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PJ37-W3-ITARO

INTEGRATED TMA, AIRPORT AND RUNWAY OPERATIONS

This Demonstration Report (DEMOR Part IV – ENVAR) is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 101017622 under European Union's Horizon 2020 research and innovation programme.



Abstract

The present document constitutes Part IV of the Demonstration Report (DEMOR), belonging to contractual deliverable (D1.5), of the SESAR2020 project PJ37-W3-ITARO. It overviews the results of the various exercises dealing with the Environmental aspects of the integrated solutions addressed by ITARO. This project carries out 'VLD-like' exercise activities that focus on the integration of different SESAR solutions and (pre-) deployment items, already validated to high Technological Readiness Levels (TRLs) individually, but being combined and applied for the first time in an operational environment. This first-step integration cannot be performed directly in a real life ATC environment hence requires an integrated Real Time Simulation (RTS) step first, thereby explaining the 'VLD-like' in its IA-naming.

This DEMOR Part covers two exercises performed as part of the PJ.37-W3-01A solution track, relating to the Arrivals Real Time Simulations (Arrival RTS1 and Arrival RTS2) performed by the NLR. NLR also performed a flight trial, however no environmental objectives have been defined for that exercise and thus is not included in this report.

This report provides a synthesis of the research objectives that relate to environmental impact, as described in the Demonstration Plan. As the simulation runs performed in the RTS focused on the integration of the previously validated SESAR solutions, various scenarios to test the robustness of the integrated solution have been performed. This results in a limited number runs to extrapolate the potential environmental impact to the ECAC region. Hence the assessment is performed for fuel and CO2 emission, and locally for the noise levels.

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1 Executive Summary

This document constitutes Part IV of the Demonstration Report (DEMOR), belonging to contractual deliverable (D1.5), of the SESAR2020 project PJ37-W3-ITARO. It overviews the results of the various exercises dealing with the Environmental aspects of the integrated solutions addressed by ITARO. This project carries out 'VLD-like' exercise activities that focus on the integration of different SESAR solutions and (pre-) deployment items, already validated to high Technological Readiness Levels (TRLs) individually, but being combined and applied for the first time in an operational environment. This first-step integration cannot be performed directly in a real life ATC environment hence requires an integrated Real Time Simulation (RTS) step first, thereby explaining the 'VLD-like' in its IA-naming.

This DEMOR Part covers two exercises performed as part of the PJ.37-W3-01A solution track, relating to the Arrivals Real Time Simulations (Arrival RTS1 and Arrival RTS2) performed by the NLR. NLR also performed a flight trial, however no environmental objectives have been defined for that exercise and thus is not included in this report.

This report provides a synthesis of the research objectives that relate to environmental impact, as described in the Demonstration Plan. As the simulation runs performed in the RTS focused on the integration of the previously validated SESAR solutions, various scenarios to test the robustness of the integrated solution have been performed. This results in a limited number runs to extrapolate the potential environmental impact to the ECAC region. Hence the assessment is performed for fuel and CO2 emission, and locally for the noise levels.

It can be concluded that due to Continuous Descent Operations (CDO), which results in efficient vertical profiles, in combination with the Flight-deck Interval Management (FIM), which step-wise reduces aircraft speed while meeting the spacing goals, a positive effect is noticed on fuel usage and CO2 emission. On ECAC/Network level, a reduction of 5.5 kg in fuel or 17.3 kg CO2 emission is expected (0.1% of the emission of an average flight).

At lower altitudes where noise is of importance, in case the aircraft performs their CDO profile as defined in combination with the fixed routes, no major differences are observed in the 55 dB noise contour areas. Few localized differences were identified but this is most probably caused by speed differences between simulation runs. This benefits noise as aircraft having higher speeds require flap selections at a later moment along the route. With increased flap settings, drag increases and thus the need for more thrust, which results in higher noise levels.

The confidence in the results is high as the data is based on the BADA aircraft performance models and the Doc29 guidance standard of computing noise contours around airports has been used [8]. The confidence in the generalised finding of the impact of the solution is low level due to the limited number of (RTS) evaluations. To increase the confidence of the generalised finding (and to also transfer this to ECAC wide level) fast-time simulations have to be performed.

2 Introduction

2.1 Purpose of the document

This document describes the results of the ‘VLD-like’ exercises carried out, normally in accordance with the SESAR Environment Assessment Process [1], in order to assess the environmental impact observed when performing the demonstration exercises. This report covers the two Real Time Simulations (Arrival RTS1 and Arrival RTS2) performed as part of the PJ.37-W3-01A solution track. It provides a synthesis of the research objectives that relate to environmental impact, as described in the Demonstration Plan [9].

2.2 Intended readership

The intended readers of this document are the PJ.37 team members working on the validation exercises, PJ.37 management, and the SESAR3 Joint Undertaking.

2.3 Scope of the document

This document provides an overview of the environmental performance described by the research objectives, as described in the Demonstration Plan, of the two RTS exercises performed as part of the PJ.37-W3-01A solution track performed by the NLR.

The environmental performance is assessed at local level to quantitatively or qualitatively identify (trends in) the performance of the ‘VLD-like’ activities. As the simulation runs performed in the RTS focused on the integration of the previously validated SESAR solutions, various scenarios to test the robustness of the integrated solution have been performed. This results in a limited number of runs to extrapolate the potential environmental impact to the ECAC region. Hence the assessment on local level.

The environmental research objectives covered by the Demonstration Plan covers the following environmental aspects:

- fuel used and CO₂ generated (at local level),
- noise at local level.

2.4 Environment work schedule within the Solution

The demonstration activities have been carried out in accordance to the Demonstration Plan and any deviation has been described in the Demonstration Report Part I [7].

2.5 Structure of the document

This document is organised as follows:

- Chapter 1 presents an executive summary of the project

- Chapter 2 gives an introduction by describing the scope, readership and structure of the document. Furthermore, some background information and an overview of the terms and acronyms used in this document.
- Chapter 3 gives an overview of the environmental assessment process objective and approach, as derived by SESAR.
- Chapter 4 presents the environmental performance assessment for fuel efficiency and CO₂ emissions as well as for noise. A summary of demonstration results is given followed by a detailed analysis per demonstration objective. This chapter concludes with an overall conclusion on the environmental impact of the demonstration.
- Chapter 5 provides an overview of referenced documents.

2.6 Terminology

Term	Description
Benefit and Impact Mechanism	A cause-effect description of the impacts of the solution proposed by a project. It describes the positive and the negative impacts that the project solution is expected to provide or demonstrate.
Benefit Diagram	A Benefit and Impact Mechanism is usually shown in a diagram giving an overview of the links between the (new) features that the project is bringing to the world of ATM and indicators (aspects which can be measured or calculated from other metrics), Positive or Negative Impacts for each performance area, and Key Performance Areas (KPA's) or Key Performance Indicators (KPI's). This diagram is supplemented by textual descriptions of the feature, the numbered links and impacts.
Business Case	A Business Case is a tool for decision-makers; it aims to provide them with the information they need to make a fully informed decision on whether funding should be provided and/or whether an investment should proceed. A Business Case is much more than just a financial analysis as it also includes quantitative and qualitative arguments on performance and transversal activities that are key elements to determining the value of the project.
Deployment Scenario	Deployment Scenario consists of a set of SESAR Solutions selected to satisfy the specific performance needs of operating environments in the European ATM System and based upon the timescales in which their performance contribution is needed in the respective operating environments
Environment	Surroundings in which humans interact with the air, water, landscape, natural resources, flora and fauna. In terms of ATM, 'the environment' will be the surroundings in which Air Traffic Management activities are planned or conducted, including research through to development, deployment, and operations.
Environmental Impact	Any modification of the environment that has or could have an effect on the ecosystem.

	In this document the main environmental impacts of concern are: • Aircraft noise in the vicinity of an airport, • Airport Local Air Quality (mainly CO, NO_x and Particulate Matter), • Global emissions (mainly CO₂) Fuel burnt is also of concern for the environment because of the direct relationship between fuel burnt and CO₂.
Environmental Impact Assessment (EIA)	The process of identifying and evaluating the environmental impacts of projects as well as proposing mitigations to reduce these impacts on the environment. The assessment scope, as it relates to ATM, considers impacts on the environment that can be affected by aircraft operations or that can affect aircraft operations, e.g. through mitigation rules. The main impacts on the environment related to aircraft movements are caused by emissions resulting from fuel burn and noise produced by the engines and airframe.
EIA plan	The Environmental Impact Assessment plan describes the hypothesis to test, metrics to assess, the tools to use, the required input variables for the tools and methodology used for analysing the results.
EUROCONTROL	European Organisation for the Safety of Air Navigation
S3JU Work Programme	The programme which addresses all activities of the SESAR3 Joint Undertaking Agency.
SESAR Programme	The programme that defines the Research and Development activities and Projects for the S3JU.

