria

In the previous paragraphs for concept 3, 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 identified risks, 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, for abnormal conditions and for failure aspects. 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 validation information regarding the safety requirements that have been derived within the safety assessment is provided in the Appendix B.

The following table summarizes the results for the Safety KPA dedicated to each of the SESAR solution success criteria identified for the validation exercises. For detailed results please see the corresponding VALR .

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage	Validation results & Level of safety evidence
VAL-EXE 02-08.V3.005: RTS conducted by EUROCONTROL to assess the operational feasibility and acceptability of	OBJ-PJ2.08-V3-VALP-	**CRT-PJ02.08-V3-VALP-SA1-001** There is evidence that the level of operational safety is maintained and not negatively impacted when ROCAT is applied compared to the current operations.	R-SAC#1	There is evidence that the safety is maintained and not negatively impacted with the ROCAT concept in terms of: - controllers are able to safely and successfully deliver the aircraft to the runway threshold - safe working practices are

the AO-0337 "Increased Runway Throughput based on local ROT characterization (ROCAT) concept when combined with the ORD tool (EUROCONTROL LORD tool with FTD and ITD) (AO-0306) and TB PWS-A separation scheme (AO-0328) under segregated runway operations to optimise runway throughput capacity.	**SA3** To assess the impact on operational safety of applying ROCAT.			observed when working with the concept - the controllers provide the feedback that the probability for human error has not increased in the solution scenario compared to the reference scenario.
		CRT-PJ02.08-V3-VALP-SA1-002 There is evidence that the level of operational safety is maintained and not negatively impacted when ROCAT is applied compared to the current operations.	**R-SAC#F1**	There is no increase in the number of vertical and horizontal separation infringements in the solution scenarios compared to the reference scenario.
		CRT-PJ02.08-V3-VALP-SA1-003 There is evidence that ROCAT does not increase the likelihood of go around compared to the current operations.	**M-SAC#F1** **W-SAC#F1**	There is evidence that the probability of go-around in the solution scenarios is not increased compared to the reference scenario under segregated RWY operations.

4.3.7 Realism of the SPR-level Design

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.

4.3.7.1 Achievability of Safety Requirements / Assumptions

All of the Safety Requirements have been demonstrated as capable of being satisfied in a typical implementation because they have been tested during validation exercises or because their achievability has been confirmed with Controllers, pilots and ground manufacturer during meetings, SAF/HP workshop or debriefing sessions.

In case achievability could not be completely demonstrated, no requirement has been derived but an issue has been identified instead.

4.3.7.2 "Testability" of Safety Requirements

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.

4.3.8 Validation & Verification of the Safe Design at SPR Level

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 checking the PJ02.01 and PJ02.03 safety assessment because these three solutions are very similar, then additional safety requirements have been derived in normal, abnormal and failure conditions to satisfy the Safety Objectives identified in concept 3. In addition to the SAF/HP workshop, several meetings were organised to consolidate the list of safety requirements in particular to obtain consistent Safety and HP requirements.

The causal analysis and the related concept 3 safety requirements derivation/update is based on the work that have been conducted by the safety assessment team on solution 1 and 3 and has been progressively validated in a HAZID identification & safety requirements validation workshop at Heathrow Airport premises. The participants to the workshop were:

Organisation	Name	Position
Vienna Airport	Günther Borek	APP ATCO & SUP
	Haris Usanovic	TWR & APP ATCO & TWR SUP
NATS	Andrew Belshaw	SAF expert
	Adam Spink	TWR ATCO
	Charles Morris	Concept design expert
	Michael Benson	TWR ATCO
	Andrew Garrett	APP ATCO
EUROCONTROL	Dana Botezan	HP expert
	Laura Carbo	SAF expert
	Nicolas Fota	SAF expert
	Mihai Ogica	SAF expert
	Mohamed Ellejmi	Project Manager

Table 52: HAZID at Heathrow Airport - Participants

The validation report has been further complemented by submitting the results to the Zurich validation team to review the report.

4.4 Concept 4 Safe Design at SPR Level

4.4.1 The Concept 4 Functional Model

Only SPR level model has been developed for the present safety assessment of Concept 4.

4.4.2 The Concept 4 SPR-level Model

Instead of separately developed SPR-level model we will use existing NSV-4 diagram from V3 TS/IRS [9].

4.4.2.1 Description of SPR-level Model

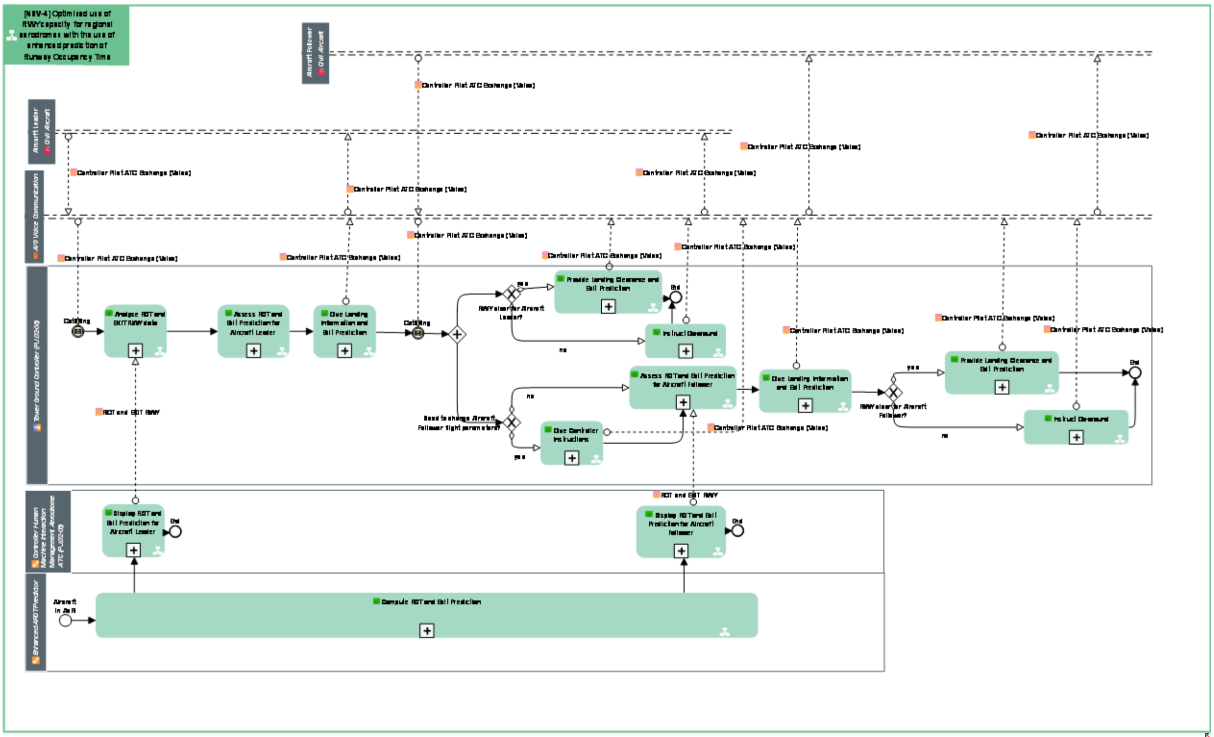


Figure 10: NSV-4 diagram for PJ.02-08 Concept 4 used as an equivalent of SPR-level model.

In depth description of NSV-4 elements is available in SESAR 2020 Solution PJ.02-08 TS/IRS [9]. Below we will only list elements of the model broken down into airborne/ground and human/machine categories.

4.4.2.1.1 Aircraft Elements

- Flight Crew

No particular machine aircraft elements are relevant for Enhanced AROT Predictor.

4.4.2.1.2 Ground Elements

- Enhanced AROT predictor
- Tower Runway Controller CWP
- Tower Runway Controller

4.4.2.1.3 External Entities

- Data sources (ground): MET, surveillance and runway surface condition.

4.4.2.2 Task Analysis

Please refer to PJ.02-08 SPR-INTEROP/OSED [5] for task description.

4.4.2.3 Derivation of Safety Requirements (Functionality and Performance – success approach)

Safety Objectives (Functionality and Performance from success approach)	Requirement (forward reference)	Maps on to
	SR-1	Enhanced AROT Predictor
	SR-2	Enhanced AROT Predictor
	SR-3	Enhanced AROT Predictor
	SR-4	Tower Controller HMI
	SR-5	Enhanced AROT Predictor
	SR-6	Enhanced AROT Predictor
	SR-7	Enhanced AROT Predictor
	SR-8	Tower Controller HMI
	SR-8a	Tower Runway Controller
	SR-9	Enhanced AROT Predictor

Table 53: Mapping of Safety Objectives to SPR-level Model Elements

Safety Requirement (functionality & performance)	Requirement	Derived from Table 10

[SPR-level Model Element]		
Enhanced AROT Predictor		
Enhanced AROT Predictor		
Enhanced AROT Predictor		
Tower Controller HMI		
Enhanced AROT Predictor		
Enhanced AROT Predictor		
Enhanced AROT Predictor		
Tower Controller HMI		
SR-8a [Tower Runway Controller]	In case a visual warning is displayed informing ATCO about lack of Enhanced AROT Predictor function Tower Runway Controller shall fall back on reference operating method where exit taxiway and AROT are estimated based on ATCO operational experience.	SO-6
Enhanced AROT Predictor		

Table 54: Derivation of Safety Requirements (functionality and performance) from Safety Objectives

ID	Assumptions
	Enhanced AROT Predictor is able to determine landing distance required for each operating aircraft type based on initial surveillance set.

Table 55: Assumptions made in deriving the above Safety Requirements

4.4.3 Analysis of the SPR-level Model – Normal Operational Conditions

This section is concerned with ensuring that the SPR-level design is complete, correct and internally coherent with respect to Scenarios for Normal Operations

PJ.02-08 SPR-INTEROP/OSED [5] introduces only one use case related to Concept 4. This use case is treated as a normal operations scenario.

ID	Scenario	Rationale for the Choice
1	Enhanced AROT Predictor use case	Use case from SPR-INTEROP OSED

Table 56: Operational Scenarios – Normal Conditions

4.4.3.1 Thread Analysis of the SPR-level Model – Normal Operations

The Enhanced AROT Predictor use case follows the flow presented in the NSV-4 model in Figure 10. Below we will analyse this flow and verify the need for defining the additional Safety Requirements. Table 57 below merges the leader and follower aircraft workflow as they are very similar. New Safety Requirements defined in the process are highlighted.

Function/Activity	Functional Blocks/Roles engaged	Safety assessment
Transfer A/C to TWR	Flight Crew, Tower ATCO	Standard procedure not impacted by PJ.02-08
Estimate exit taxiway and ROT	Enhanced AROT Predictor	This must be achievable for neutral safety impact (SR-1, SR-2)
Assess exit and ROT for arriving aircraft	Tower Runway ATCO HMI, Tower Runway ATCO	ATCO must be able to roughly verify the achievability of predicted exit and ROT (SR-10), HMI shall be fully integrated into EFS system to avoid confusion (SR-11).
Give Landing information	Tower Runway ATCO, Fight Crew	Flight Crew shall check for achievability and inform ATCO immediately if proposed exit is not achievable (SR-12)
Give Controller Instructions	Tower Runway ATCO, Fight Crew	Controller instructions should follow verification of prediction by ATCO and Flight Crew (SR-12, SR-13)
Provide Landing Clearance	Tower Runway ATCO, Fight Crew, Tower Runway ATCO HMI, Enhanced AROT Predictor	Enhanced AROT Predictor updates its prediction (SR-3) and communicates any significant change clearly to ATCO (SR-4). ATCO re-evaluates ROT and exit estimate before landing clearance provision (SR-14)

Table 57: Thread analysis of Enhanced AROT Predictor use case

4.4.3.2 Effects on Safety Nets – Normal Operational Conditions

No effect of the Concept 4 on the safety nets has been found in the course of the present safety assessment.

