Contextual note
SESAR Solution PJ.02-08-01 and SORT VLD 3 WP5

"Integrated runway sequence for full traffic optimization on single and multiple runway Airports"

Purpose:

This contextual note introduces the SESAR SORT VLD3 WP5 IRSF including Solution PJ02-08-01 (for which maturity has been assessed as sufficient to support a decision for industrialization) with a summary of the results stemming from R&D activities contributing to deliver it. It provides to any interested reader (external and internal to the SESAR programme) an introduction to the SESAR Solution in terms of scope, main operational and performance benefits, relevant system impacts as well as additional activities to be conducted during the industrialization phase or as part of deployment. This contextual note complements the technical data pack comprising the SESAR deliverables required for further industrialization/deployment.

Improvements in Air Traffic Management (ATM)

This Contextual Note is focusing on solution PJ.02-08-01 "Integrated runway sequence for full traffic optimization on single and multiple runway airports".

The efficient use of integrated arrival and departure planning requires the development of early and dynamic planning of arrival and departure sequences into the runway of an airport. Today limitations with static patterns, lack of predictability and high manual workload need to be improved. To reduce extensive queuing in the air and on ground for reduction of airline fuel consumption/cost, there is a need of trajectory based and early planning for improved operational efficiency.

The concept of Traffic Optimisation on single and multiple runway airports is applicable for all airport layouts that have dependencies between arrivals and departures. This includes runways operated in mixed mode as well as runway layouts with interdependencies between arrivals and departures.

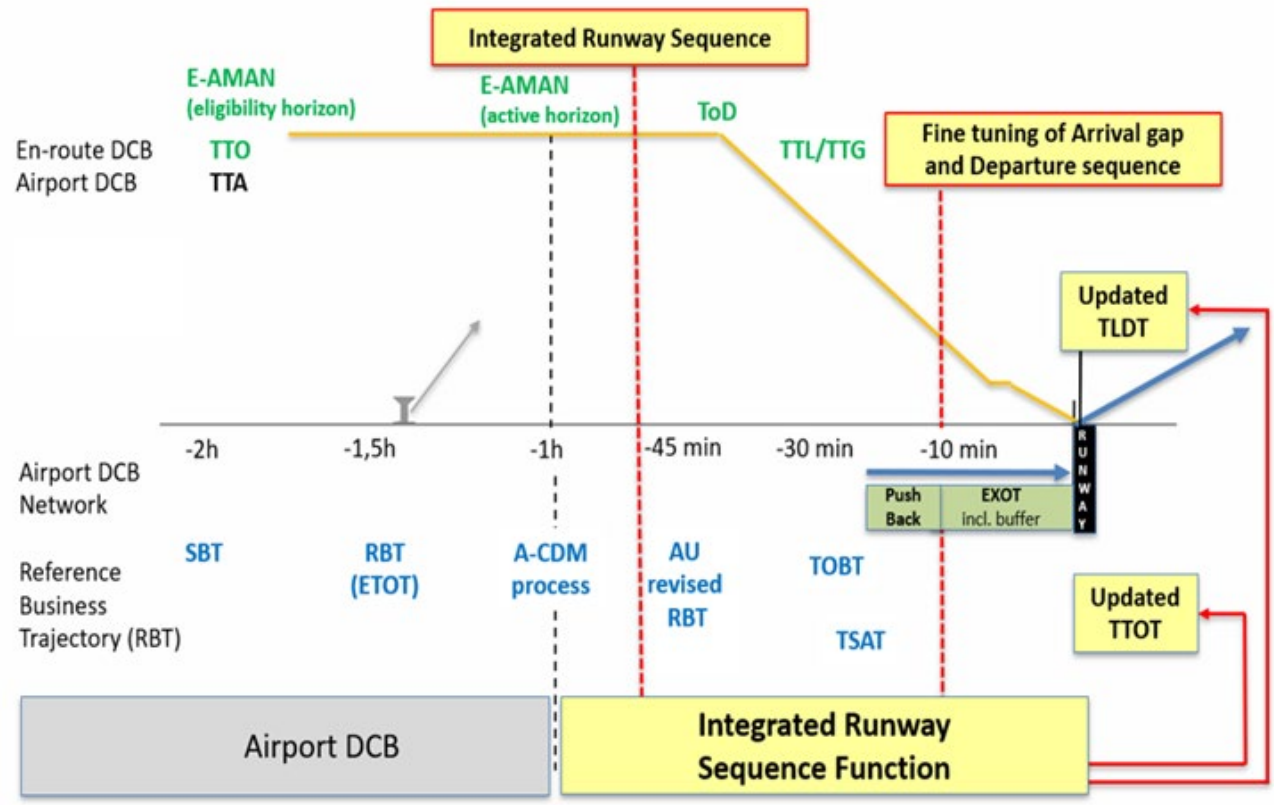
The airport layout may bring constraints on the traffic flow management flexibility and then yield less coupling potential. The single runway and parallel runways in mixed mode is currently recognised to be the most constrained situation.