Table 1: Terminology

2.7 Acronyms

Term	Description
CDO	Continuous Descent Operation
CO	Carbon Monoxide
CO ₂	Carbon Dioxide
FIM	Flight-deck Interval Management
IMPACT	EUROCONTROL web portal for the analysis of aircraft noise and emissions
JU	Joint Undertaking
KPA	Key Performance Area
KPI	Key Performance Indicator
LAQ	Local Air Quality
NO _x	Oxides of Nitrogen, including nitrogen dioxide (NO ₂) and nitrogen oxide (NO).
PM	Particulate Matter
SEL	Sound Exposure Level
S3JU	SESAR3 Joint Undertaking (Agency of the European Commission)
SO _x	Oxides of Sulphur
VOC	Volatile organic compounds

Table 2: Acronyms

3 The Environment Assessment Process: Objective and Approach

The SESAR Environment Assessment Process [1] was derived from the ICAO Guidance document (Doc 10031) [3] “Guidance on Environmental Assessment of Proposed Air Traffic Management Operational Changes” and adapted to the SESAR validation framework.

As can be seen in the Figure below, which shows the correspondence between the ICAO assessment process (right-hand side) and the one adopted for SESAR (left-hand side), the resulting process is quite generic and straightforward. Results from the environmental impact assessments can also be used to refine the ATM change, making the process cyclic and compatible with the classic Plan-Do-Check-Act approach to validation.

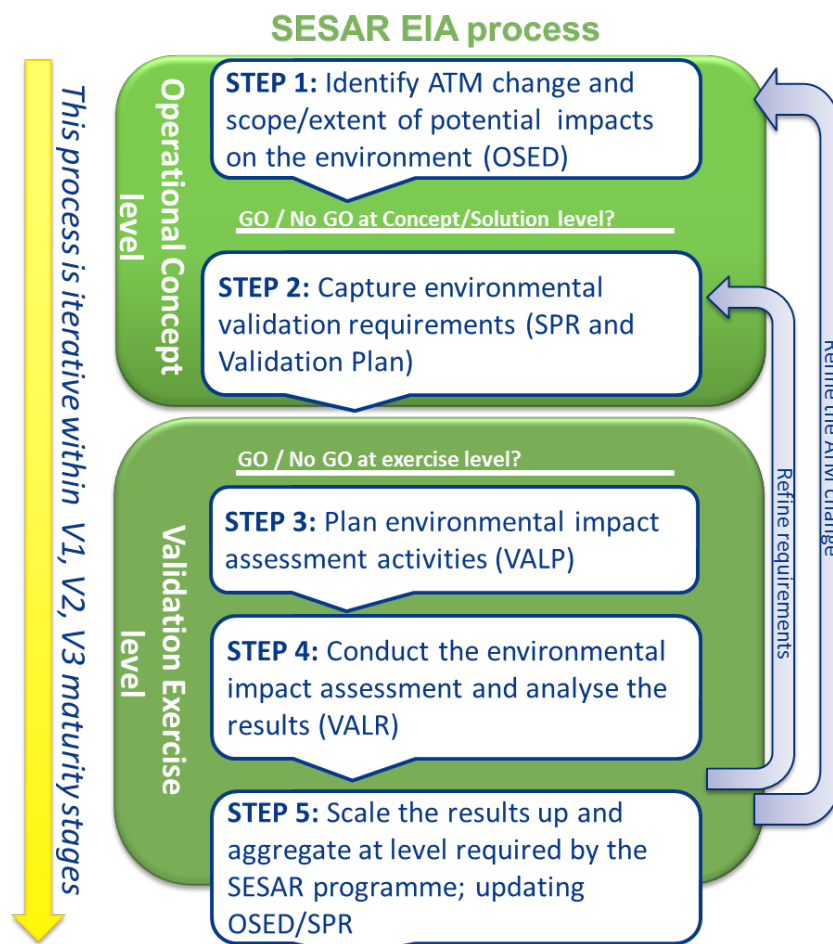


Figure 1: SESAR environmental impact assessment process.

This process should enable environmental impact assessment activities to be easily carried out as part of the overall validation process where necessary.

The SESAR EIA process consists of 5 main steps:

- EIA Step 1: Identify ATM change and the scope of potential impacts on the environment;
- EIA Step 2: Define environmental validation requirements;
- EIA Step 3: Plan environmental impact assessment activities;
- EIA Step 4: Conduct the environmental impact assessment exercise;
- EIA Step 5: Scale the results up and aggregate.

The SESAR EIA process encompasses two "Go-No-Go" decisions about carrying out further environmental impact assessments. The first one occurs after EIA Step 1 in order to identify very early on in the process whether it is worth undertaking an environmental impact assessment or whether or not more assessments are required later on in the process. The second one occurs at the Exercise level and allows the decision on conducting a detailed environmental impact assessment to be taken before the writing of the demonstration plan for that exercise. This decision will be based on criteria determined by the demonstration exercise management. In any case, every "Go-No-Go" decision should be included in the demonstration plan.

Please refer to the SESAR Environment Assessment Process for full guidance [1].

4 Environment Performance Assessment

4.1 Assessment Sources and Summary of Validation Exercise Performance Results

Previous Validation Exercises (pre-SESAR2020, etc.) relevant for this assessment are listed below.

None are listed as previous Validation Exercises have analysed a specific SESAR solution and not an integrated set of SESAR solutions.

Organisation	Document Title	Publishing Date
N/A	N/A	N/A

Table 3: Pre-SESAR2020 Exercises

SESAR Validation Exercises of this Solution (completed ones and planned ones) are listed below.

Exercise ID	Exercise Title	Release	Maturity	Status
EXE.PJ.37-W3-001	Real time simulation 1 for the integrated arrival management process solution for the Schiphol TMA operations		TRL7 ongoing	Completed
EXE.PJ.37-W3-002	Real time simulation 2 for the integrated arrival management process solution for the Schiphol TMA operations		TRL7 ongoing	Completed

Table 4: SESAR2020 Validation Exercises

The SESAR 1 and SESAR2020 Wave 1 projects all have contributed to the integrated arrival concept exercises validated by this project. As not all the previously performed exercises have made conversions to ECAC level, a realistic one-on-one comparison of the performance results is unreasonable. Furthermore, previous solutions have analysed their results against different references or using different metrics.

The following table provides a summary of information collected from available performance outcomes.

Exercise	OI Step / SESAR Solution	Exercise scenario & scope	Performance Results	Notes
	TS-0305-A Arrival Management Extended to En-Route Airspace - single TMA			SESAR 1 Solution #5 Extended Arrival Management (E-AMAN) horizon
	AO-0326			-

Exercise	OI Step / SESAR Solution	Exercise scenario & scope	Performance Results	Notes
	Optimisation of Separation Minima on Approach and Departure thanks to European Wake Turbulence Categorisation (RECAT EU)			Re-CATegorisation (RECAT-EU) ¹
	AOM-0603 Enhanced Terminal Airspace for RNP-based Operations			SESAR 1 Solution #9, #51, #62 Enhanced Terminal Airspace using RNP-Based Operations
	AOM-0605 Enhanced Terminal Operations with RNP ² transition to ILS/GLS/LPV			SESAR 1 Solution #9, #51, #62 Enhanced Terminal Airspace using RNP-Based Operations
	AO-0303 Time Based Separation for Final Approach - full concept			SESAR 1 Solution #64 Time Based Separation (TBS)
PJ.01-05 FTS#1 to FTS#3 PJ.01-05 RTS#1 to RTS#3	TS-0108 Airborne Spacing Flight Deck Interval Management (FIM)	The baseline scenario is a fixed route network with step-wise altitude profiles. The solution scenario is a fixed route network with continuously descending altitude profiles and IM operations.	Fuel-efficiency: Fuel benefit of 1.65 to 2.05% for very high and high complexity TMAs in peak hours. Noise: Total noise contour area benefit of 14% (L _{Aeq} 40 dB(A) and 400 arrival operations) and 46% (L _{Aeq} 55 dB(A) and 400 arrival	Details presented in [4] FTS results used for evaluation

¹ RECAT-EU and TBS are supported by functionalities of the ORD tool

² RNP refers as well to the usage of Fixed Approach Routes (FAR)