4.4.3.3 Dynamic Analysis of the SPR-level Model – Normal Operational Conditions

PJ.02-08 Concept 4 has been validated during two exercises:

- PANSA FTS 8
- PANSA RTS 4

For detailed description of the exercises and their results please refer to PJ.02-08 V3 VALR [7]. The main results of RTS exercise are already included in this Safety Assessment Report as the debriefings of this exercise were used as an integral part of Concept 4 safety process.

4.4.3.4 Additional Safety Requirements (functionality and performance) – Normal Operational Conditions

ID [SPR-level Model element]	Description	Thread Action Number [Scenario # xx]
SR-10 [Tower Runway ATCO]	Tower Runway Controller shall judge the achievability of predicted exit taxiway and ROT upon reception of the estimate from Enhanced AROT Predictor.	Assess exit and ROT for arriving aircraft
SR-11 [Tower Runway ATCO HMI]	Enhanced AROT Predictor HMI shall be integrated into EFS system.	Assess exit and ROT for arriving aircraft
SR-12 [Fight Crew]	Flight Crew shall check for achievability and inform ATCO immediately if proposed exit is not achievable.	Give Landing information
SR-13 [Tower Runway ATCO]	Tower Runway Controller shall judge achievability of estimated exit taxiway and ROT prior to giving any controller instructions based on those estimates.	Give Controller Instructions
SR-14 [Tower Runway ATCO]	Tower Runway Controller shall judge achievability of estimated exit taxiway and ROT before providing landing clearance.	Provide Landing Clearance

Table 58: Additional SR from Thread Analysis – Normal Operational Conditions

4.4.4 Analysis of the SPR-level Model – Abnormal Operational Conditions

4.4.4.1 Scenarios for Abnormal Conditions

The set of abnormal conditions defined for PJ.02-08 Concept 4 can be divided into two groups impacting operations in three different ways.

Abnormal conditions with bearing on the Concept 4 performance (Group 1)

Those are the abnormal conditions that impact Concept 4 initial estimate performance. In this group Abn#2 is not concerned with landing roll performance.

- Abn#1 Sudden change of weather conditions along approach trajectory
- Abn#2 Approaching aircraft performance is different than normal
- Abn#3 Approach execution irregularities

Abnormal conditions forcing sudden interruption in the Enhanced AROT use case execution (Group 2)

- Abn#2 Approaching aircraft performance is different than normal (Flight Crew detected landing roll performance issue)
- Abn#4 Missed approach.

Abnormal conditions causing Enhanced AROT Predictor function loss (Group 3)

- Abn#5 Surveillance data connection is lost or data is erroneous
- Abn#6 MET data connection is lot or data is erroneous

As abnormal conditions with bearing on Concept 4 performance are mitigated by SO-3 and all related Safety Requirements, in those conditions the Normal Operations are effectively followed. The remaining two groups merit essentially random interruption of the Enhanced AROT Predictor use case. As a result we will not define specific scenarios for any of the groups but will analyse normal scenario taking into account occurrence of abnormal conditions belonging to a given group.

4.4.4.2 Derivation of Safety Requirements (Functionality and Performance) for Abnormal Conditions

Any new requirements identified in the table below are highlighted.

Ref	Abnormal Conditions / SO (*Functionality and Performance)*	Mitigations (SR 0xx and/or A 0xx)
1	Group 1 / SO-3	SR-3, SR-4, SR-10, SR-12, SR-13, SR-14
2	Group 2 / SO-6	A-2 (pilot informs landing roll), SR-15 (ATCO transitions to

		reference operating method (ignore EARP))
3	Group 3 / SO-6, SO-7	SR-7, SR-8, SR-9

Table 59: Safety Requirements or Assumptions to mitigate abnormal conditions

4.4.4.3 Thread Analysis of the SPR-level Model - Abnormal Conditions

4.4.4.3.1 Group 1

Abnormal conditions from this group do not cause deviations from the normal operations.

4.4.4.3.2 Group 2

Abnormal conditions from this group usually would cause interruption of the normal use scenario before granting of landing clearance. The interruption is initiated by Flight Crew.

Function/Activity	Functional Blocks/Roles engaged	Safety assessment
Transfer A/C to TWR	Flight Crew, Tower ATCO	Standard procedure not impacted by PJ.02-08
Estimate exit taxiway and ROT	Enhanced AROT Predictor	This must be achievable for neutral safety impact (SR-1, SR-2)
Assess exit and ROT for arriving aircraft	Tower Runway ATCO HMI, Tower Runway ATCO	ATCO must be able to roughly verify the achievability of predicted exit and ROT (SR-10), HMI shall be fully integrated into EFS system to avoid confusion (SR-11).
Give Landing information	Tower Runway ATCO, Fight Crew	Flight Crew shall check for achievability and inform ATCO immediately if proposed exit is not achievable (SR-12)
Give Controller Instructions	Tower Runway ATCO, Fight Crew	Controller instructions should follow verification of prediction by ATCO and Flight Crew (SR-12, SR-13)
Declare Group 2 abnormal condition	Flight Crew, Tower Runway ATCO	Flight Crew either initiates missed approach procedure (standard, no Concept 4 impact) or informs ATCO of landing roll performance deficiency (A-2) which results in ATCO

		subsequently ignoring Enhanced AROT Predictor indications (SR-15)

Table 60: Assessment of abnormal conditions

4.4.4.3.3 Group 3

Abnormal conditions from this group cause cessation of Concept 4 function delivery. They are covered by SO-6 and SO-7 with associated safety requirements.

4.4.4.4 Effects on Safety Nets – Abnormal Operational Conditions

No effect on safety nets have been identified during present safety assessment.

4.4.4.5 Dynamic Analysis of the SPR-level Model – Abnormal Operational Conditions

The abnormal conditions evaluated during PANSA RTS 4 [7] belonged to the Group 3. RTS findings indicate that both loss of Enhanced AROT Predictor function and recovery have neutral safety effect. Controllers were able to seamlessly ingest new system state as well as switch between solution and reference modes of operation. Objective measures such as go-around number and separation maintenance quality

4.4.4.6 Additional Safety Requirements – Abnormal Operational Conditions

ID [SPR-level Model element]	Description	Thread Action Number [Scenario # xx]
SR-15 [Tower Runway ATCO]	Upon receiving communication from the Flight Crew about landing roll performance deficiency Tower Runway Controller shall ignore the indications of Enhanced AROT Predictor.	Declare Group 2 abnormal condition

Table 61: Additional Safety Requirements from Thread Analysis – Abnormal Operational Conditions

ID	Description
A-2	Detected landing roll performance deficiency is communicated by the Flight Crew to Tower Runway Controller (either directly or via Approach Controller).

Table 62: Additional assumptions underlying Thread Analysis - Abnormal Operational Conditions

4.4.5 Design Analysis – Case of Internal System Failures

Section 3.4.7.1 above identifies two relevant system generated hazards:

- **SHz#1** Predicted exit taxiway/ROT is not achievable by the aircraft.
- **SHz#2** Predicted ROT and exit taxiway are not in agreement with the execution of final approach.

4.4.5.1 Causal Analysis

The causal analysis has comprised of technical fault identification summarised in table.

Failure ID	Hazard ID	Description
FA#1	SHz#1	Aircraft type occurrence did not allow for good inference of performance.
FA#2	SHz#1	Aircraft type is not correctly identified.
FA#3	SHz#1	There is an error in the MET or RWY condition data that has not been detected by the QC.
FA#5	SHz#1	System prediction is not correct due to algorithm imperfection.
FA#6	SHz#2	There is an error in the surveillance data that has not been detected by the QC.
FA#7	SHz#2	Enhanced AROT Predictor is not updating prediction.
FA#5	SHz#2	System prediction is not correct due to algorithm imperfection.

Table 63: Internal system failures leading to occurrence of System Generated Hazards

4.4.5.2 Common Cause Analysis

Enhanced AROT Predictor comprises of the following technical systems/system elements:

- Data source connections: MET, surveillance, runway surface condition
- Data pre-processing module (feature extraction, QC)
- Inference engine

- HMI connection (link to CWP)

We will now consider separately the consequences of failures in each of those systems. Starting with data source connections since consequences here are relatively easy to infer. PANSA FTS 8 [7] has established that the Enhanced AROT Predictor is vulnerable to random errors or data missing for any data source (but especially surveillance). The only safe behaviour of such system is to cease provision of service while the data issue persists. This has already been analysed and reflected in Safety Requirements in this document.

Data pre-processing module failures may be twofold: either there is an error in feature inference algorithm (may be a bug) or QC is not detecting some errors occurring in the data. Errors in this system can result in both SHz#1 and SHz#2 occurrence even despite fully functional inference engine. As a result, we may formulate two new safety requirements: SR-16 and SR-17.

Errors in the inference engine result directly in performance degradation and, as a result, both SHz#1 and SHz#2 occurrence. They are very hard to detect an diagnose during operations. To mitigate or limit their occurrence (which always will be non-zero) the inference engine should undergo periodical calibration and diagnostic procedures (SR-16).

Finally, loss of link to CWP effectively causes loss of Enhanced AROT Predictor functionality leading to switching to reference scenario. If the loss of connectivity would happen during an approach this could lead to FA#7 on Tower Runway Controller CWP leading potentially to SHz#2 occurrence. This should be accompanied by appropriate error message (SR-18).

4.4.5.3 Formalization of Mitigations

ID [SPR-level Model element]	Description	Technical system / system element
SR-16 [Enhanced AROT Predictor]	Enhanced AROT Prediction shall undergo periodical evaluation and calibration procedure aimed at investigating and eliminating encountered errors.	Data pre-processing module, Inference engine
SR-17 [Enhanced AROT Predictor]	Enhanced AROT Predictor input data QC algorithms shall be periodically reviewed and, if possible fixed and improved.	Data pre-processing module
SR-18 [Tower Runway ATCO HMI]	Tower Runway Controller HMI shall generate appropriate message when Enhanced AROT Predictor connection is lost.	HMI connection

Table 64: Additional safety requirements (functionality and performance) to mitigate system generated hazards.

4.4.5.4 Safety Requirements (integrity/reliability)

The requirements below have been derived using AIM models [8] and methodology proposed in [1]. For FA#3, FA#6 and FA#7 we had to perform conversion of likelihood from "per arrival" to "per each 30s of Enhanced AROT Predictor operation". For this we have used arrival rate of 50 arrivals per hour.

ID [System failure]	Description
SR-19 [FA#1, FA#2]	Likelihood incorrect arrival type treatment by the Enhanced AROT Predictor shall be no greater than 5.2E-7 per movement.
SR-20 [FA#3, FA#6]	Likelihood of failure of the Enhanced AROT Predictor QC of input data shall be no greater than 2.2E-7 per each 30s of function delivery.
SR-21 [FA#5]	Likelihood of unachievable Enhanced AROT Predictor recommendation shall be no greater than 5.2E-7 per movement.
SR-22 [FA#7]	Likelihood of unannounced cessation of Enhanced AROT Predictor function shall be no greater than 1.1E-7 per each 30s of function delivery

Table 65: Safety Requirements (integrity/reliability) for Concept 4

The resulting Safety Requirements (integrity) are most probably very hard to satisfy and need to be revised. However, in-depth analysis of existing fault trees or a construction of custom fault trees that could make the fault analysis more realistic was not possible given the very short timeframe and limited resources dedicated to independent Concept 4 safety assessment.

4.4.6 Achievability of the SAfety Criteria

Safety Objectives have been shown to support Safety Criteria0. The safety objectives have been subsequently supported by a set of Safety Requirements for normal and abnormal operational conditions. Provided that the Safety Requirements are satisfied the Safety Criteria can be thus satisfied.