Optimised integration of arrival and departure traffic flows with the use of a trajectory based Integrated Runway Sequence addresses a number of significant operational environments as validations are performed with a variation of industrial prototypes in advanced IBP´s.

Trajectory based Integrated Runway Sequence;
The main goal for the Integrated RWY Sequence function is to establish an optimized integrated arrival and departure sequence by providing accurate Target Take off Times (TTOTs) and Target Landing Times (TLDTs), including dynamic balancing of arrivals and departures while optimising the runway throughput.

The look ahead Time Horizon e.g. 1 hour 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 value of these time horizons is determined by the local implementation and they are not necessarily the same for arrivals and departures.

The Integrated Runway Sequence is planned before Arrival flights top of decent and linked with Airport CDM procedures for departures. Fine tuning of Arrival and Departure target times is provided to ensure efficient runway throughput.



Operational Improvement Steps (OIs) & Enablers

The following table presents the Operation improvement (OI) step for solution PJ.02-08-01 "Integrated runway sequence for full traffic optimization on single and multiple runway airports" including the description and coverage. The relevant Enablers, both required and optional are listed below.

Applicable Integrated Roadmap Dataset is DS20.

OI Step code	OI Step title	OI Step coverage
TS-0301	Integrated Arrival Departure Management for full Traffic Optimisation on the Runway	Fully
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		

Required Enablers

AERODROME-ATC-33	"Coupled sequencing tool enhanced to better handle arrivals and departures"
AERODROME-ATC-58	"Agile synchronisation of arrivals with departure information for the same airport"
APP-ATC-164	"APP ATC System adapted to support integrated arrival/departure sequence in ATCOs HMI"

Optional Enablers;

AERODROME-ATC-09c "Improvement of operational orchestration among arrival / departure management and surface management services

SWIM –APS-12a "Provision and Consumption of general information for air traffic management using SWIM"

Background and validation process

Traffic optimization with IRSF on single and multiple runway airports is applicable for all airport layouts that have dependencies between arrivals and departures. This includes runways operated in mixed mode as well as runway layouts with interdependencies between arrivals and departures.
Optimized integration of arrival and departure traffic flows with the use of IRSF addresses a number of significant operational improvements. The presentation of both arrivals and departures for all users will enhance awareness and coordination between arrival and departure management.

The main goal for the IRSF is to establish the best possible integrated arrival and departure sequence by providing accurate target take-off times and target landing times, including dynamic balancing of arrivals and departures. The integrated runway sequence is planned before the arrival flight's top of descent

and synchronized with progress of departure flights, by use of the A-CDM. Fine tuning of arrival and departure target times is provided to ensure efficient runway throughput.