Exercise	OI Step / SESAR Solution	Exercise scenario & scope	Performance Results	Notes
		Noted that the results and conclusions about the noise contour areas depend on the traffic mix and number of flight operations and the defined approach procedures.	operations) and a total benefit regarding the number of people living inside the noise contours of 4% (L _{Aeq} 40 dB(A), 400 Arrival Operation) and 70% (L _{Aeq} 55 dB(A), 400 Arrival Operations).	
EXE-PJ2.01-VALP-RTS1, RTS2, RTS3a, RTS3b, RTS4a, RTS4b, RTS6, FTS9	AO-0328 Optimised Runway Delivery (ORD) on Final Approach	A generic environment derived from Vienna airport (Large airport with complex TMA), with according traffic mix. Reference Scenario-RECAT-EU TBS with FTD only. Solution Scenario-RECAT-EU TBS with ORD. The fuel burn savings is computed based on the comparison of the averaged flying time per flight.	Fuel-efficiency: Fuel benefit of 0.59% to 1.6% for ORD tool with RECAT-EU TBS compared to TBS (AO-0303) FTD Indicator only tool support. Noise: N/A	Details presented in [5] FTS results used for evaluation
EXE-PJ2.01-VALP-RTS2, RTS3a, RTS4b, RTS6, FTS9	AO-0306 Static Pairwise Separations (S-PWS) for Arrivals	A generic environment derived from Vienna airport (Large airport with complex TMA), with according traffic mix. Reference Scenario-RECAT-EU TBS with FTD only. Solution Scenario-RECAT-EU-PWS TBS with ORD. The fuel burn savings is computed based on the comparison of the averaged flying time per flight.	Fuel-efficiency: Fuel benefit of 1.1% to 3.33% for S-PWS and TBS (AO-0303) with ORD (AO-0328) tool compared to TBS (AO-0303) FTD Indicator only tool support. Noise: N/A	Details presented in [5] FTS results used for evaluation
EXE.02-08.V3.005 (RTS)	AO-0337 Increased Runway Throughput based on local ROT characterization	Real Time Simulation of Zurich Airport and TMA environment with focus on Approach with application of the ROCAT concept	Fuel-efficiency: N/A Noise: N/A	Details presented in [6] No evaluation of ENVAR KPI, focus on SAF and HUP.

Table 5: Summary of Validation Results.

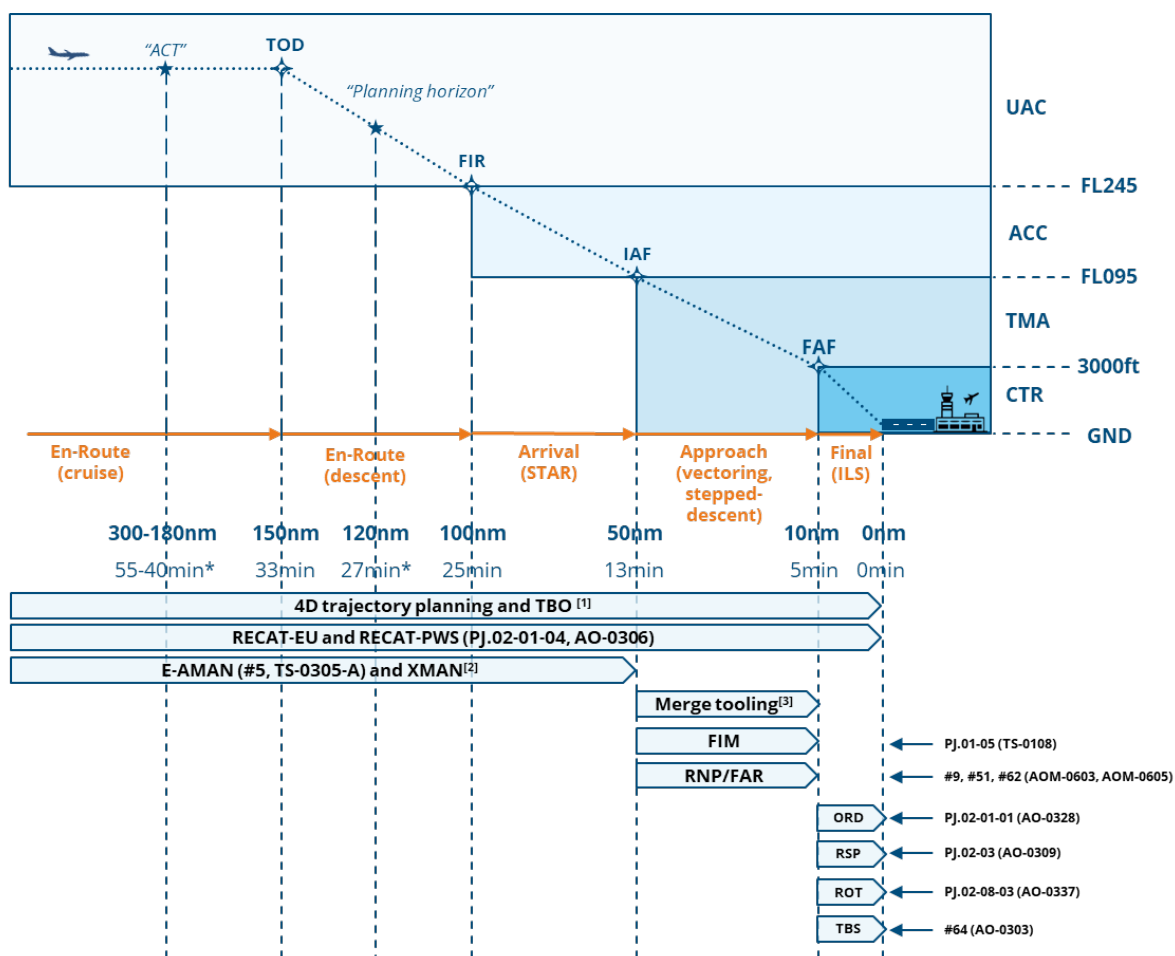
4.2 Conditions / Assumptions for Applicability

The following Table 6 summarises the applicable operating environments.

OE	Applicable sub-OE	Special characteristics
Schiphol TMA Airspace layout	Very high complexity, High complexity, Medium complexity	Representative large International Airport with congested airspace and mixed traffic. The simulated airspace is based on a realistic operational situation which represents the Dutch airspace in line with its national airspace redesign programme, which is derived from today's operational situation and to be implemented in 2030-2035. The routes consist of CDO on RNP routes for the main runway configurations, 4 IAFs and FARs with fixed nominal speed profiles. All IAFs have entry flight level of FL100 as it is the most realistic procedure to have one fixed TMA entry altitude according to the local ANSP. Each FAR has a fixed descent angle. ATCOs are not familiar with the 4 IAF CDO procedure. Introduction of varied IAF entry FLs would increase the vertical spread along the FAR for each flight, resulting in more challenging simulations for the ATCO.
Airport	Very Large Airport, Large Airport, Medium Airport	Representative large International Airport with congested airspace and mixed traffic.
Airspace	Good weather conditions	The weather conditions such as wind, visibility and precipitation, are such that it does not negatively impact the operation with FAR, CDO and the integrated tool.
Aircraft Performance	Aircraft Performance Models	BADA 3.7 models are used to model aircraft performance and are controlled by pseudo pilots.

Table 6: Applicable Operating Environments.

Solution PJ.37-W3-01A, focuses on the arrival management process of Amsterdam Schiphol Airport, which forms the reference scenario related to EXE-PJ.37-W3-001, EXE-PJ.37-W3-002, and EXE-PJ.37-W3-003. A schematic of the Schiphol arrival management process is provided in Figure 2, which includes an overview of the most relevant flight phases. The figure also includes an overview of the various SESAR solutions which form the integrated solution PJ.37-W3-01A, and in which part(s) of the Schiphol arrival management process they are active.



The following techniques will be embedded in the PJ.37-W3-01A Schiphol-RTS, however these are not part of a SESAR solution which will be validated within PJ.37-W3-ITARO:

[1] all simulated flights will have flight plan, which has the form of a 4D trajectory. Parts of the trajectory which are not actively monitored/controlled by humans-in-the-loop will adhere to this planned 4D trajectory, unless there is a disturbance in the ATM network.

[2] cross-border arrival management instructions are emulated in such a manner that it only affects the TMA-entry of the simulated flights.

[3] a merge tool will be provided to the ATCOs to facilitate the merging of FAR/RNP routes in the TMA

Figure 2: Relevant flight phases and airspaces. All distances/times/altitudes are indicative and not to scale. ACC/TMA/CTR is controlled by the LVNL, UAC is controlled by a different ANSP. All SESAR solutions at the bottom of the figure, which form the integrated PJ.37-W3-01A solution, indicate in which part(s) of the arrival management process they are active.

The following solutions presented in Table 7 are part of the reference scenario.

SESAR Solution and/or OI which are part of the reference scenario in EXE-PJ.37-W3-001 / 002		OI step
#5	Extended Arrival Management (E-AMAN) horizon	TS-0305-A Arrival Management Extended to En-Route Airspace - single TMA

SESAR Solution and/or OI which are part of the reference scenario in EXE-PJ.37-W3-001 / 002	OI step
Re-CATegorisation (RECAT-EU) ³	AO-0326 Optimisation of Separation Minima on Approach and Departure thanks to European Wake Turbulence Categorisation (RECAT EU)
#9, #51, #62 Enhanced Terminal Airspace using RNP-Based Operations	AOM-0603 Enhanced Terminal Airspace for RNP-based Operations AOM-0605 Enhanced Terminal Operations with RNP ⁴ transition to ILS/GLS/LPV
#64 Time Based Separation (TBS)	AO-0303 Time Based Separation for Final Approach - full concept

Table 7: Reference scenario relevant for EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002

SESAR Solution in Reference Scenario for PJ.37-W3-01A	OI step
PJ.02-01-01 Optimised Runway Delivery (ORD) on Final Approach	AO-0328 Optimised Runway Delivery (ORD) on Final Approach
PJ.02-08-03 Increased Runway Throughput based on local ROT characterization	AO-0337 Increased Runway Throughput based on local ROT characterization

Table 8: Solutions which are part of the reference and solution scenario for i EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002.