4.4.7 Realism of the SPR-level Design

4.4.7.1 Achievability of Safety Requirements / Assumptions

Safety Requirement	Requirement	Achieved? [evidence source]

SR-1	Predicted exit taxiway shall require longer or equal braking distance than minimum braking distance for given arrival type in given conditions.	Requirement achieved (medium confidence – indirect evidence) [PANSA FTS 8]
SR-2	Predicted ROT shall be equal or greater to minimum reasonable ROT achievable by a given arrival type for the given braking distance.	Requirement achieved via algorithm construction
SR-3	Predicted ROT and exit taxiway shall be recalculated at most every 20s from the time of first prediction for a given arrival until the arriving aircraft reaches distance 2NM from the designated runway threshold.	Requirement not achieved but considered achievable with concept revision
SR-4	In case predicted ROT is changed by more than 10% or predicted taxiway is changed the appropriate visual warning shall be displayed on Tower Controller CWP.	Requirement not achieved but considered achievable with concept revision
SR-5	Enhanced AROT Predictor shall have availability to ingest either RCR produced by the local AO or, if available, direct data feed from automatic runway surface condition estimation system.	Requirement achieved by design
SR-6	Enhanced AROT Predictor shall have access to local aerodrome MET data feed.	Requirement achieved by design
SR-7	In case any input is found missing or erroneous Enhanced AROT Predictor shall cease function while the issue persists.	Requirement achieved by design [result of PANSA FTS 8]
SR-8	In case Enhanced AROT Predictor ceases its function appropriate visual warning shall be displayed on Tower Controller CWP. The warning shall give clear reason for lack of Enhanced AROT Prediction function.	Requirement achieved [PANSA RTS 4: visual form of the warning needs to be revised]
SR-9	Enhanced AROT Predictor shall evaluate each of its inputs using quality check procedures.	Requirement achieved by design
SR-10	Tower Runway Controller shall judge the achievability of predicted exit taxiway and ROT upon reception of the estimate from Enhanced AROT Predictor.	Requirement achieved [PANSA RTS 4]
SR-11	Enhanced AROT Predictor HMI shall be integrated into EFS system.	Requirement achieved by design [PANSA RTS 4: platform limitations excluded this]

SR-12	Flight Crew shall check for achievability and inform ATCO immediately if proposed exit is not achievable.	Requirement achieved [PANSA RTS 4]
SR-13	Tower Runway Controller shall judge achievability of estimated exit taxiway and ROT prior to giving any controller instructions based on those estimates.	Requirement achieved [PANSA RTS 4]
SR-14	Tower Runway Controller shall judge achievability of estimated exit taxiway and ROT before providing landing clearance.	Requirement achieved [PANSA RTS 4]
SR-15	Upon receiving communication from the Flight Crew about landing roll performance deficiency Tower Runway Controller shall ignore the indications of Enhanced AROT Predictor.	Requirement achievable [assumed to be standard procedure]
SR-16	Enhanced AROT Prediction shall undergo periodical evaluation and calibration procedure aimed at investigating and eliminating encountered errors.	Requirement achievable in practise
SR-17	Enhanced AROT Predictor input data QC algorithms shall be periodically reviewed and, if possible fixed and improved.	Requirement achievable in practises
SR-18	Tower Runway Controller HMI shall generate appropriate message when Enhanced AROT Predictor connection is lost.	Requirement achievable [Not tested due to platform limitations]
SR-19	Likelihood incorrect arrival type treatment by the Enhanced AROT Predictor shall be no greater than 5.2E-7 per movement.	Requirement very hard to evaluate and probably not realistic
SR-20	Likelihood of failure of the Enhanced AROT Predictor QC of input data shall be no greater than 2.2E-7 per each 30s of function delivery.	Requirement very hard to evaluate and probably not realistic
SR-21	Likelihood of unachievable Enhanced AROT Predictor recommendation shall be no greater than 5.2E-7 per movement.	Requirement very hard to evaluate and probably not realistic
SR-22	Likelihood of unannounced cessation of Enhanced AROT Predictor function shall be no greater than 1.1E-7 per each 30s of function delivery	Requirement very hard to evaluate and probably not realistic

Table 66: Achievability of Safety Requirements / Assumptions for Concept 4

Assumptions made during derivation of above Safety Requirements rely on widely implemented procedures and therefore are realistic.

4.4.7.2 "Testability" of Safety Requirements

Requirements SR-1 to SR-18 are either shown to be achieved or easily testable. However, we consider SR-19 to SR-22 to be not realistic and very hard to evaluate. The corresponding process of safety assessment process should be revised.

4.4.7.3 Concept 4 Validation Conclusions Relevant to Safety Assessment

The general conclusion of the operational safety assessment is as follows:

- SO-3 is not met by design. Operational experts state that this most probably will not have detrimental effect on safety (expert judgement) based on the fact that Concept 4 is only an advisory tool. Some evidence (distribution of go-arounds in non-nominal or intended error cases) originating from RTS may contradict this but this evidence has very low level of confidence (platform R/T issues were occurring at the same time).
- SO-4 to SO-7 are achieved by design as corresponding Safety Requirements are met.
- There is evidence based on PANSA FTS 8 [7] that SO-1 and SO-2 are met but confidence level is medium.
- There is no conclusive evidence available to support or deny SO-8 to SO-11 on operational level. Expert judgement points towards SO-9 and SO-11 being easily satisfied. Subsequent FT analysis on the SPR level is necessary to identify safety impact.

General conclusion on the operational level is that the safety impact is neutral and Safety Criteria are met. However, this is mostly based on expert judgement from a small pool of experts and necessarily must be allocated low level of confidence.

4.4.8 Validation & Verification of the Safe Design at SPR Level

Due to very limited timeframe the details of validation and verification process of PJ.02-08 Concept 4 are the same as in Section 3.4.10.

5 Detailed Safe Design at Physical Level

The Solution PJ02-08 needs to cope with multiple different physical solution for the implementation of Concept 1, 2, Concept 3 and Concept 4. Within V3 no specific physical model has been designed. Consequently, this chapter remains unpopulated.

6 Acronyms and Terminology

Term	Definition
AFI	Arrival Free Interval
ATOT	The Actual Take Off Time (ATOT) is the time that an aircraft takes off from the runway. (Equivalent to ATC ATD–Actual Time of Departure, ACARS = OFF).
CTOT	The Calculated Take Off Time (CTOT) is a time calculated and issued by the Central Flow Management unit, as a result of tactical slot allocation, at which a flight is expected to become airborne. (ICAO Doc 7030/4 – EUR, Table 7)
Departure Management Service	Departure Management Service describes the procedures used to establish sequences and target times planned by the departure manager.
Departure Manager (DMAN)	DMAN is a planning system to improve departure flows at one or more airports by calculating the Target Take Off Time (TTOT) and Target Start Up Approval Time (TSAT) for each flight, taking multiple constraints and preferences into account.
ELDT	The Estimated Landing Time (ELDT) is the estimated time that an aircraft will touchdown on the runway. (Equivalent to ATC ETA–Estimated Time of Arrival = landing). [A-CDM Manual]
ELRP	The Estimated Line-up and Roll to Airborne Period is the estimated time that an aircraft will take to line up and roll to airborne from the holding position
EIBT	The Estimated In-Block Time (EIBT) is the estimated time that an aircraft will arrive in-blocks. (Equivalent to Airline/Handler ETA – Estimated Time of Arrival).
EOBT	The estimated time at which the aircraft will commence movement associated with departure.
ERBP	Runway Delay Buffer (ERBP) is the buffer of delay planned at runway hold to maintain pressure on runway
ERWP	The Expected Runway Waiting Period (ERWP) is the planned delay at the runway holding point.
ESWP	Expected Stand Waiting Period (ESWP) is the planned delay waiting on the stand
ETA	Estimated Time of Arrival (ETA)

	1. (SESAR) the time computed by the FMS for the flight arriving at a point related to the destination airport 2. (ICAO) For IFR flights, the time at which it is estimated that the aircraft will arrive over that designated point, defined by reference to navigation aids, from which it is intended that an instrument approach procedure will be commenced, or, if no navigation aid is associated with the aerodrome, the time at which the aircraft will arrive over the aerodrome. For VFR flights, the time at which it is estimated that the aircraft will arrive over the aerodrome.
ETOT	Forecast of time when aircraft will become airborne taking into account the EOBT plus EXOT
EXIT	The estimated taxi-in time between landing and in-block
EXOP	The estimated Outbound Taxi (EXOP) is the Expected Taxi Period from Off-Block to Take-Off (with no buffer or delay)
EXOT	The estimated time between off-block and take off. This estimate includes any delay buffer time at the holding point or remote de-icing prior to take off.
Holding point	A geographical location that serves as a reference for a holding procedure. (Holding Fix)
Push-Back	Movement of an aircraft on the ground consisting of leaving the parking area in reverse motion as far as alignment on the taxiway.
Reference Business Trajectory (RBT)	The business trajectory which the airspace user agrees to fly and the ANSP and Airports agree to facilitate (subject to separation provision).
ROCAT	ROT characterization (ROCAT)
ROT	Runway Occupancy Time
Runway availability delay	The Runway availability delay represents the time an aircraft has to wait before its actual departure slot on the runway.
Runway Pressure	The Runway Pressure represents the number required by the controller to guarantee that RWY is not under-utilized.
Shared Business Trajectory (SBT)	Published business trajectory that is available for collaborative ATM planning purposes.
SID	A designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en-route

	phase of a flight commences.
SOBT	The time that an aircraft is scheduled to depart from its parking position.
TLDT	Targeted Time from the Arrival management process at the threshold, taking runway sequence and constraints into account. It is not a constraint but a progressively refined planning time used to coordinate between arrival and departure management processes.
TOBT	The Target Off-Block Time (TOBT) is the time that an Aircraft Operator or Ground Handler estimates that an aircraft will be ready, all doors closed, boarding bridge removed, push-back vehicle available and ready to start up / push-back immediately upon reception of clearance from the Tower Controller.
TSAT	The time provided by ATC taking into account TOBT, CTOT and/or the traffic situation that an aircraft can expect start-up / push-back approval Note: The actual start up approval (ASAT) can be given in advance of TSAT
TSAT Window	A time-frame of +/- 5 minutes around the TSAT, in which a Start-Up and Push-Back approval may be issued.
TTOT	The Target Take Off Time taking into account the TOBT/TSAT plus the EXOT. Each TTOT on one runway is separated from other TTOT or TLDT to represent vortex and / or SID separation between aircraft.
Tower Controller	Position(s) or person(s) in a control tower responsible for take-off and landing of aircraft on airports. Also includes En-route, pushback and start-up clearances and ground movement roles and responsibilities.
Variable Taxi Time	The estimated time that an aircraft spends taxiing between its parking stand and the runway or vice versa. Variable Taxi Time is the common name for inbound (EXIT) and outbound (EXOT) taxi times, used for calculation of TTOT or TSAT.

Table 67: Acronyms and terminology

7 References

[1] SESAR, Safety Reference Material, Edition 4.1, December 2018

[2] SESAR, Guidance to Apply the Safety Reference Material, Edition 3.1, December 2018, Deliverable ID D.0.050

[3] SESAR, Final Guidance Material to Execute Proof of Concept, Ed00.04.00, August 2015, Deliverable ID: 16.01.04 – D07

[4] SESAR 1 Coupled AMAN/DMAN - S02V2 Final SPR, Deliverable ID: D30, Date: 22/07/2016, Edition: 00.02.01

[5] SESAR 2020 Solution PJ02-08 OSED SPR INTEROP V3 Part I, 18 October 2019, Edition 00.01.02, Deliverable ID D6.1.20

[6] SESAR 2020 Solution PJ02-08 V3 Safety Plan, Date: 08 March 2019, Edition: 00.01.00, Deliverable ID: D6.1.22

[7] SESAR 2020 Solution PJ.02-08 V3 VALR, Date: 06 September 2019, Edition: 00.01.04, Deliverable ID: D6.1.233

[8] Accident Incident Models in MS Visio – AIM2017, available at Stellar SJU Extranet, Date: September 2017

[9] SESAR 2020 Solution PJ.02-08 V3 TS/IRS, Date: 11 September 2019, Edition: 00.02.00, Deliverable ID: D6.1.214

Appendix A Concept 1 and 2 Safety Objectives and Requirements

A.1 Concept 1 and 2 Safety Objectives (Functionality and Performance)

ID	Safety Objective (Functionality and Performance)
SO#1	The Integrated Runway Sequence function shall support coordination between TWR and Approach
SO#2	The Integrated Runway Sequence function shall support effective ATC runway management
SO#3	The Integrated Runway Sequence function shall support managing the sequence in mixed and dependent mode environment
SO#4	The Integrated Runway Sequence function shall be provided with accurate and correct wake vortex information
SO#5	The Integrated Runway Sequence function shall be provided with reliable demand prediction
SO#6	The Integrated Runway Sequence function needs to be provided with all relevant information for sequencing traffic
SO#7	For abnormal conditions the same safety objectives remain as for stand-alone AMAN and stand-alone DMAN.