In the SESAR large scale demonstration project VLD3-W2-SORT the IRSF was demonstrated with live traffic in a shadow-mode setup. Feedback from air traffic controllers confirmed the value of increased awareness with early planning of an integrated runway sequence, including new functions to update the plan progressively based on real time flight events. Safety and human performance areas were addressed where the air traffic controllers confirmed the concept of integrated runway sequence with the ability to handle the balance between predictability, flexibility, and stability, while meeting requirements for operational acceptability.

The Integrated Runway Sequence Function were validated in SESAR PJ02-08 through a series of activities including three V3 Real-Time Simulations and one V3 Fast Time Simulation, focusing on a range of objectives from the High Level objectives in SESAR Validation Strategies for V3 Maturity.

- ENAV V3 Fast Time Simulation on multiple dependent runways of Roma Fiumicino Airport and TMA environment linked to ENAV V2 Real Time Simulation. ENAV FTS coordinated and planned by ENAV with the support of its LTP (Technosky and NAIS), validated the application of a support decision tool to optimise traffic flow to Roma Fiumicino airport and TMA: Assessment of integrated dynamic assistance tool (Integrated Runway Sequence function).

- LFV-COOPANS V3 Real-Time Simulation on parallel runways in independent mixed mode of Stockholm-Arlanda Airport and TMA environment focus on Tower and Approach. LFV- COOPANS coordinated and planned this simulation with the support of SINTEF (NATMIG) and THALES AIR SYS. The Integrated Runway Sequence function is working with mixed-mode operations on two parallel runways to optimise the combined sequence of arrival and departure flights for each runway and also balance the number of flights between the runways.
  Link to PJ02-08 Validation Video; https://www.youtube.com/watch?v=urynweDiWv4

- SKYGUIDE V3 Real-Time Simulation in Geneva Airport on single runway in mixed mode in a narrow complex airspace; SKYGUIDE RTS, coordinated and planned by SKYGUIDE with the support of SKYSOFT ATM, focused on the operational use of Integrated Runway Sequence function in Geneva Airport. The objective was to assess the operational feasibility and the potential benefits of the use of an Integrated Runway Sequence function in an Airport with single RWY in mixed mode operations.

In SESAR Wave 2 SORT Project LFV(COOPANS) performed a Very Large Demonstration (VLD) activity in order to bridge the gap between Pre-Industrial Development and Industrialisation.

Link to Scientific paper from SESAR 2022 Innovation days;
https://www.sesarju.eu/sites/default/files/documents/projects/SID2022%20SORT%20VLD03%20-%20Paper%20Optimized%20IRSM.pdf

Optimized Integrated Runway Sequence Management

Results and performance achievements

The positive results of the V3 CBA for solution PJ.02-08-01 support the decision of proceeding with the Solution to V4 phase - Industrialisation.

Through the validations, experience has been gained in the balancing and trade-off between different KPAs (Punctuality, Environment and Capacity) and achieving the required Integrated Runway Sequence stability and accuracy to ensure usability and ATCOs trust in the solution.

Capacity benefits of Integrated Runway Sequence Function results derived from LFV-COOPANS V3 RTS, were 5.1% and 90 flights per hour with Stockholm-Arlanda Airport operating on independent parallel runways show an improvement higher than the validation target whereas results derived from ENAV FTS show an improvement slightly lower than the validation target. The influence of the specific environment needs to be taken into account. Overall, the Concept 1 provides a higher improvement than the validation target.

Fuel Efficiency benefits of Integrated Arrival Departure management for full traffic optimisation on the RWY with the introduction of Integrated Runway Sequence Function were analysed using validation results from ENAV V3 FTS and confirmed by the other V3 exercises covering the same operational improvement in the solution. Net benefit was identified in terms of Fuel Efficiency and related CO_2/Flight Time Efficiency.

The Real Time Simulation results of Integrated Runway Sequence Function show that the level of Safety is maintained in the solution while increasing capacity. This is possible thanks to the enhancement of situation awareness and the reduction of workload and stress provided by the use of the integrated runway sequence.

The ATCOs confirmed ability to safely work with separation management and handle situations with reduced functionality during the failure mode tests.