Since E-AMAN, TBS, RECAT-EU, RNP, ORD and FARs with a fixed profile descent are already part of the reference scenario, most of the required infrastructure for the solution scenario is already present in the reference scenario. As the implementation of Time Based Separation (TBS) and more sophisticated wake turbulence categories (RECAT-EU) compared to current operations, an Optimised Runway Delivery (ORD) tool, PJ.02-01-01, is implemented in the reference scenario. As the ORD tool also needs to consider Runway Occupancy Time (ROT), PJ.02-08-03 is included in the reference scenario.

The introduction of IM, combined with S-PWS, into the arrival management process in the solution scenario is likely to be one of the biggest changes in terms of operating method for the Air Traffic Controllers (ATCOs) and airspace users (AU).

The SESAR solutions under the scope of this exercise are provided in Table 9:

³ RECAT-EU and TBS are supported by functionalities of the ORD tool

⁴ RNP refers as well to the usage of Fixed Approach Routes (FAR)

SESAR Solutions to be validated in EXE-PJ.37-W3-001		OI step
PJ.02-01-04 Wake Turbulence Separations (for Arrivals) based on Static Aircraft Characteristics	AO-0306 Static Pairwise Separations (S-PWS) for Arrivals	
PJ.02-01-01 Optimised Runway Delivery (ORD) on Final Approach	AO-0328 Optimised Runway Delivery (ORD) on Final Approach	
PJ.02-08-03 Increased Runway Throughput based on local runway occupancy time (ROT) categorisation	AO-0337 Increased Runway Throughput based on local ROT characterization	
PJ.01-05 Airborne Spacing Flight-deck Interval Management (FIM)	TS-0108 Airborne Spacing Flight-deck Interval Management (FIM)	

Table 9: Solutions to be demonstrated for EXE-PJ.37-W3-001. The solutions are extracted from DS22 Draft.

4.3 Environment: Fuel Efficiency / CO₂ emissions

Fuel efficiency and CO₂ emissions are impacted by the solution.

Although in both the reference and solution scenario FARs and CDOs are performed, in the solution scenario the combination of IM and a more refined time-based pair-wise separation used by the ORD tool, it is expected that aircraft will fly different speed profiles on the FAR and thus affecting the fuel efficiency.

To reduce the CO₂ emissions from flights, it is necessary to reduce their fuel consumption as every tonne of fuel burned generates 3.15 tonnes of CO₂ emissions.

4.3.1 Performance Mechanism

Figure 2 presents an overview of the integrated arrival management process. Between the reference and solution scenario, TS-0108 Airborne Spacing Flight Deck Interval Management (FIM) and the use of the more sophisticated AO-0306 Static Pairwise Separations (S-PWS) for Arrivals (RECAT-EU-PWS) instead of the RECAT-EU separation minima in combination with the AO-0328 Optimised Runway Delivery (ORD) on Final Approach and AO-0337 Increased Runway Throughput based on local ROT characterization will improve fuel efficiency per flight.

By delivering aircraft with further optimised wake separations at threshold there is a positive impact on arrival delay and thus a reduction of flying time that impacts fuel burn and emissions. The Airborne Spacing Flight-deck Interval Management (TS-0108 – FIM) is an enabler for fixed route network with high capacity and consequently fixed route network which enables continuous descending altitude profiles. RECAT-EU-PWS, ROT and ORD tool results in reduction of separations and spacing delivery. FIM ensures that the airborne spacing in high capacity airspace is optimised. Both aid in reducing airborne time and thus resulting in a reduction of fuel usage. As fuel use is also impacted by speed and thrust profiles flown, the impact of flying IM Speeds might offset the expected decrease in fuel usage.

4.3.2 Assessment Data (Exercises and Expectations)

The data logs obtained in validation exercise EXE.PJ.37-W3-001 and EXE.PJ.37-W3-002 were analysed to perform the assessment. Note that both exercises are Real-Time Simulations (RTS) with a focus on the safety and human performance aspects of the integrated solutions. Thus a limited number of

simulations have been performed. The outcome of this analysis will provide an indication of the impact of the integrated arrival solution. Fast-Time Simulations (FTS) evaluating a large number of scenarios is required to more accurately assess the impact of the integrated solutions.

In the data logging, for every timestamp the fuel flow is logged. The fuel flow is determined based on the thrust level and the aircraft performance characteristics in accordance with BADA. Total fuel burn is evaluated for flights in the TMA.

In EXE-PJ.37-W3-001, the traffic sample of the landed aircraft were not completely identical between the reference and solution run. As slight differences in ICAO Wake Turbulence Category of the landed aircraft impacts the fuel burn (and thus CO₂ emissions), the benefit contribution presented in the table below refers to the reference-solution pair where the difference was the least. For further details of this exercise, please refer to Section 4.3.5.1

In EXE-PJ.37-W3-002, the traffic sample was identical. However not all the runs lasted the same duration. It was observed that with low IM equipage, there is a slightly negative influence on the CO₂ emissions. With increasing IM equipage rate, the benefits are observed. For further details, please refer to Section 4.3.5.2.

Exercise ID or Expert judgement	Benefits contribution to FEF1	Benefits contribution to ENV1
EXE.PJ.37-W3-001	9.9%	9.9%
EXE.PJ.37-W3-002	6.7%	6.7%

Table 10: Local fuel burn and CO₂ emissions saving per Exercise (solution scenario compared to reference scenario)

As in this solution the impact of the integrated solution is evaluated, the relative benefits of each OI step is left out of the analysis.

4.3.3 Extrapolation to ECAC wide

On ECAC/Network level, to translate the 6.7% reduction in fuel and CO₂, use is made of the S2020 Common Assumptions [2]. Average fuel burn per flight is 5280 kg (F-0001), of which 5% (F-0006) is the TMA arrival fuel consumption contribution or 264 kg. 6.7% of 264 is 17.7 kg. However, the integrated solution works for peak arrivals at Very Large and Large airports (APT-PC-VL-2035, APT-PC-L-2035, from which only 50% is arriving traffic) or $((47.23\% + 14.99\%)/2 = 31.11\%)$. This results in $17.7 * 31.11\%$ is 5.5 kg reduction in fuel usage. Out of the total fuel burn per flight, 5.5 kg equals to $(5.5/5280 * 100 = 0.1\%)$. The CO₂ emissions results from multiplying the fuel burn by 3.15, or 17.3 kg.

As only a limited number of simulations have been performed in the RTS, extrapolating the results to ECAC wide network level requires further investigation using FTS.

KPIs / Pls	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
FEFF1 Actual Average fuel burn per flight	Kg fuel per movement	Total amount of actual fuel burn divided by the number of movements	YES	5.5 kg	0.1%
ENV1 Actual Average CO ₂ Emission per flight	Kg CO ₂ per flight	Amount of fuel burnt x 3.15 (CO ₂ emission index) divided by the number of flights	YES	17.3 kg	0.1%

Table 11: Fuel burn and CO₂ emissions saving for Mandatory KPIs / Pls

Table 12 is showing the average fuel burn per phase of flight (provided when applicable).

	Taxi out	TMA departure	En-route	TMA arrival	Taxi in
FEFF1 Actual Average fuel burn per flight	N/A	N/A	N/A	5.5 kg saving per flight	N/A
ENV1 Actual Average CO ₂ Emission per flight (Kg)	N/A	N/A	N/A	17.3 kg saving per flight	N/A

Table 12: Average fuel burn and fuel burn savings per phase of flight.

4.3.4 Discussion of Assessment Result

The reference scenario used in the demonstration exercise makes use of CDOs and fixed routes. Compared to current vectoring operation with level flight, a fuel burn benefit is to be expected. The integrated arrival process shows its potential to even further reduce CO₂ emissions by nearly 10% per flight in EXE-PJ.37-W3-001 and nearly 7% in EXE-PJ.37-W3-002, which outlines the potential of this integrated arrival process.

The confidence⁵ in the results is high as the data is based on the BADA aircraft performance models. The confidence in the generalised finding of the impact of the solution is low level due to the limited number of (RTS) evaluations. To increase the confidence of the generalised finding (and to also transfer this to ECAC wide level) FTS have to be performed.