Table 68: Summary for Concept 1 and 2 functional and performance safety objectives

A.2 Concept 1 and 2 Consolidated List of Safety Requirements

Reference	Safety Requirement
REQ-02.08-SPRINTEROP-FUN1.0001	In order to achieve an optimal integration of arrival and departure flows, the ATCO shall be provided with an automatically calculated integrated arrival and departure sequence based on the following inputs if available:

Reference	Safety Requirement
	• Flight progress reports • Input clearances from the controller • Arrival and Departure traffic volumes from the airport • Estimated Take-off and Landing times • Airport priorities and constraints • Updated manual sequences from the controller • Arrival and departure required spacing • SID Constraints • Planned runway configuration • The variable taxi-out times Actual landing and actual off-block and take-off times • Weather conditions • Runway Occupancy Times static values • Wake vortex separations
REQ-02.08-SPRINTEROP-FUN1.0002	The Sequence Manager shall be able to manually adjust the criteria for the calculation of the integrated sequence by setting the priority on proposed KPAs (e.g. capacity, efficiency) off-line configurable based on local implementation needs.
REQ-02.08-SPRINTEROP-FUN1.0007	The Integrated Runway Sequence function shall consider the airport priorities and constraints (off-line configurable operational indicators based on local implementation needs) in the provision of the optimised integrated runway sequence.
REQ-02.08-SPRINTEROP-FUN1.0008	The ATCO shall be able to manually freeze/un-freeze a flight in the Integrated Runway Sequence.
REQ-02.08-SPRINTEROP-FUN1.0010	When an aircraft estimated landing time/take-off time is within an off-line defined stability time horizon, the Integrated Runway Sequence function shall freeze its position in the Integrated Runway Sequence avoiding any automatic sequence order change unless specific rules apply to cope with local exceptions.
REQ-02.08-SPRINTEROP-FUN1.0012	When a runway closure is manually input, the Integrated Runway Sequence function shall automatically recalculate the Integrated Runway Sequence accordingly.
REQ-02.08-SPRINTEROP-FUN1.0013	The Integrated Runway Sequence shall recalculate the Integrated Runway Sequence after a go-around (either automatically or after manual input from the controller).

Reference	Safety Requirement
REQ-02.08-SPRINTEROP-FUN1.0014	The ATCO shall be able to manually change the Integrated Runway Sequence.
REQ-02.08-SPRINTEROP-FUN1.0015	The Integrated Runway Sequence function shall re-compute the Integrated Runway Sequence based on manual update.
REQ-02.08-SPRINTEROP-FUN1.0016	The Integrated Runway Sequence shall provide TTOT compliant with CTOT.
REQ-02.08-SPRINTEROP-FUN1.0017	The Integrated Runway Sequence function shall update the Integrated Runway Sequence at the runway holding point with one of the following options: • The Tower Runway controller manually updates the sequence OR, The system updates the sequence accurately reflecting actual situation.
REQ-02.08-SPRINTEROP-HMI1.0001	Based on off-line configuration by role, the Integrated Runway Sequence function shall provide each ATCO with the appropriate information on the HMI, among the following: - Time horizon of the time line; - Calculated target times (TSAT, TTOT, TLDT); - Sequence number; - Advisories (time to loose/gain, tactical); - Airport priorities.
REQ-02.08-SPRINTEROP-HMI1.0002	The Integrated Runway Sequence function shall provide the Approach Controller with at least the TLDT on the HMI.
REQ-02.08-SPRINTEROP-HMI1.0003	Minimum required Integrated Runway Sequence information for Tower Runway Controller.
REQ-02.08-SPRINTEROP-HMI1.0004	The Integrated Runway Sequence function shall provide the Tower Clearance Delivery Controller and the Apron Manager (where applicable) with the TSAT and TTOT values on the HMI.
REQ-02.08-SPRINTEROP-HMI1.0005	The Integrated Runway Sequence function shall provide En–Route Controllers with advisories on time to lose or gain for arrival traffic on the HMI.
REQ-02.08-SPRINTEROP-HMI1.0008	The Integrated Runway Sequence display shall include indication of any runway closure.

Reference	Safety Requirement
REQ-02.08-SPRINTEROP-HMI2.0001	If RMAN is not available, the Airport Tower Supervisor shall be able to insert the runway capacities manually.
REQ-02.08-SPRINTEROP-SAF1.0001	The Integrated Runway Sequence function shall support shared situation awareness between TWR and Approach by providing the relevant information (based on local implementation needs) of the up-to-date integrated arrival/departure sequence.
REQ-02.08-SPRINTEROP-SAF1.0003	An alert on the HMI shall warn the Controller and Supervisor in case of a failure (partial or total loss) of the Integrated Runway Sequence function.
REQ-02.08-SPRINTEROP-SAF1.0004	The responsible units shall ensure that Controllers are properly trained in the back up procedures for failures (partial or total loss) of Integrated Runway Sequence function
REQ-02.08-SPRINTEROP-SAF1.0008	The Integrated Runway Sequence function shall never override a manual update of the Integrated Runway Sequence with an automatic update.
REQ-02.08-SPRINTEROP-PRF1.0002	The Integrated Runway Sequence stability time horizon shall be off-line configurable according to local preferences.
REQ-02.08-SPRINTEROP-PRF1.0003	The Integrated Runway Sequence frozen time horizon shall be off-line configurable according to local preferences.
REQ-02.08-SPRINTEROP-PRF1.0004	The Integrated Runway Sequence function shall update the Integrated Runway Sequence as soon as new arrival or departure information becomes available.
REQ-02.08-SPRINTEROP-PRF1.0005	The Integrated Runway Sequence function shall maximize runway throughput.
REQ-02.08-SPRINTEROP-PRF1.0006	The planned number of arrivals and departures shall not exceed the available capacity.
REQ-02.08-SPRINTEROP-PRF1.0007	The Integrated Runway Sequence function shall avoid providing the ATCO with updates in the Arrival part of the Integrated Runway Sequence that are no longer feasible.
REQ-02.08-SPRINTEROP-PRF1.0008	The Integrated Runway Sequence function shall provide the ATCO with an Integrated Runway Sequence with an adequate level of stability.

Table 69: Concept 1 and 2 Consolidated list of safety relevant requirements

Appendix B Concept 3 Validation Results used in Safety Analysis

This section presents a summary of the results for the exercise safety validation objective relating to assessing the safety impact of the concept 3 during interception and final approach.

Impact on operational safety

The evidence for this exercise validation safety objective was based on controller feedback (through questionnaires and debriefings) and observations combined with expert judgement.

Safe standard practices were observed during the runs with the ROCAT with the FTD and RECAT-EU as well as with the ORD tool and PWS. Additionally, no specific comments related to potential impact on operational safety were reported by the controllers.

Impact on separation conformance at threshold

No large under-spacing pairs (with an under-spacing larger than 0.5 NM) were observed in any of the simulation runs.

Small under-spacing: pairs with an under-spacing of more than 0.1 NM (i.e. corresponding to the under-spacing tolerance) and at most 0.5 NM have been further analysed with the following categories:

- Under-spaced pairs by more than 1 NM
- Under-spaced pairs by more than 0.5 NM and at most 1 NM
- Under-spaced pairs by more than 0.25 NM and at most 0.5 NM
- Under-spaced pairs by more than 0.1 NM and at most 0.25 NM
- Pairs under-spaced by less than 0.1 NM and delivered with a buffer of less than 0.25 NM
- Pairs delivered with a buffer of at least 0.25NM and less than 0.5 NM
- Pairs delivered with a buffer of at least 0.5NM and less than 1 NM
- Pairs delivered with a buffer of at least 1 NM and less than 2 NM
- Pairs delivered with a buffer larger than 2 NM

Table 70 presents the number of occurrences and Table 71 provide the percentages for each run.

Scenario	ATCoOConfig	<-1	[-1, -0.5[	[-0.5, -0.25[	[-0.25, -0.1[	[-0.1, 0.25[	[0.25, 0.5[	[0.5, 1[	[1, 2[	>2
Reference	1	0	0	1	1	11	18	12	0	0
Reference	2	0	0	3	6	23	6	3	0	2
Reference	3	0	0	1	3	21	10	4	0	0
Reference	4	0	0	0	3	18	15	4	0	0
FTD with RECAT-EU	1	0	0	0	2	10	24	15	0	0
FTD with RECAT-EU	2	0	0	0	0	10	13	19	3	0
FTD with RECAT-EU	3	0	0	0	0	6	21	16	5	0
FTD with RECAT-EU	4	0	0	0	0	9	24	13	2	0
ORD with PWS	1	0	0	0	0	2	16	23	5	0
ORD with PWS	2	0	0	0	0	13	20	10	2	0
ORD with PWS	3	0	0	0	0	4	20	19	3	0
ORD with PWS	4	0	0	0	0	8	26	11	5	0

Table 70: Separation conformance at threshold: number of pairs with various under-spacing ranges.

Scenario	ATCo Config	<-1	[-1, -0.5[	[-0.5, -0.25[	[-0.25, -0.1[	[-0.1, 0.25[	[0.25, 0.5[	[0.5, 1[	[1, 2[	>2
Reference	1	0%	0%	2%	2%	26%	42%	28%	0%	0%
Reference	2	0%	0%	7%	14%	53%	14%	7%	0%	5%
Reference	3	0%	0%	3%	8%	54%	26%	10%	0%	0%
Reference	4	0%	0%	0%	8%	45%	38%	10%	0%	0%
FTD with RECAT-EU	1	0%	0%	0%	4%	20%	47%	29%	0%	0%
FTD with RECAT-EU	2	0%	0%	0%	0%	22%	29%	42%	7%	0%
FTD with RECAT-EU	3	0%	0%	0%	0%	13%	44%	33%	10%	0%
FTD with RECAT-EU	4	0%	0%	0%	0%	19%	50%	27%	4%	0%
ORD with PWS	1	0%	0%	0%	0%	4%	35%	50%	11%	0%
ORD with PWS	2	0%	0%	0%	0%	29%	44%	22%	4%	0%
ORD with PWS	3	0%	0%	0%	0%	9%	43%	41%	7%	0%
ORD with PWS	4	0%	0%	0%	0%	16%	52%	22%	10%	0%

Table 71: Separation conformance at threshold: percentages of pairs with various under-spacing ranges.

For the Reference runs, up to 7 % of the pairs are seen to be delivered with an under-spacing larger than 0.25 whereas the others are delivered with less than 0.25 NM under-spacings.

For the enhanced ROT predictability with FTD and RECAT-EU runs, for the only run with under-spacing, the under-spaced pairs show an infringement of the FTD by less than 0.25 NM. This further confirms the safety benefit related to the FTD tool as the obtained under-spacing rates are lower as well as the under-spacing values.

For the enhanced ROT predictability with ORD tool and PWS no under-spacing occurred. The positive impact of the use of the ORD tool with ITD and FTD on the separation conformance is thus clearly visible.

Impact on separation conformance before alignment on the final approach

The conformance to horizontal and vertical separation minima was assessed for aircraft operations before alignment to runway centreline and when the aircraft were within 25 NM from the runway threshold. Only region of space where ATCOs are assumed to actually control the aircraft flights during the simulations are assessed.

For this phase of operation, the following criteria have to be met:

- the horizontal separation shall be larger than or equal to the minimum radar separation equal to 3 NM, or
- the vertical separation shall be larger than or equal to 1000 ft.

Table 72 provides the number of separation non-conformances prior to interception of the final approach for all twelve runs. A distinction is also made between conflicts occurring with East traffic flow and conflict with West traffic flows.