The Real Time Simulation results of the solution with Integrated Runway Sequence Function show an improvement in Human Performance, especially related to an enhancement of situation awareness of most ATCOs (particularly at Tower and Approach), good trust in the system and a reduction of physical and mental workload and stress.

The SESAR large scale demonstration confirmed the ability to increase runway throughput by early and enhanced planning of an integrated runway sequence, applicable both in single runway operations, dependent runways and when using the two parallel runways in mixed mode.

According to the environmental permit for Stockholm-Arlanda Airport, up to five additional arrival flights per hour can land on the runway mainly used for departures, when runway configuration is set to use the parallel runways in segregated mode. When the IRSF was set to semi-automatic or automatic runway balancing modes for parallel runways in segregated mode, we observed that the system was able to identify and plan five landings on the departure runway, thereby with a potential increase of the capacity from forty to forty-five landings per hour. This is equivalent to a capacity increase for arrivals of 12.5%.

The use of an IRSF has been confirmed by air traffic controllers to provide valuable support to enable an increase in the number of planned and assigned curved approaches, particularly when used together with performance-based navigation. In this way the arrival flying time can be reduced and noise levels to be minimized over noise sensitive areas.

While the IRSF can produce integrated runway sequences automatically, it also supports decision-making involving human experts. Through the support of what-if analysis in the IRSF, the expert can evaluate the implication of tactical decisions "offline" before they are implemented.

Through the V3 validations, experience has been gained in the balancing and trade-off between different KPAs (Punctuality, Environment and Capacity) and achieving the required Integrated Runway Sequence stability and accuracy to ensure usability and ATCOs trust in the solution.

The V3 Real Time Simulation results of Integrated Runway Sequence Function show that the level of Safety is maintained in the solution while increasing capacity. This is possible thanks to the enhancement of situation awareness and the reduction of workload and stress provided by the use of the integrated runway sequence.

Safety was addressed and confirmed to be maintained during validation of both nominal and non-nominal situations, including planned runway closure and unplanned runway closure with go-around. The ATCOs confirmed ability to safely work with separation management and handle situations with reduced functionality during the failure mode tests.

Large Scale Demonstration of an integrated runway sequence management confirmed ways to meet requirements for **sustainability, predictability and efficiency with high runway throughput:**

Integrated runway sequence showed ability to handle the **balance between predictability, flexibility, and stability**, while meeting requirements for **operational acceptability**

Early prediction of runway sequences **improve efficiency and situational awareness**

Many of these enhancements are **applicable for a large number of international airports**

Recommendations and Additional activities

The VLD demonstration of an integrated runway sequence function performed for Stockholm-Arlanda airport, demonstrated ways to meet requirements for sustainability, predictability, and efficiency. Many of these enhancements are applicable also for other international airports.

Trajectory predictions with a high quality and integration of ground surveillance data will further enhance the quality of the integrated sequences made by the IRSF.

When implementing the IRSF at international airports, there is an option to use a stepwise approach;

1. DMAN functionality with display of arrivals
2. Display departures in AMAN
3. Fully Integrated Runway Sequence in both DMAN and AMAN

When moving towards implementation it is recommended to address;

- Locally defined Airport and ATC prioritisation strategies in view of different objectives per KPA/KPI depending on the traffic and the time of the day.

- Local tuning and adaption of the algorithm, HMI, gap sizes, how the system updates according to real events, procedures for failure mode and recovery from failure mode and how the system is affected by the turn-around process.

- The possibility to combine the concept with spacing advisories (either in distance or time) by use of chevrons (defined for Time based separation).