⁵ High – the results might change by +/-10%
Medium – the results might change by +/-25%
Low – the results might change by +/-50% or greater

4.3.5 Additional Comments and Notes

The fuel assessment for each validation exercise is elaborated in the following sections. Calculation to ECAC values is performed for EXE-PJ.37-W3-002.

4.3.5.1 EXE-PJ.37-W3-001

Demonstration objective OBJ-37-W3-DEMOP-ENV1-0001 “The CO₂ emissions will not increase against the reference scenario” has been assessed as [POK] as the CO₂ emissions was lower for most of the solution runs. However, the traffic sample, as presented in Table 13, was not completely identical between the reference and solution run, requiring further analysis to quantify the effect of the solution on the total CO₂ emissions in EXE-PJ.37-W3-002.

Scenario	Run #	Reference / Solution	Simulated entry throughput per hour per runway	Nr of good flights	WTC			
					<i>H</i>	<i>M</i>	<i>L</i>	<i>J</i>
RWY 06+36R / 36L+36C, calm wind	2	Reference	35	51	8	43	0	0
	1	Solution	35	45	6	38	0	1
RWY 18R+18C / 24+18L, strong wind	4	Reference	35	47	7	40	0	0
	3	Solution	35	48	8	39	0	1
RWY 18R+18C / 24+18L, light wind	8	Reference	35	50	7	43	0	0
	5	Solution	35	50	8	41	0	1
RWY 06+36R / 36L+36C, calm wind	7	Reference	40	54	6	47	0	1
	6	Solution	40	63	5	58	0	0
RWY 18R+18C / 24+18L, light wind	10	Reference	40	53	5	48	0	0
	9	Solution	40	54	5	49	0	0
RWY 06+36R / 36L+36C, calm wind, MRS 2.0	11	Solution	40	56	7	48	0	1

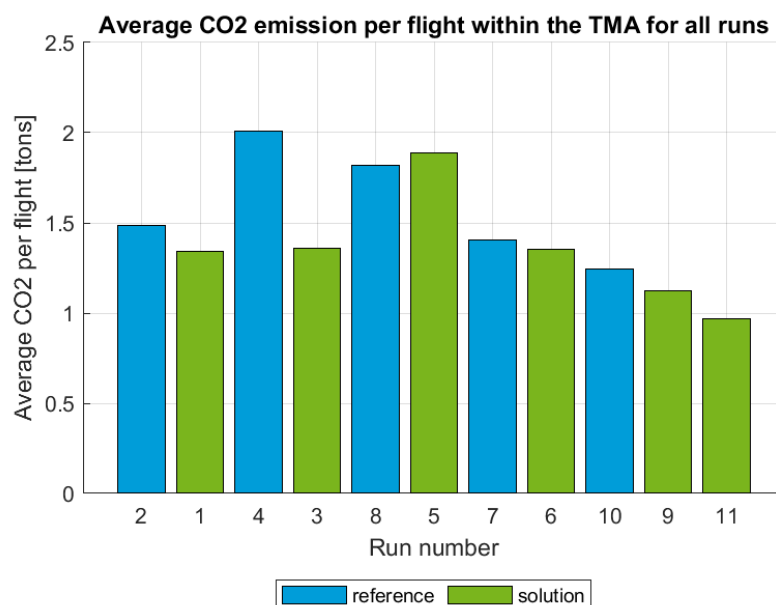
Table 13: EXE-PJ.37-W3-001 validation run data

The success criteria of this objective is defined as “The use of the integrated tool does not increase the CO₂ emissions in the nominal simulation against the reference scenario”. Table 14 and Figure 3 presents the difference in CO₂ emissions between the solution and reference runs for the arrivals. As validation run #11 was only performed as solution run, it is not included in the table. The result for this run was that the average CO₂ emissions per flight was 0.97 tonne. The calculations are in-line with the KPI ENV1 “Actual Average CO₂ Emissions per flight” introduced in the SESAR Performance Framework.

Important considerations in the analysis:

- The CO₂ emissions is determined by converting the fuel burn by the conversion factor of 3.15 (the CO₂ emissions index).
- The fuel burn in the TMA is determined by the aircraft performance model (BADA 3.7) for each flight.
- *The number of flights in the table equals the number of flights that have landed. Go arounds and flights which deviated from the fixed approach route (i.e. radar vectoring) are excluded*

Scenario	Ref. run #	Nr of flights	Total CO ₂ [tonne] emitted	Avg. CO ₂ [tonne] emitted per flight	Sol. Run #	Nr of flights	Total CO ₂ [tonne] emitted	Avg. CO ₂ [tonne] emitted per flight	% Δ between Ref. and Sol. run
06+36R / 36L+36C, calm wind, 35 p/h	2	51	75.62	1.48	1	45	60.31	1.34	-9.6%
18R+18C / 24+18L, strong wind, 35 p/h	4	47	94.40	2.01	3	48	65.13	1.36	-32.4%
18R+18C / 24+18L, light wind, 35 p/h	8	50	90.88	1.82	5	50	94.49	1.89	4.0%
06+36R / 36L+36C, calm wind, 40 p/h	7	54	75.86	1.40	6	63	85.43	1.36	-3.5%
18R+18C / 24+18L, light wind, 40 p/h	10	53	65.98	1.24	9	54	60.59	1.12	-9.9%

Table 14: OBJ-37-W3-DEMOP-ENV1-0001 CO₂ emissions of arrivals in the TMAFigure 3: OBJ-37-W3-DEMOP-ENV1-0001 CO₂ emissions of arrivals in the TMA

It is noted that in general, the solution run emits less CO₂ emissions. However, in the scenario with 35 aircraft per hour per runway with light wind (Run #8 - #5), it is noticed that the solution run emits around 4% more CO₂. Analysing the traffic sample of the landed aircraft using the runway throughput

table (Table 13), it is noticed that the solution run had one ICAO Wake Turbulence Category (WTC) Class H (Heavy) and one WTC Class J (Super) more, and two less WTC Class M (Medium) as compared to the reference run. This has likely caused the difference in CO₂ emissions.

The traffic sample between the different runs were similar in the total number and percentage of RECAT-EU category aircraft A-E. To perform an exact comparison between the reference and solution runs, the traffic sample, their arrival sequence and the planned time of TMA entry should be identical. This information is used as valuable feedback and input for EXE-PJ.37-W3-002.

If based on EXE-PJ.37-W3-001 an conclusion should be provided, the comparison between run #9 and #10 is most representable as both runs had a similar number of aircraft and aircraft wake category which have been considered in the analysis. Based on this 1 comparison, it is concluded that the solution run had a reduction of CO₂ emissions near to 10%.

4.3.5.2 EXE-PJ.37-W3-002

Demonstration objective OBJ-37-W3-DEMOP-ENV1-0001 “The CO₂ emissions will not increase against the reference scenario” has been assessed as [OK] as the CO₂ emissions was lower for the solution runs. Initial implementation with a low IM equipage rate would initially increase the CO₂ emissions.

The average CO₂ burn per flight is presented in Table 15, with the same considerations taken as in EXE-PJ.37-W3-001 to select the suitable flights. In EXE-PJ.37-W3-002, the traffic sample between the reference and the solution runs were identical in order to compare the fuel burn and CO₂ emissions.

Between the reference run #1 and solution run #2, the average CO₂ emissions is reduced. However, run #2 did not include the WTC “J” aircraft. In mixed IM operation, 20% (run #3) and 80% (run #4), it is observed that in a mixed operation with low equipage rate the average CO₂ emissions increases as compared to the reference run. However, with increasing equipage rate, a reduction is observed. With strong headwind conditions, run #8 and #9, also a reduction in CO₂ emissions is observed in the solution run. With increased traffic load, run #10, the lowest average CO₂ emissions is observed.

Run #	Nr of good flights	WTC				Total CO ₂ [tonne] emitted	Avg. CO ₂ [tonne] emitted per flight
		H	M	L	J		
1 (REF)	55	10	44	0	1	75.89	1.38
3 (SOL)	55	10	44	0	1	78.61	1.43
4 (SOL)	55	10	44	0	1	74.09	1.35
2 (SOL)	38	8	30	0	0	46.08	1.21
8 (REF)	29	1	28	0	0	27.45	0.95
9 (SOL)	31	1	30	0	0	28.08	0.91
5 (SOL)	58	8	49	0	1	81.16	1.40
7 (SOL)	58	8	49	0	1	73.82	1.27
10 (SOL)	64	6	58	0	0	69.36	1.08

Table 15: OBJ-37-W3-DEMOP-ENV1-0001 CO₂ emissions of arrivals in the TMA

To compare the performance of an identical traffic sample, the flights which are not in the traffic sample of the other runs have been filtered. The results are presented in Table 16 to Table 18. It is noticed that in all runs, the solution run has the most favourable CO₂ emissions.