For the Reference runs, 0-2 conflicts are found per run with a total of 4 conflicts when considering all Reference runs.

For the enhanced ROT predictability with FTD and RECAT EU runs, only one run shows 2 conflicts whereas none are found for the three other FTD with RECAT-EU runs. All of them involved MEDIUM or SMALL aircraft as leader and/or follower. Most of them involve East traffic flow aircraft flights.

For the enhanced ROT predictability with ORD tool and PWS, no conflict pairs are found.

Scenario	ATCo Config	# East Approach	#West Approach	# Total
Reference	1	0	0	0
Reference	2	1	0	1
Reference	3	2	0	2
Reference	4	0	1	1
RECAT-EU with FTD	1	2	0	2
RECAT-EU with FTD	2	0	0	0
RECAT-EU with FTD	3	0	0	0
RECAT-EU with FTD	4	0	0	0
PWS with ITD	1	0	0	0
PWS with ITD	2	0	0	0

PWS with ITD	3	0	0	0
PWS with ITD	4	0	0	0

Table 72: Comparison of separation non-conformances between Reference and Solution runs.

The use of reduced MRS to 2.5NM and ROT based on aircraft type delivered with a separation delivery tool (either with FTD only or with ORD (i.e. both ITD and FTD)) is thus not seen to negatively impact the separation conformance before alignment.

On the contrary, the controller support tools (FTD alone and or ITD plus FTD) it is even seen to improve the separation conformance compared to the Reference runs.

Impact on number of go-arounds

Table 73 provides, the number of go-around for each run.

Scenario	ATCo Config	N GA	N Killed arr	N landings	Average of DBS minima
Reference	1	0	0	44	3.2
Reference	2	0	2	45	3.2
Reference	3	2	0	42	3.2
Reference	4	2	0	43	3.2
RECAT-EU with FTD	1	0	0	52	3.2
RECAT-EU with FTD	2	0	1	47	3.2
RECAT-EU with FTD	3	0	0	49	3.2
RECAT-EU with FTD	4	0	0	49	3.2
PWS with ITD	1	1	0	48	3.2
PWS with ITD	2	1	2	48	3.2
PWS with ITD	3	0	1	48	3.2
PWS with ITD	4	0	0	51	3.3

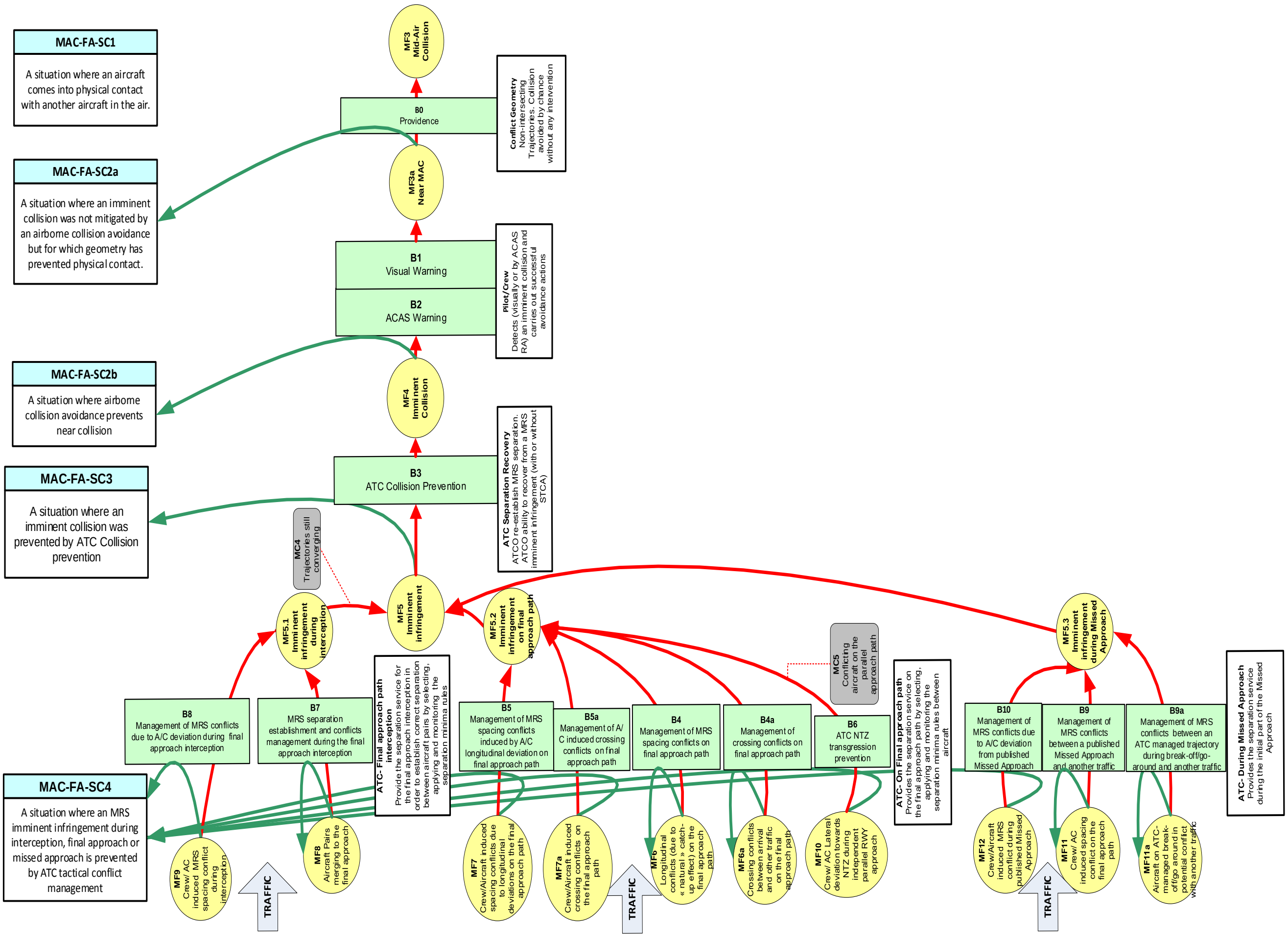
Table 73: Number of go-around, killed and landing aircraft for each run.

Overall in the runs with enhanced ROT predictability with FTD, no go-arounds occurred compared to 4 occurrences in the reference runs indicating a positive impact of the FTD tool on ATCO performance.

Two go-arounds occurred in the enhanced ROT predictability with ORD tool runs compared to 4 go-arounds in Reference, thus a positive impact of the solution scenario on ATCO performance could again be concluded.

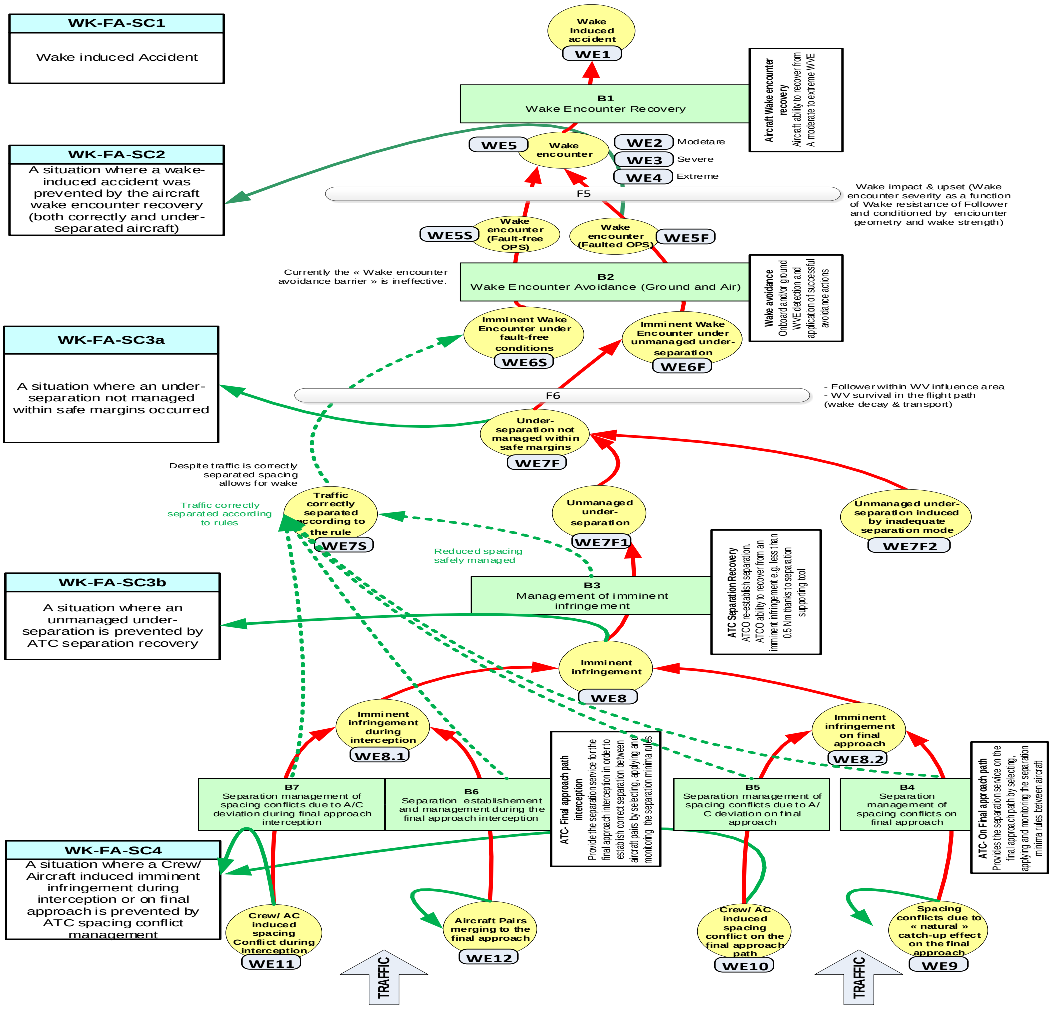
B.1 AIM Models applicable to concept 3

B.1.1 MAC on FAP



Founding Members

B.1.2 WAKE on FAP



Severity Class Scheme for final approach Wake Induced Accident
AIM WAKE BARRIER MODEL (Final Approach) v2.1

Appendix C Concept 4 Safety Objectives and Requirements

C.1 Concept 4 Safety Criteria to Safety Objectives traceability

The mapping of the Safety Objectives to Safety Criteria is established as follows for Concept 4

SAC	Safety Objectives
SAC-4-11 With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of planned tactical taxiway conflicts shall not increase.	(SO-1) Predicted exit taxiway shall be achievable by the arriving aircraft. (SO-2) Predicted ROT shall not be underestimated. (SO-3) ROT and exit taxiway prediction shall be repeatedly verified and updated according to approach execution and weather conditions. (SO-4) Enhanced ROT Predictor shall be provided the most up to date runway surface condition information. (SO-5) Enhanced ROT Predictor shall be provided up to date aerodrome MET data. (SO-6) In case any input for which the system was configured is missing or found erroneous Enhanced AROT Predictor shall cease function and display appropriate error message until issue is resolved. (SO-7) Enhanced AROT Predictor shall run quality check on its input data. (SO-9) The likelihood that incorrect prediction of exit taxiway or ROT will result in taxiway conflict shall be less than 1.1E-3 per movement. (SO-11) The likelihood prediction of exit taxiway or ROT being invalid due to execution of final approach will result in taxiway conflict shall be less than 1.1E-3 per movement.
SAC-4-12 With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of runway separation infringements shall not increase.	(SO-1) Predicted exit taxiway shall be achievable by the arriving aircraft. (SO-2) Predicted ROT shall not be underestimated. (SO-3) ROT and exit taxiway prediction shall be repeatedly verified and updated according to approach execution and weather conditions. (SO-4) Enhanced ROT Predictor shall be provided the

	most up to date runway surface condition information. (SO-5) Enhanced ROT Predictor shall be provided up to date aerodrome MET data. (SO-6) In case any input for which the system was configured is missing or found erroneous Enhanced AROT Predictor shall cease function and display appropriate error message until issue is resolved. (SO-7) Enhanced AROT Predictor shall run quality check on its input data. (SO-8) The likelihood that incorrect prediction of exit taxiway or ROT will result in failure to timely exiting the runway shall be less than 1.1E-6 per movement. (SO-10) The likelihood prediction of exit taxiway or ROT being invalid due to execution of final approach will result in failure to timely exiting the runway shall be less than 1.1E-6 per movement.
SAC-4-21 With the introduction of Enhanced ROT Prediction integrated into TWR ATCO CWP the number of imminent inappropriate landings shall not increase.	(SO-1) Predicted exit taxiway shall be achievable by the arriving aircraft. (SO-2) Predicted ROT shall not be underestimated. (SO-3) ROT and exit taxiway prediction shall be repeatedly verified and updated according to approach execution and weather conditions. (SO-8) The likelihood that incorrect prediction of exit taxiway or ROT will result in failure to timely exiting the runway shall be less than 1.1E-6 per movement. (SO-10) The likelihood prediction of exit taxiway or ROT being invalid due to execution of final approach will result in failure to timely exiting the runway shall be less than 1.1E-6 per movement.