Actors impacted by the SESAR Solution

Actors involved in the operations are;

- Aerodrome ATS
  - TWR Runway Controller
  - TWR Ground Controller
  - TWR Clearance Delivery
  - TWR Supervisor
- En Route/Approach ATS
  - Executive Controller ACC/APP
  - Planning Controller
  - Approach Coordinator
- Flight Deck
  - Pilots
- Airspace Users OPS support

Impact on Aircraft System

No impact

Impact on Ground Systems

Integrated Runway Sequence Function will calculate an optimized runway sequence including both arrival and departure flights and linked to following functionality:

- Arrival Management based on arrival Trajectory Prediction to provide estimated arrival landing times, including updates. Upstream En-Route sectors will receive advisories of arrival delay times when applicable.
- Departure Management based on Airport CDM procedures to provide estimated take-off times, calculated from airlines preference on readiness with use of target off-block time.

To support ATC with an overview of the integrated runway sequence an appropriate HMI presenting the integrated runway sequence order for both arrivals and departures will be provided. This HMI will provide to each ATC role the relevant information on the integrated runway sequence. This HMI may include support functions to enhance awareness and increase controller ability to comply with a predefined integrated runway sequence.

Example of options for ATC support/HMI functions (not used in today operations) are the provision of:

- Arrival sequence number(ER, APP TWR)
- Departure sequence number(APP, TWR)
- Speed instructions for arrivals (APP)
- Integrated Runway sequence list (APP, TWR)
- Spacing indicators for arrivals on final approach, distance based or time based (APP)
- Spacing advisories and planned gap size between arrivals to accommodate planned departing flights (APP, TWR)

To support ATC with an overview of the integrated runway sequence an appropriate HMI presenting the integrated runway sequence order for both arrivals and departures. Additional HMI functions can be used according to local ATC preferences.

Regulatory Framework Considerations

None

Standardization Framework Considerations

Applicably standard;

Standard Name	Standard Description	Comment
EUROCAE ED-141 Airport-CDM Technical Specification	Minimum Technical specification for Airport-CDM	Existing standard.

Considerations of Regulatory Oversight and Certification Activities

None

Solution Data pack

The SESAR SORT VLD3 WP5 Data pack includes the following documents;

- D5.1-Availability Note
  - D5.1_SESAR 2020 VLD03-004 EXE-VLD-03-004_Availability Note_v00.01.01

- D1.1.04-DEMOP-VLD3-W2
  - Part I – D1.1.04 Edition 00.03.00 (10/02/2023)
  - Part II – D1.1.04 Edition 00.03.00 (10/02/2023)Safety Assessment Plan
  - Part III – D1.1.04 Edition 00.03.00 (10/02/2023) Human Performance Assessment Plan
  - Part IV – D1.1.04 Edition 00.03.00 (10/02/2023) Environmental Assessment Plan
  - Part V – D1.1.04 Edition 00.03.00 (10/02/2023) Performance Assessment Plan

- D1.4-DEMOR-VLD3-W2
  - Part I – D1.4 Edition 00.03.00 (24/05/2023)
  - Part II – D1.4 Edition 00.03.00 (24/05/2023) Safety Assessment Report
  - Part III – D1.4 Edition 00.03.00 (24/05/2023) Human Performance Assessment Report
  - Part IV – D1.4 Edition 00.03.00 (24/05/2023) Environmental Assessment Report
  - Part V – D1.4 Edition 00.03.00 (24/05/2023) Performance Assessment Report

The SESAR PJ02-08 V3 Data pack includes the following documents:

- V3 SPR-INTEROP/OSED
  - Part I – D6.1.20 Edition 00.03.00 (31/01/2020)
  - Part II – D6.1.20, Edition 00.04.00 (31/01/2020), Safety Assessment Report
  - Part IV – D6.1.20, Edition 00.03.00 (08/11/2019), Human Performance Assessment Report
  - Part V – D6.1.20, Edition 00.03.00 (08/11/2019), Performance Assessment Report
- V3 TS/IRS, D6.1.21, Edition 00.04.00 (17/01/2020)
- V3 VALR, D6.1.23, Edition 00.04.00 (31/01/2020)
- V3 CBA, D6.1.24, Edition 00.03.00 (08/11/2019)

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