Run #	Nr of good flights – 18R	Nr of good flights – 18C	Flights considered in this analysis	WTC				Total CO ₂ [tonne] emitted	Avg. CO ₂ [tonne] emitted per flight
				H	M	L	J		
1 (REF)	29	26	54	10	43	0	1	74.70	1.38
3 (SOL)	28	27						77.32	1.43 (+3.5%)
4 (SOL)	29	26						73.03	1.35 (-2.2%)

Table 16: OBJ-37-W3-DEMOP-ENV1-0001 CO₂ emission of arrivals in the TMA with adjusted traffic sample to compare run #1, #3 and #4

Run #	Nr of good flights – 18R	Nr of good flights – 18C	Flights considered in the analysis	WTC				Total CO ₂ [tonne] emitted	Avg. CO ₂ [tonne] emitted per flight
				H	M	L	J		
4 (SOL)	29	26	38	8	30	0	0	48.26	1.27
2 (SOL)	20	18						46.08	1.21 (-4.5%)

Table 17: OBJ-37-W3-DEMOP-ENV1-0001 CO₂ emission of arrivals in the TMA with adjusted traffic sample to compare run #2 and #4

Run #	Nr of good flights – 18R	Nr of good flights – 18C	Flights considered in the analysis	WTC				Total CO ₂ [tonne] emitted	Avg. CO ₂ [tonne] emitted per flight
				H	M	L	J		
8 (REF)	29	N/A	29	1	28	0	0	27.45	0.95
9 (SOL)	31	N/A						26.67	0.92 (-2.8%)

Table 18: OBJ-37-W3-DEMOP-ENV1-0001 CO₂ emission of arrivals in the TMA with adjusted traffic sample to compare run #8 and #9

Since run #2 ended earlier than anticipated, no direct comparison is made between run #1 and run #2. However, the performance of run #2 is compared against the run with the highest IM equipage rate (run #4). Extrapolating the benefit of run #2 over run #4 to a comparison with run #1, a total CO₂ reduction of 6.7% can be obtained between run #1 and run #2 (a 4.5% reduction over 1.35 tonne equals 1.29 tonne. Comparing 1.29 against 1.38 tonne obtained in run #1 results in the 6.7% reduction).

On ECAC/Network level, to translate the 6.7% reduction in fuel and CO₂, use is made of the S2020 Common Assumptions [2]. Average fuel burn per flight is 5280 kg (F-0001), of which 5% (F-0006) is the TMA arrival fuel consumption contribution or 264 kg. 6.7% of 264 is 17.7 kg. However, the integrated

solution works for peak arrivals at Very Large and Large airports (APT-PC-VL-2035, APT-PC-L-2035, from which only 50% is arriving traffic) or $((47.23\% + 14.99\%)/2 = 31.11\%)$. This results in $17.7 * 31.11\%$ is 5.5 kg reduction in fuel usage. Out of the total fuel burn per flight, 5.5 kg equals to $(5.5/5280*100=0.1\%)$. The CO₂ emission results from multiplying the fuel burn by 3.15, or 17.3 kg.

4.4 Environment: Noise, Local Air Quality, and non-CO₂ Emissions

Aircraft noise is impacted by the solution.

The noise focus area only covers aircraft noise source; other noise sources around the airport contributing to the background noise are not considered. This KPA is evaluated by the notion of noise exposure (noise energy perceived on the ground). The result is not quantified in the number of people exposed to aircraft noise in order not to have the result of the integrated solution depend on the considered, simulated operational environment.

No analysis has been performed for local air quality or other aviation emissions.

Extrapolation at the ECAC level is not provided as it is not possible for noise and local air quality, and not required for non-CO₂ emissions.

4.4.1 Performance Mechanism

It is expected that due to a variation in speed profiles flown, the exposure time to aircraft noise will vary between the reference and solution runs. The faster the aircraft flies, the lower the exposure time to the sound and thus a lower sound exposure level for 1 aircraft flyover. In addition, the IM system will aid the pilot in arriving at the merge point and final approach on time more accurately. Thereby limiting the need for increasing of thrust levels at low altitude levels. For the full performance mechanism, please review the elaboration provided in Section 4.3.1.

4.4.2 Assessment Data (Exercises and Expectations)

The data logs obtained in validation exercise EXE.PJ.37-W3-001 and EXE.PJ.37-W3-002 are analysed to perform the assessment. Note that both exercises are Real-Time Simulations (RTS) with a focus on the safety and human performance aspects of the integrated solutions. Thus a limited number of simulations have been performed. The outcome of this analysis will provide an indication of the impact of the integrated arrival solution. Fast-Time Simulations (FTS) evaluating a large number of scenarios is required to more accurately assess the impact of the integrated solutions.

In the data logging, for every timestamp the position (x, y and height), speed (CAS), total thrust, aircraft configuration (gear up/down) is logged. The thrust level is in accordance with the aircraft performance characteristics as defined in the BADA models. The noise exposure is analysed by computing the L_{den} using doc29 calculation methods. Each scenario has been normalized to 50.000 flights per scenario in order to achieve a meaningful comparison with L_{den} values common to larger airports. For each flight, based on the speed profiles, the use of the high lift devices have been assumed.

In EXE-PJ.37-W3-001, the traffic sample of the landed aircraft were not completely identical between the reference and solution run. As slight differences in ICAO Wake Turbulence Category of the landed aircraft impacts the noise emission, the benefit contribution presented in the table below refers to the reference-solution pair where the difference was the least. For further details of this exercise, please refer to Section 4.4.5.1.

In EXE-PJ.37-W3-002, the traffic sample was identical. However not all the runs lasted the same duration. It was observed that the difference in 55dB contour areas are 1% or lower. Differences in local noise levels are also very limited. Most differences are between 0 and 1 dB, only few localized differences are between 1 and 2 dB and in one case a difference of 4 dB occurs. The 4 dB difference however was due to one flight that flew a level segment, while its counterpart in the matching scenario did not. This is not inherent to a certain IM equipage percentage. The few localized differences are most probably mainly due to speed differences between two scenarios. This benefits noise as aircraft having higher speeds require flap selections at a later moment along the route. With increased flap settings, drag increases and thus the need for more thrust, which results in higher noise levels. For further details, please refer to Section 4.4.5.2.

Exercise ID or Expert judgement	Benefits contribution to NOI1	Benefits contribution to NOI2	Benefits contribution to NOI4	Benefits contribution to LAQ1
EXE-PJ.37-W3-001		3-7% decrease of 55dB contour area		
EXE-PJ.37-W3-002		1% or lower decrease of 55dB contour area		

Table 19: Noise and Local Air Quality benefits per Exercise (solution scenario compared to reference scenario)

As in this study the impact of the integrated solutions is evaluated, the relative benefits of each OI step is left out of the analysis.

In SESAR2020 Wave1, only the individual OI for FIM reported a benefit to noise levels. Other OIs did not evaluate the impact of aircraft noise. As presented in Table 5, the reported noise benefit has been presented in LA_{eq} for the total noise contour area and number of people living inside the noise contour. However, the reference scenarios in this research and the SESAR2020 Wave1 research is different and thus it is difficult to extrapolate the previously obtained results to this research. Thus the result of the integrated solutions evaluated in this research should be treated as new performance, and does not replace the individually obtained performance.

4.4.3 Extrapolation to ECAC wide

There is no ECAC wide extrapolation required for NOI1, NOI2, NOI4 and LAQ1 in the Performance Assessment Report.

PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
NOI1 Relative noise scale	-2 to +2	It is a qualitative scale based on expert judgment. -2 very negative effect or benefit, 0 neutral and +2 very positive effects or benefit. The objective of this metric is to provide a global assessment of the noise impact. This metric is built upon the other quantitative noise PIs (NOI2, NOI3, NOI4, NOI5)	YES for Airport OE Solutions		

PIs	Unit	Calculation	Mandatory	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
NOI2 Size and location of noise contours	Contours of noise level thresholds (e.g. LDEN 55 see ERM document for the list of recommended PIs). Surface of these contours(Km ²)	Noise contours to be calculated according to the ECAC Doc.29 methodology. Surface of the noise contours calculated using a GIS tool or modules. Recommended tool: IMPACT.	YES for Airport OE Solutions	NA	1% or lower decrease of 55dB contour area
(NOI4) Number of people exposed to noise levels exceeding a given threshold	Number of people inside noise contours.	Population count inside the contours calculated above. Need the availability of population census data. Calculated using a GIS tool or modules. Recommended tool: IMPACT.	YES for Airport OE Solutions		
LAQ1 Geographic distribution of pollutant concentrations	Airport Local Air Quality Studies (ALAQs) inventory method generally uses mg/m ³ for each pollutant	Measurement to be performed within LTO cycle. • NOx: Nitrogen oxides, including nitrogen dioxide (NO₂) and nitrogen oxide (NO); • VOC: Volatile organic compounds (including non-methane hydrocarbons (NMHC)); • CO: Carbon monoxide; • PM: Particulate matter (fraction size PM_{2.5} and PM₁₀); • SOx: Sulphur oxides. Recommended tool: Open-ALAQs	YES for Airport OE Solutions relative to LTO (=>below 3000ft)		

Table 20: Noise and Local Air Quality benefit for Mandatory PIs

4.4.4 Discussion of Assessment Result

The reference scenario used in the validation exercise makes use of CDOs and fixed routes. Compared to current vectoring operation with level flight, a noise benefit is to be expected due to the optimised vertical flight profiles. The integrated arrival process shows its potential to even further reduce the noise emission by the decrease of 3-7% of the 55 dB contour area between the reference and solution runs. This outlines the potential of the integrated arrival process. However when an identical traffic sample is simulated without level flight at lower altitude, the noise contour area between the reference and solution run varies very limitedly.