Table 74: Mapping of SO to SAC for Concept 4.

C.2 Concept 4 Safety Objectives (Functionality and Performance)

ID	Safety Objective (Functionality and Performance)
SO 1	Predicted exit taxiway shall be achievable by the arriving aircraft.
SO 2	Predicted ROT shall not be underestimated.

SO 3	ROT and exit taxiway prediction shall be repeatedly verified and updated according to approach execution and weather conditions.
SO-4	Enhanced ROT Predictor shall be provided the most up to date runway surface condition information.
SO-5	Enhanced ROT Predictor shall be provided up to date aerodrome MET data.
SO 6	In case any input for which the system was configured is missing or found erroneous Enhanced AROT Predictor shall cease function and display appropriate error message until issue is resolved.
SO 7	Enhanced AROT Predictor shall run quality check on its input data.

Table 75: Summary for Concept 4 functional and performance safety objectives

C.3 Concept 4 Safety Objectives (Integrity/Reliability)

ID	Safety Objectives (Integrity/Reliability)
SO-8	The likelihood that incorrect prediction of exit taxiway or ROT will result in failure to timely exiting the runway shall be less than 1.1E-6 per movement.
SO-9	The likelihood that incorrect prediction of exit taxiway or ROT will result in taxiway conflict shall be less than 1.1E-3 per movement.
SO-10	The likelihood prediction of exit taxiway or ROT being invalid due to execution of final approach will result in failure to timely exiting the runway shall be less than 1.1E-6 per movement.
SO-11	The likelihood prediction of exit taxiway or ROT being invalid due to execution of final approach will result in taxiway conflict shall be less than 1.1E-3 per movement.

Table 76: Summary of Concept 4 integrity/reliability safety objectives

C.4 Concept 4 Consolidated list of Safety Requirements

Reference	Safety Requirement
SR-1	Predicted exit taxiway shall require longer or equal braking distance than minimum braking distance for given arrival type in given conditions.
SR-2	Predicted ROT shall be equal or greater to minimum reasonable ROT achievable by a given arrival type for the given braking distance.
SR-3	Predicted ROT and exit taxiway shall be recalculated at most every 20s from the time of first prediction for a given arrival until the arriving aircraft reaches distance 2NM from the designated runway threshold.
SR-4	In case predicted ROT is changed by more than 10% or predicted taxiway is changed the appropriate visual warning shall be displayed on Tower Controller CWP.

Reference	Safety Requirement
SR-5	Enhanced AROT Predictor shall have availability to ingest either RCR produced by the local AO or, if available, direct data feed from automatic runway surface condition estimation system.
SR-6	Enhanced AROT Predictor shall have access to local aerodrome MET data feed.
SR-7	In case any input is found missing or erroneous Enhanced AROT Predictor shall cease function while the issue persists.
SR-8	In case Enhanced AROT Predictor ceases its function appropriate visual warning shall be displayed on Tower Controller CWP. The warning shall give clear reason for lack of Enhanced AROT Prediction function.
SR-8a	In case a visual warning is displayed informing ATCO about lack of Enhanced AROT Predictor function Tower Runway Controller shall fall back on reference operating method where exit taxiway and AROT are estimated based on ATCO operational experience.
SR-9	Enhanced AROT Predictor shall evaluate each of its inputs using quality check procedures.
SR-10	Tower Runway Controller shall judge the achievability of predicted exit taxiway and ROT upon reception of the estimate from Enhanced AROT Predictor.
SR-11	Enhanced AROT Predictor HMI shall be integrated into EFS system.
SR-12	Flight Crew shall check for achievability and inform ATCO immediately if proposed exit is not achievable.
SR-13	Tower Runway Controller shall judge achievability of estimated exit taxiway and ROT prior to giving any controller instructions based on those estimates.
SR-14	Tower Runway Controller shall judge achievability of estimated exit taxiway and ROT before providing landing clearance.
SR-15	Upon receiving communication from the Flight Crew about landing roll performance deficiency Tower Runway Controller shall ignore the indications of Enhanced AROT Predictor.
SR-16	Enhanced AROT Prediction shall undergo periodical evaluation and calibration procedure aimed at investigating and eliminating encountered errors.
SR-17	Enhanced AROT Predictor input data QC algorithms shall be periodically reviewed and, if possible fixed and improved.
SR-18	Tower Runway Controller HMI shall generate appropriate message when Enhanced AROT Predictor connection is lost.

Reference	Safety Requirement
SR-19	Likelihood incorrect arrival type treatment by the Enhanced AROT Predictor shall be no greater than 5.2E-7 per movement.
SR-20	Likelihood of failure of the Enhanced AROT Predictor QC of input data shall be no greater than 2.2E-7 per each 30s of function delivery.
SR-21	Likelihood of unachievable Enhanced AROT Predictor recommendation shall be no greater than 5.2E-7 per movement.
SR-22	Likelihood of unannounced cessation of Enhanced AROT Predictor function shall be no greater than 1.1E-7 per each 30s of function delivery

Table 77: Concept 4 Consolidated list of safety relevant requirements

Appendix D PJ02-08 V3 RTS Concept 1 Safety Results

Safety Results from PJ02-08 V3 Real Time Simulations for Concept 1. Additional information on validation results can be found in PJ.02-08 V3 Validation Report.

Taking into account that RTS cannot provide relevant data to make statistics on probability of separation infringement, the main criteria we can use to provide evidence that safety is not impaired is the subjective assessment of ATCOs. After V3 validations including safety assessment in two RTS, following main results can be summarised on safety;

- ATCOs participating to V3 RTS consider that the use of an Integrated Runway Sequence does not introduce new hazards compared to the situation of using a standalone AMAN with a standalone DMAN.
- ATCOs participating to V3 RTS consider that the implemented safety requirements are sufficient and efficient barriers to mitigate all the possible hazards.

D.1 LFV-COOPANS V3 RTS Safety Results

SAFETY - EX2-OBJ-PJ02.08-V3-VALP-SA1 – Results

Objective title: Safety acceptability and feasibility (TS-0301)

Objective description: To assess the impact of the operational improvement on safety.

Success Criteria:

The objective is fulfilled by making an initial Safety Assessment, i.e. identifying potential Safety Hazards with the introduction of the operational improvement.

Results:

Operational improvement impact on safety

Safety areas were addressed during both weeks of validation. In the second week there was an increased focus on non-nominal situations (unplanned runway closure with go around and also failure mode).

During a separate Safety Workshop in the second simulation week, a number of safety objectives were discussed. Safety related feedback was also described in debriefings and in the end of week questionnaires.

Regarding the overall safety controllers confirmed a high level of safety during all simulator runs (nominal and non-nominal).

Controller feedback: “The level of safety was kept at a high level. During test of irregular events there is no or just a small difference from how we handle it today. These events can happen and safety will be contained.”

Operational feedback on safety during the simulation, with individual statements when working with the Integrated Runway Sequence function provided by controllers:

- Always remember this is a planning tool.
- The safety is not affected in any way (nor good or bad) by the Integrated Runway Sequence function during the non-nominal situations tested.
- The level of safety was kept at a high level.
- Proper training can eliminate target fascination and also risk of too much trust in system sequence proposals. Shared view of the Planned Integrated Sequence

The Integrated Runway Sequence Function provided TWR and Approach with a shared situation awareness (similar views) with balancing of arrival and departure flights, controllers found safety maintained while coordination workload was reduced.

Failure mode and back up procedures

In a specific validation run with failure mode, a total loss of Integrated Runway Sequence function was addressed, including loss of both AMAN and DMAN. In this failure situation parts of the CWP provided black screen on windows displaying AMAN and DMAN timelines and lists. The controllers could directly see and understand a need to work with predefined backup procedures.

In briefing before the run with failure mode controllers were informed on operational procedures to use in different situations. The Sequence Manager and TWR Supervisor had additional tasks for manual coordination between APP and TWR.

- The controllers confirmed the ability to safely work with separation management and manual coordination in the tested failure mode.

During the second phase of failure mode test we could also in this simulator provide testing of recovery to advanced operations when ATC revert to the use of Integrated Runway Sequence Function with AMAN and DMAN. It was identified a need to further clarify procedures for Sequence Manager and Tower Supervisor to accept and coordinate when systems are back to normal (full use of Integrated Runway Sequence function).

Failure mode test included assessment of controller ability to handle situations with degraded mode.

Controller capability to take control and perform sequencing by reference techniques in case of cancellation of the functionality of the Integrated Runway Sequence Function.

- All controllers confirmed ability to handle situations with reduced functionality during degraded mode.

Priority of manual updates versus automatic updates

During the validation, the Sequence Manager performed swap of arrivals flights. For departure flights the Tower Supervisor performed sometimes manual move of departure flight to update the departure sequence. These manual updates were accepted by the Integrated Runway Sequence function and automatic updates were no more applied for flights affected by a manual update.

- The controllers confirmed the system ability to safely integrate manual updates into the calculated runway sequence.

D.2 SKYGUIDE V3 RTS Safety Results

SAFETY – EX3-OBJ-PJ02.08-V3-VALP-SA1 – Results

Objective title: Safety acceptability and feasibility (TS-0301)

Objective description: To assess the impact of the operational improvement on safety.

Success Criteria:

The objective is fulfilled by making an initial Safety Assessment, i.e. identifying potential Safety Hazards with the introduction of the operational improvement.

Results:

Impact on safety

The impact on safety was addressed during the second day of the validation, which was also devoted to runs on special situations.

The feedback from the ATCOs participating to the exercise are summarised as follows:

- **The coupled AMAN/DMAN remains a planning tool that does not impact safety as directly as tactical control tools**;
- **The coupled AMAN/DMAN contributes to indirectly improve safety as it increases team and individual situation awareness and reduces ATCOs mental workload and stress** especially at Approach;
- **The use of coupled AMAN/DMAN is considered not to have any direct impact in the safety indicators** (potential number of loss of separation, potential number of runway incursions);
- **The level of automation provided by the coupled AMAN/DMAN is not sufficiently high to realistically consider a risk of loss of skills from ATCOs** triggering major problems in case of unavailability;
- The failure of the coupled AMAN/DMAN was analysed. In the proposed implementation, **the unavailability of the coupled AMAN/DMAN implied the rollback to the current situation (no sequencing tools), and not to the reference scenario**. This transition was found easy to handle, as the ATCOs are currently more used to work without a sequencer than to work with a sequencer. However, for an operational implementation, it has to be considered that degraded mode procedures (that will imply the **rollback to current procedures requiring reduction of complexity/capacity measures to compensate for the additional workload**) will have to be put in place and properly trained to cope with the situation where no sequence is available any more.

Appendix E Concept 1 Safety Requirements mapping

This Appendix is structured as follows:

1. SESAR 2020 Safety Criteria model
2. Mapping of SESAR 1 Safety Requirement with SESAR 2020 Requirement: as a prerequisite for the mapping between the Safety Objectives and Safety Requirements, it is made use of the V1 and V2 work done in the context of SESAR 1, this paragraph shows the link between the SESAR 1 and 2020 requirements and provides thus the complete list of necessary requirements from a safety view point.
3. Mapping between SO and SR: allocates to each Safety Objective the relevant (Safety) Requirement.

E.1 SESAR 2020 Safety Criteria model

The Safety Objectives for the success case are defined based on the Services (AIM functions) that are related to each Safety Criteria. Then for the failure case, Hazards are identified based on those services – AIM functions. These hazards are analysed as usual and a SO is then defined based on the consequence of each hazard.

Concerning the SR, they are defined based on the SO. The SO defines what needs to be done, the SR how this will be done. In the SPR you sent you see the traceability between the SR and the SO from which they are derived.

For the validation of the achievability of the Safety Criteria in SESAR 2020, the PJ19 provides the following model:

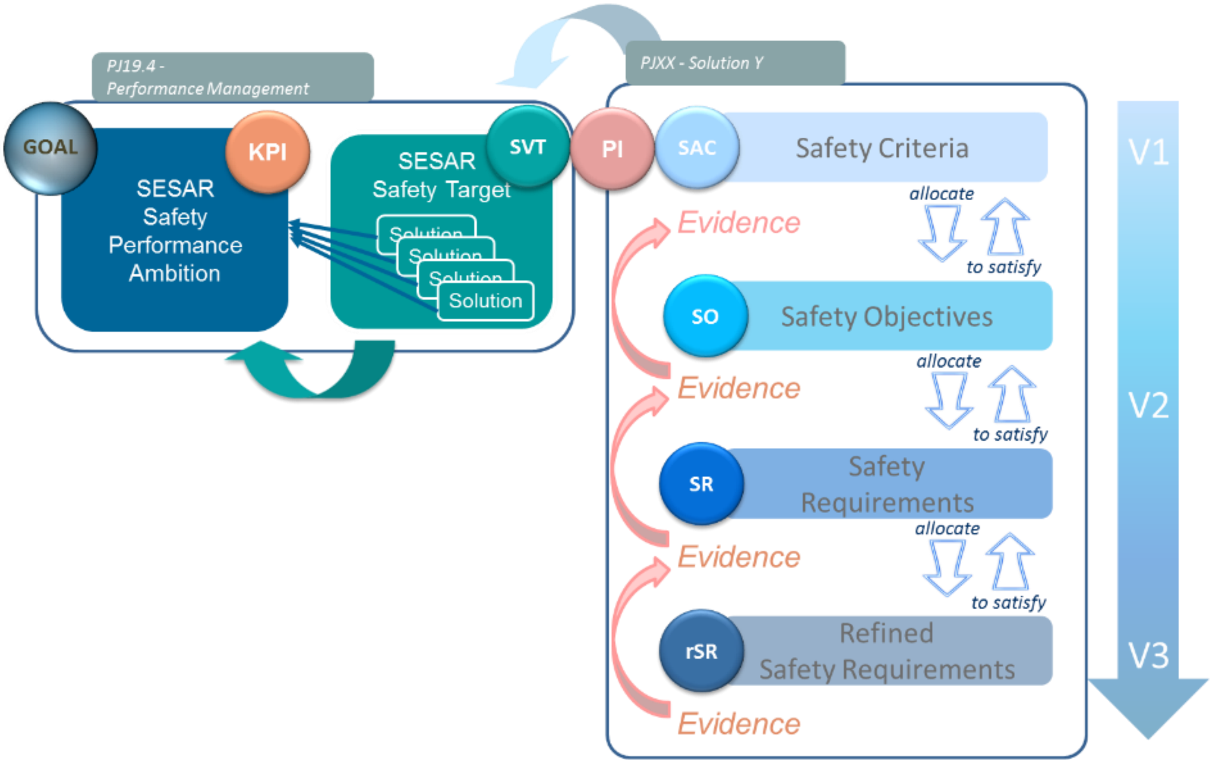


Figure 11: PJ19 model for the validation of the achievement of the Solution Safety Criteria

E.2 Mapping to SESAR1 Safety Requirement

The safety assessment approach implies to make use of the work done within SESAR 1. As such, in a first step, the safety requirements stemming from SESAR 1, that contains the set of minimum positive, and maximum negative, safety contributions for the solution, have been assessed in the context of the evolved solution. The assessment aimed at aligning the existing requirements.

The rational for such an approach lies in the multiple duplications of requirement that existed between the Functional, HMI, Performance and Safety requirements. As a rule, requirements have been classified as a priority as Functional, HMI, Performance, and Interoperability. The remaining requirement where kept as safety requirements. As a consequence, Functional, HMI and Performance requirements are contributing to the achievement of the Safety Objectives and not solely Safety labelled requirements.

The following table shows the resulting mapping between the SESAR 1 Safety Requirements and the SESAR 2020 requirements:

SESAR 1	SESAR 2020	Comment
Safety Requirements	**Requirements relevant for the achievement of the Safety Objectives**	

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0221.0210 The Integrated RWY Sequence shall display any runway closure on the HMI	**REQ-02.08-SPRINTEROP-HMI1.0008** The Integrated Runway Sequence display shall include indication of any runway closure	NIL
REQ-06.08.04-SPR-0221.0220 The Integrated RWY Sequence shall re-plan traffic if a runway closure is entered	**REQ-02.08-SPRINTEROP-FUN1.0012** When a runway closure is manually input, the Integrated Runway Sequence function shall automatically recalculate the Integrated Runway Sequence accordingly	NIL
REQ-06.08.04-SPR-0221.0230 The Integrated RWY Sequence shall re-plan a go-around (either automatically or manually by the controller, analogous to current AMAN/DMAN)	**REQ-02.08-SPRINTEROP-FUN1.0013** The Integrated Runway Sequence shall recalculate the Integrated Runway Sequence after a go-around (either automatically or after manual input from the controller)	NIL
REQ-06.08.04-SPR-0221.0240 The Integrated RWY Sequence shall allow ATCO to manually change the sequence (analogous to current AMAN/DMAN)	**REQ-02.08-SPRINTEROP-FUN1.0014** The ATCO shall be able to manually change the Integrated Runway Sequence.	NIL
REQ-06.08.04-SPR-0221.0250 The Integrated RWY Sequence shall re-plan the sequence after a manual update (analogous to current AMAN/DMAN)	When ATCO forces a manual update of the sequence, Integrated Runway Sequence function shall calculate a new Integrated Runway Sequence considering ATCO intervention as a constraint.	NIL
REQ-06.08.04-SPR-0221.0260 The Integrated RWY Sequence shall freeze aircraft in the sequence below a defined time horizon (analogous to current AMAN/DMAN)	**REQ-02.08-SPRINTEROP-FUN1.0008** The ATCO shall be able to manually freeze/un-freeze a flight in the Integrated Runway Sequence. **REQ-02.08-SPRINTEROP-PRF1.0003** The Integrated Runway Sequence frozen time horizon shall be off-line configurable according to local preferences	NIL

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0221.0270 The Integrated RWY Sequence may warn ATCO if the actual separation between two arrivals is less than the expected	NIL	This requirement should be part of the STCA and not the Integrated RWY Sequence.
REQ-06.08.04-SPR-0221.0010 The Integrated RWY Sequence shall receive and take into account the following flight data: • Call sign • Departure Aerodrome • Destination Aerodrome • Wake Turbulence Category/ Aircraft Type • Estimated times (EOBT/TOBT/ELDT/CTOT/EXOP) • Actual times (ATOT/ASAT/ALDT) • SID • STAR	**REQ-02.08-SPRINTEROP-FUN1.0001** In order to achieve an optimal integration of arrival and departure flows, the Integrated Runway Sequence function shall provide ATCOs with an automatically calculated integrated arrival and departure sequence (the Integrated Runway Sequence) based on the following inputs if available: • ... • SID Constraints • ...	NIL
REQ-06.08.04-SPR-0221.0020 The Integrated RWY Sequence shall take into account the TOBT data, continuously updated through the A-CDM process.	NIL	Considered as a FUN requirement not SPR related.

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0221.0030 The Integrated RWY Sequence shall receive the allocated runway from the Tower Controller.	**REQ-02.08-SPRINTEROP-FUN1.0001** In order to achieve an optimal integration of arrival and departure flows, the Integrated Runway Sequence function shall provide ATCOs with an automatically calculated integrated arrival and departure sequence (the Integrated Runway Sequence) based on the following inputs if available: • ... • Airport priorities and constraints ...	NIL
REQ-06.08.04-SPR-0221.0040 The Integrated RWY Sequence shall receive the arrival/departure ratio from the Tower Supervisor.	**REQ-02.08-SPRINTEROP-FUN1.0002** The Sequence Manager shall be able to manually adjust the criteria for the calculation of the integrated sequence by setting the priority on proposed KPAs (e.g. capacity, efficiency) off-line configurable based on local implementation needs.	NIL
REQ-06.08.04-SPR-0221.0050 The planned separation between successive arrivals with the Integrated RWY Sequence shall not be lower than the applicable minimum separations between arrivals as used today with AMAN.	NIL	Minimum Separation Criteria not changed by the Integrated RWY Sequence
REQ-06.08.04-SPR-0221.0060 The planned separation between departures with the Integrated RWY Sequence when considering wake vortex shall not be lower than the applicable minimum separations between departures as used today with DMAN, if baseline DMAN already includes this function. Considering the arrivals shall only result in an increase in departure separations.	NIL	Minimum Separation Criteria not changed by the Integrated RWY Sequence

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0221.0070 The Integrated RWY Sequence shall be provided with reliable demand prediction.	**REQ-02.08-SPRINTEROP-PRF1.0008** The Integrated Runway Sequence function shall provide the ATCO with an Integrated Runway Sequence with an adequate level of stability.	NIL
REQ-06.08.04-SPR-0221.0080 Synchronisation of arrivals and departures should not be worse than in current operations with standalone AMAN and DMAN.	NIL	Synchronisation is undefined.
REQ-06.08.04-SPR-0221.0090 Integrated RWY Sequence shall support coordination between TWR and Approach by showing the planned integrated sequence	**REQ-02.08-SPRINTEROP-SAF1.0001** The Integrated Runway Sequence function shall support shared situation awareness between TWR and Approach by providing the relevant information (based on local implementation needs) of the up-to-date integrated arrival/departure sequence.	NIL
REQ-06.08.04-SPR-0221.0100 The information provided to the Integrated RWY Sequence shall be correct up to a <parameter to be determined>%.	NIL	SESAR 1 requirement underspecified.
REQ-06.08.04-SPR-0221.0110 The planned number of arrivals and departures shall not exceed the available capacity.	**REQ-02.08-SPRINTEROP-PRF1.0006** The planned number of arrivals and departures shall not exceed the available capacity.	NIL
REQ-06.08.04-SPR-0221.0120 The Integrated RWY Sequence shall display the departure sequence to the Clearance Delivery Controller.	**REQ-02.08-SPRINTEROP-SAF1.0001** The Integrated Runway Sequence function shall support shared situation awareness between TWR and Approach by providing the relevant information (based on local implementation needs) of the up-to-date integrated arrival/departure sequence.	NIL
REQ-06.08.04-SPR-0221.0140 The integrated sequence shall be compliant with CTOT.	**REQ-02.08-SPRINTEROP-FUN1.0016** The Integrated Runway Sequence shall provide TTOT compliant with CTOT.	Not safety relevant