The confidence in the results is high as the data is based on the BADA aircraft performance models and the Doc29 guidance standard of computing noise contours around airports has been used. The confidence in the generalised finding of the impact of the solution is low level due to the limited number of (RTS) evaluations. To increase the confidence of the generalised finding (and to also transfer this to ECAC wide level) FTS have to be performed.

4.4.5 Additional Comments and Notes

The noise assessment for each validation exercise is elaborated in the following sections.

4.4.5.1 EXE-PJ.37-W3-001

Demonstration objective OBJ-37-W3-DEMOP-NOI1-0001 “The noise profile will not increase against the reference scenario” has been assessed as POK as the 55 dB noise contour area decreased and the noise emission for individual flights with similar vertical profiles has decreased. However, the traffic sample, as presented in Table 13, was not completely identical between the reference and solution run due to limited number of flights in the simulation. This could cause some small variation on the impact on the 55 dB contour areas. In addition, the vertical profile in a couple of flights in both the reference and solution runs showed a slightly steeper descent on the fixed angle glide path just before glideslope interception. This resulted in level flight at low altitude, negatively impacting the noise emission. Improving the above in EXE-PJ.37-W3-002, it is expected that the integrated solution would yield a more realistic results with regards to noise emission.

The success criteria of this objective is defined as “The use of the integrated tool does not increase the noise profile in the nominal simulation against the reference scenario”.

Figure 4 to Figure 6 present the noise contour areas of the reference scenario (to the left) and the solution scenario (to the right). Table 21 presents and compares the 55 dB contour areas of the reference-solution set. The calculations are in-line with the KPI NOI “Size and location of noise contours” introduced in the SESAR Performance Framework.

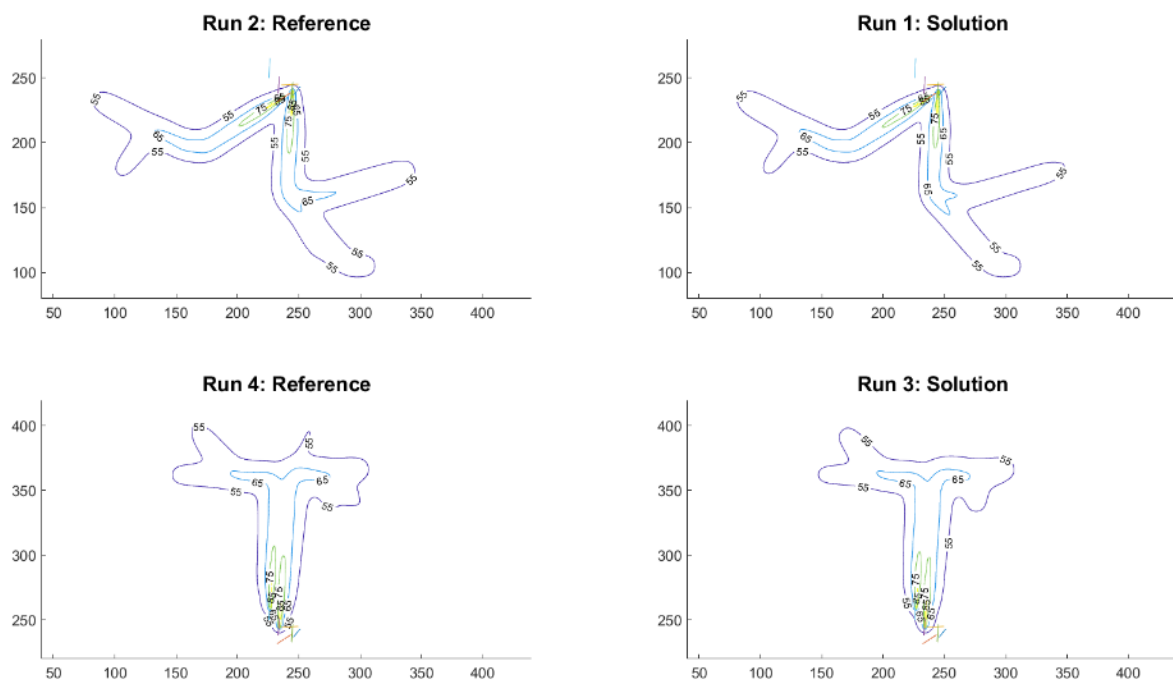
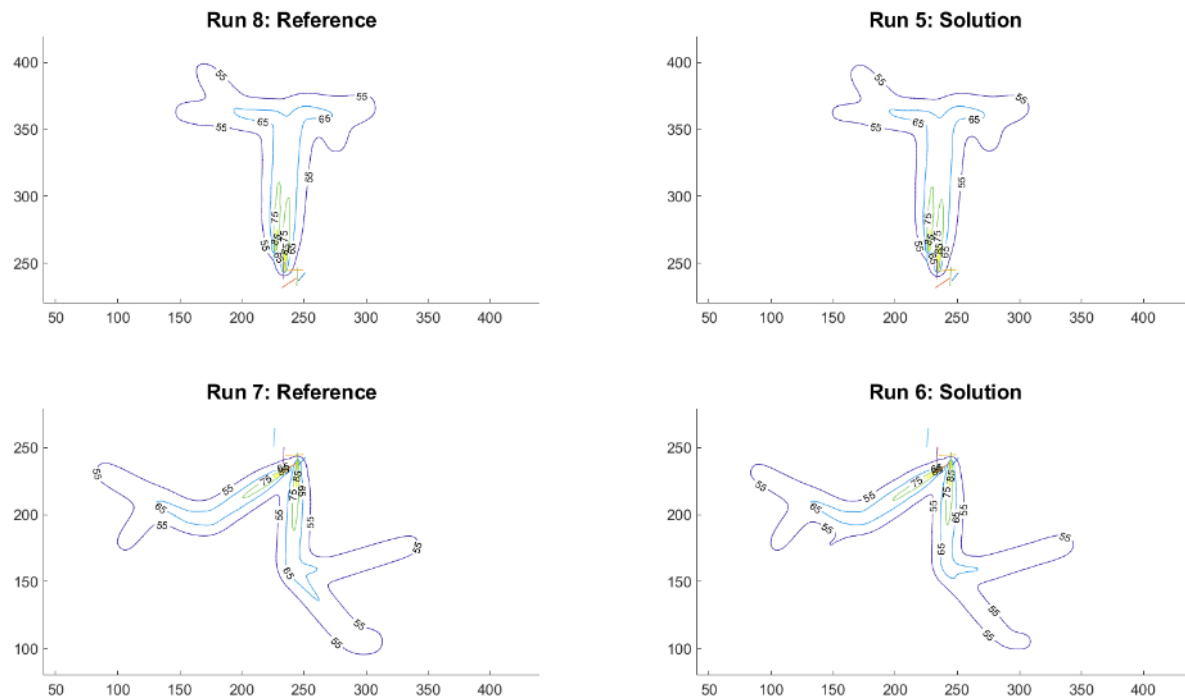
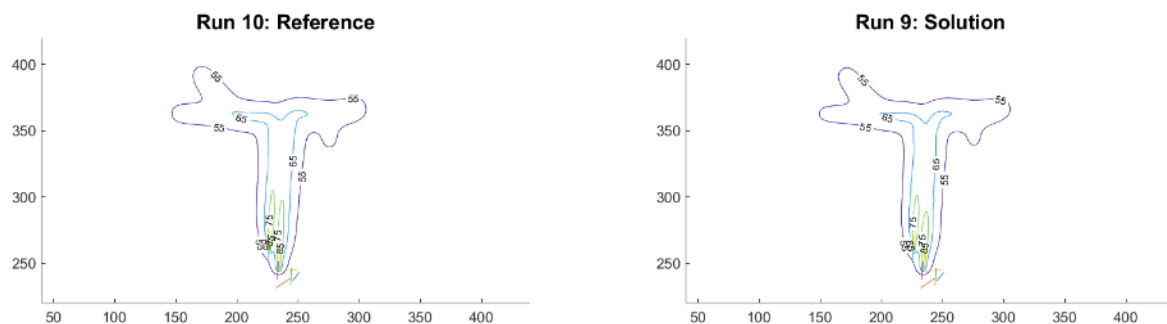


Figure 4: OBJ-37-W3-DEMOP-NOI1-0001 L_{den} noise contour areas for run #1 – #4 for 1 year of operation