SESAR 1 **Safety Requirements**	**SESAR 2020** **Requirements relevant for the achievement of the Safety Objectives**	**Comment**
REQ-06.08.04-SPR-0221.0150 ATCO shall compare the planned sequence with the actual aircraft position in order to detect any inconsistencies.	NIL	Requirement disregarded. The ATCO shall not be the means to detect inconsistencies.
REQ-06.08.04-SPR-0221.0160 An alert shall warn the Controller and Supervisor HMI in case of a failure (partial or total loss) of the Integrated RWY Sequence function.	**REQ-02.08-SPRINTEROP-SAF1.0003** An alert on the HMI shall warn the Controller and Supervisor in case of a failure (partial or total loss) of the Integrated Runway Sequence function.	NIL
REQ-06.08.04-SPR-0221.0170 The Integrated RWY Sequence function shall allow reverting to un-integrated RWY Sequence	NIL	Un-integrated RWY Sequence is no more considered as a back-up for the Integrated RWY Sequence
REQ-06.08.04-SPR-0221.0180 Controllers shall be properly trained in the back up procedures for failures (partial or total loss) of AMAN/DMAN functionality	**REQ-02.08-SPRINTEROP-SAF1.0004** The responsible units shall ensure that Controllers are properly trained in the back up procedures for failures (partial or total loss) of Integrated Runway Sequence function	NIL

Founding Members

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0231.0300 Sequence information shall be integrated in the HMI's radar display for the approach controller and tower runway controller (e.g. in radar label), in addition to the sequence timeline display	**REQ-02.08-SPRINTEROP-HMI1.0001** Based on off-line configuration by role, the Integrated Runway Sequence function shall provide each ATCO with the appropriate information on the HMI, among the following: - Time horizon of the time line; - Calculated target times (TSAT, TTOT, TLDT); - Sequence number; - Advisories (time to loose/gain, tactical) **REQ-02.08-SPRINTEROP-HMI1.0002** The Integrated Runway Sequence function shall provide the Approach Controller with at least the TLDT on the HMI. **REQ-02.08-SPRINTEROP-HMI1.0003** The Integrated Runway Sequence function shall provide the Tower Runway Controller with at least the TTOT and TLDT on the HMI. **REQ-02.08-SPRINTEROP-SAF1.0001** The Integrated Runway Sequence function shall support shared situation awareness between TWR and Approach by providing the relevant information (based on local implementation needs) of the up-to-date integrated arrival/departure sequence.	NIL

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0231.0310 Spacing indicators shall be integrated into the Approach controller HMI.	**REQ-02.08-SPRINTEROP-HMI1.0001** Based on off-line configuration by role, the Integrated Runway Sequence function shall provide each ATCO with the appropriate information on the HMI, among the following: - Time horizon of the time line; - Calculated target times (TSAT, TTOT, TLDT); - Sequence number; - Advisories (time to loose/gain, tactical) - Airport priorities. **REQ-02.08-SPRINTEROP-HMI1.0002** The Integrated Runway Sequence function shall provide the Approach Controller with at least the TLDT on the HMI.	NIL
REQ-06.08.04-SPR-0231.0320 Integrated RWY Sequence shall update the sequence according to the actual traffic situation once the arrival sequence is fixed.	**REQ-02.08-SPRINTEROP-PRF1.0007** The Integrated Runway Sequence function shall avoid providing the ATCO with updates in the Arrival part of the Integrated Runway Sequence that are no longer feasible.	NIL
REQ-06.08.04-SPR-0231.0330 Integrated RWY Sequence shall be able to generate a departure sequence with an adequate level of stability.	**REQ-02.08-SPRINTEROP-FUN1.0010** When an aircraft estimated landing time/take-off time is within an off-line defined stability time horizon, the Integrated Runway Sequence function shall freeze its position in the Integrated Runway Sequence avoiding any automatic sequence order change unless specific rules apply to cope with local exceptions. **REQ-02.08-SPRINTEROP-PRF1.0002** The Integrated Runway Sequence stability time horizon shall be off-line configurable according to local preferences.	NIL

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0231.0340 Integrated RWY Sequence shall update the sequence at the runway hold with one of the following options: • The Tower Runway controller is to manually update the sequence (which then cannot be updated automatically by the system anymore); OR, • The system is to update the sequence accurately reflecting actual situation.	**REQ-02.08-SPRINTEROP-FUN1.0017** The Integrated Runway Sequence function shall update the Integrated Runway Sequence at the runway holding point with one of the following options: • The Tower Runway controller manually updates the sequence OR, • The system updates the sequence accurately reflecting actual situation.	NIL

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0222.0010 The Integrated RWY Sequence shall provide an integrated arrival and departure sequence based on the following inputs if available: • ATC information and inputs • Arrival and Departure traffic volumes from the airport • *Airport DCB inputs (per runway arrival and departure capacity)* • Airport priorities and constraints • *Airport DCB planned runway configuration* • The (remaining) taxi-out times from A-SMGCS • Actual landing and actual off-block times from A-SMGCS • *Operational information from the controller* • Updated manual sequences from the controller • *UDPP from the airspace user* • Weather conditions • Arrival and departure separation • Runway Occupancy Times • Dynamic Wave Vortex	**REQ-02.08-SPRINTEROP-FUN1.0001** In order to achieve an optimal integration of arrival and departure flows, the Integrated Runway Sequence function shall provide ATCOs with an automatically calculated integrated arrival and departure sequence (the Integrated Runway Sequence) based on the following inputs if available: • Flight progress reports • Input clearances from the controller • Arrival and Departure traffic volumes from the airport • Estimated Take-off and Landing times • Airport priorities and constraints • Updated manual sequences from the controller • Arrival and departure required spacing • SID Constraints • Planned runway configuration • The variable taxi-out times Actual landing and actual off-block and take-off times • Weather conditions • Runway Occupancy Times static values • Wake vortex separations **REQ-02.08-SPRINTEROP-FUN1.0007** The Integrated Runway Sequence function shall consider the airport priorities and constraints (off-line configurable operational indicators based on local implementation needs) in the provision of the optimised integrated runway sequence.	NIL

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0222.0050 The Integrated RWY Sequence function shall operate a time horizon configurable according to local preferences (e.g. 40 minutes for arrivals and 20 minutes for departures)	**REQ-02.08-SPRINTEROP-PRF1.0008** The Integrated Runway Sequence function shall provide the ATCO with an Integrated Runway Sequence with an adequate level of stability. **REQ-02.08-SPRINTEROP-PRF1.0002** The Integrated Runway Sequence stability time horizon shall be off-line configurable according to local preferences. **REQ-02.08-SPRINTEROP-PRF1.0003** The Integrated Runway Sequence frozen time horizon shall be off-line configurable according to local preferences.	NIL
REQ-06.08.04-SPR-0222.0060 The Integrated RWY Sequence function shall update the arrival and departure plans when new arrival or departure information becomes available.	**REQ-02.08-SPRINTEROP-PRF1.0004** The Integrated Runway Sequence function shall update the Integrated Runway Sequence as soon as new arrival or departure information becomes available.	NIL
REQ-06.08.04-SPR-0222.0070 The Integrated RWY Sequence function shall monitor the EXOT and provide an update of the sequence if this cannot be established anymore because of delay in the outbound process.	NIL	SERAR 2020 concept considers other reference times as SESAR I.
REQ-06.08.04-SPR-0222.0080 The Integrated RWY Sequence shall provide an optimised AMAN/DMAN sequence maximizing runway throughput and minimising delay.	**REQ-02.08-SPRINTEROP-PRF1.0005** The Integrated Runway Sequence function shall maximize runway throughput.	NIL

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
REQ-06.08.04-SPR-0222.0100 ATCO shall be provided with: • Integrated sequence • Specific information for each flight (Ex: sequence order, TTL/TTG). • Airports priorities and constraints.	**REQ-02.08-SPRINTEROP-FUN1.0001** Based on off-line configuration by role, the Integrated Runway Sequence function shall provide each ATCO with the appropriate information on the HMI, among the following: • ... • Airport priorities • ... **REQ-02.08-SPRINTEROP-HMI1.0002** The Integrated Runway Sequence function shall provide the Approach Controller with at least the TLDT on the HMI. **REQ-02.08-SPRINTEROP-HMI1.0003** The Integrated Runway Sequence function shall provide the Tower Runway Controller with at least the TTOT and TLDT on the HMI. **REQ-02.08-SPRINTEROP-HMI1.0004** The Integrated Runway Sequence function shall provide the Tower Clearance Delivery Controller and the Apron Manager (where applicable) with the TSAT and TTOT values on the HMI. **REQ-02.08-SPRINTEROP-HMI1.0005** The Integrated Runway Sequence function shall provide En–Route Controllers with advisories on time to lose or gain for arrival traffic on the HMI.	NIL
NIL	**REQ-02.08-SPRINTEROP-HMI2.0001** If RMAN is not available, the Airport Tower Supervisor shall be able to insert the runway capacities manually	NEW

SESAR 1 Safety Requirements	SESAR 2020 Requirements relevant for the achievement of the Safety Objectives	Comment
NIL	**REQ-02.08-SPRINTEROP-SAF1.0008** The Integrated Runway Sequence function shall never override a manual update of the Integrated Runway Sequence with an automatic update.	NEW

Table 78: Concept 1 mapping between SESAR 1 Safety Requirements and SESAR 2020 requirements

E.3 Concept 1 mapping between SO and SR

This paragraph lays down the allocation of the (Safety) Requirements to the Safety Objectives defined in the paragraphs 3.2.7.2 and 3.2.8.2.

The table below shows the Concept 1 allocation of SO to each Safety Requirement:

Safety Objective	Allocated (Safety) Requirement	Condition
SO#1 Integrated RWY Sequence shall support coordination between TWR and Approach	REQ-02.08-SPRINTEROP-FUN1.0001	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0002	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0013	Non-nominal
	REQ-02.08-SPRINTEROP-FUN1.0015	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0001	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0002	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0003	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0004	Nominal
	REQ-02.08-SPRINTEROP-SAF1.0001	Nominal
SO#2 Integrated RWY Sequence shall support effective ATC runway management	REQ-02.08-SPRINTEROP-FUN1.0001	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0007	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0008	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0010	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0012	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0014	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0016	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0017	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0005	Nominal

Safety Objective	Allocated (Safety) Requirement	Condition
	REQ-02.08-SPRINTEROP-HMI1.0008	Non-nominal
	REQ-02.08-SPRINTEROP-PRF1.0004	Nominal
	REQ-02.08-SPRINTEROP-PRF1.0005	Nominal
	REQ-02.08-SPRINTEROP-PRF1.0006	Nominal
	REQ-02.08-SPRINTEROP-PRF1.0007	Nominal
	REQ-02.08-SPRINTEROP-PRF1.0008	Nominal
SO#3 Integrated RWY Sequence shall support managing the sequence in mixed mode environment	REQ-02.08-SPRINTEROP-FUN1.0001	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0007	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0010	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0012	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0017	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0008	Non-nominal
	REQ-02.08-SPRINTEROP-PRF1.0004	Nominal
	REQ-02.08-SPRINTEROP-PRF1.0005	Nominal
	REQ-02.08-SPRINTEROP-PRF1.0006	Nominal
	REQ-02.08-SPRINTEROP-PRF1.0007	Nominal
SO#4 Integrated RWY Sequence shall be provided with accurate and correct wake vortex information	REQ-02.08-SPRINTEROP-FUN1.0001	Nominal
SO#5 Integrated RWY Sequence shall be provide with reliable demand prediction	REQ-02.08-SPRINTEROP-FUN1.0001	Nominal
	REQ-02.08-SPRINTEROP-SAF1.0008	Nominal
SO#6 Integrated RWY Sequence needs to be provided with all relevant information for sequencing	REQ-02.08-SPRINTEROP-FUN1.0001	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0007	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0010	Nominal
	REQ-02.08-SPRINTEROP-FUN1.0016	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0002	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0003	Nominal
	REQ-02.08-SPRINTEROP-HMI1.0004	Nominal
SO#7 The degraded modes of the Integrated	REQ-02.08-SPRINTEROP-HMI1.0009	Failure
	REQ-02.08-SPRINTEROP-SAF1.0003	Failure

Safety Objective	Allocated (Safety) Requirement	Condition
RWY Sequence should not be worse than the current one with de-coupled AMAN and DMAN	REQ-02.08-SPRINTEROP-SAF1.0004	Failure
	REQ-02.08-SPRINTEROP-PRF1.0002	Nominal
	REQ-02.08-SPRINTEROP-PRF1.0003	Nominal

Table 79: Concept 1 Mapping between SO and SR

END OF DOCUMENT-