Figure 5: OBJ-37-W3-DEMOP-NOI1-0001 L_{den} noise contour areas for run #5 – #8 for 1 year of operationFigure 6: OBJ-37-W3-DEMOP-NOI1-0001 L_{den} noise contour areas for run #9 – #10 for 1 year of operation

Scenario	Run #	Reference / Solution	55dB contour area [km ²]	Delta
RWY 06+36R / 36L+36C, calm wind	2	Reference	634	-6.3%
	1	Solution	594	
RWY 18R+18C / 24+18L, strong wind	4	Reference	521	-6.0%
	3	Solution	490	
RWY 18R+18C / 24+18L, light wind	8	Reference	504	-2.8%
	5	Solution	490	
RWY 06+36R / 36L+36C, calm wind	7	Reference	610	-6.7%
	6	Solution	569	

RWY 18R+18C / 24+18L, light wind	10	Reference	466	-5.8%
	9	Solution	439	
RWY 06+36R / 36L+36C, calm wind, MRS 2.0	11	Solution	589	-

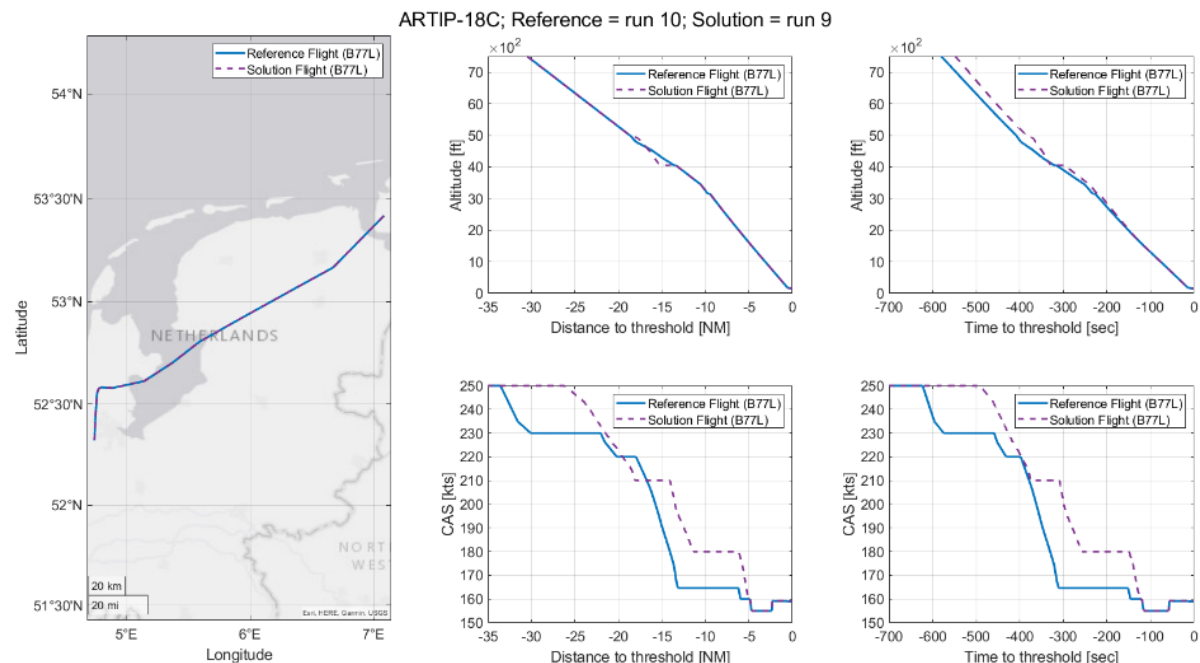
Table 21: OBJ-37-W3-DEMOP-NOI1-0001 55 dB noise contour areas

Important considerations in the analysis:

- The L_{den} contours are calculated using doc29 calculation methods.
- Each scenario has been normalized to 50.000 flights per scenario in order to achieve a meaningful comparison with L_{den} values common to larger airports.
- Use of flaps/slats as a function of speed
- *The number of flights in the table equals the number of flights that have landed. Go arounds and flights which deviated a lot from the fixed approach route (i.e. radar vectoring) are excluded*

As can be seen in the reference/solution pairs the contours are largely the same, however differences exist. Part of the decrease may be attributed to isolated events where aircraft have flown for some time on a level segment at a lower altitude. Also attributing to the decrease in contour area may be the higher speed observed in the solution runs, and thus lower exposure time, of aircraft in the final stages of the landing.

To analyse the differences, the flight profiles on a FAR have been analysed and compared between the reference and the solution run. For an isolated comparison, example flight profiles for an aircraft type on a FAR is presented in Figure 7 for the arrivals from ARTIP to runway 18C and in Figure 8 for arrivals from SUGOL to runway 18R. The lateral track of the flights follow the FAR. The figures present the altitude and CAS against the distance to threshold and time to threshold. The distance to threshold is determined based on the length of the FAR.

**Figure 7: OBJ-37-W3-DEMOP-NOI1-0001 Flight profile comparison ARTIP-18C (run #9 - #10)**

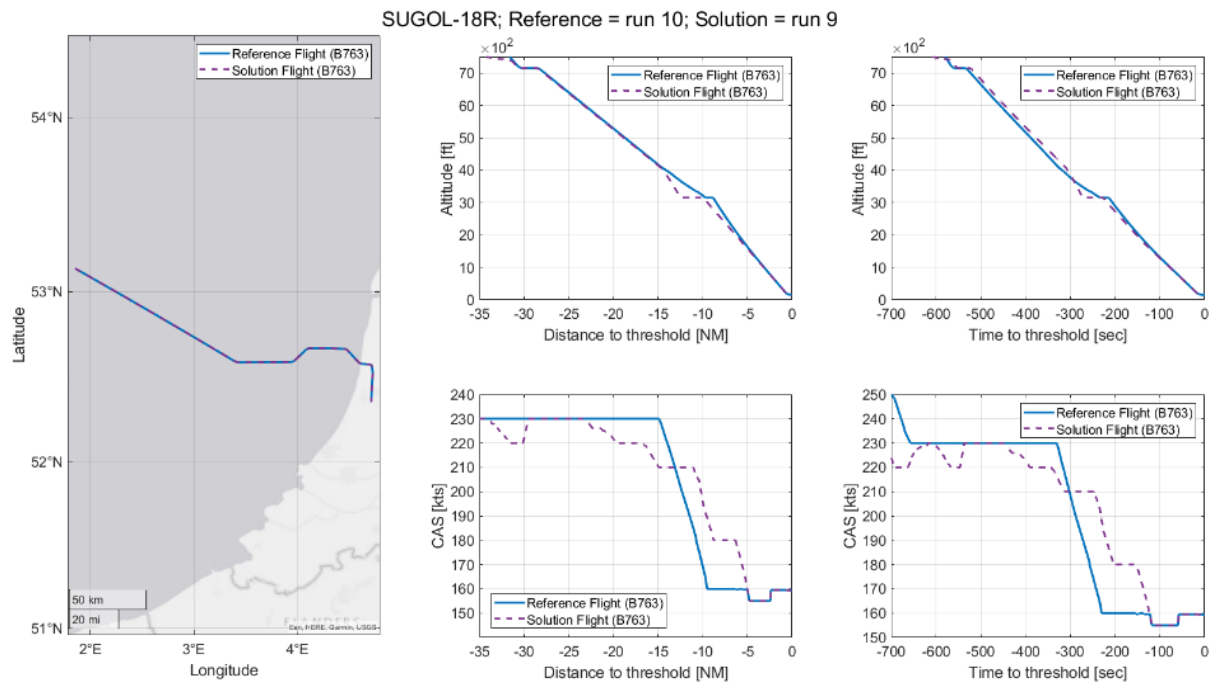


Figure 8: OBJ-37-W3-DEMOP-NOI1-0001 Flight profile comparison SUGOL-18R (run #9 - #10)

For the ARTIP-18C flights, it is noticed that the vertical profile in the reference flight follows the descent path whereas the solution flight has a slight level flight at 4,000 ft. In general, the speed of the solution flight is higher than the reference. For the SUGOL-18R flights, It is observed that both the reference and solution flight have a level segment at 3,000 ft. The reference flight followed its descent path where after it flew a short level segment before following the glidepath. The solution flight increased its descent angle after passing 4,000 ft, resulting in level flight at 3,000 ft before entering its glide path.

After analysing these level flight behaviour in more detail, it was determined that this was not caused by the interaction of solutions within the integrated solution, but the root cause was identified within the simulation environment. Before performing EXE-PJ.37-W3-002, the mentioned behaviour is to be mitigated.

The speed differences remain when comparing isolated flight pairs. To quantify the effect of the speed difference on the noise contour, 2 flight pairs from run #9 and #10, which had the same or very similar vertical profile, have been analysed.

From Solution scenario 9 and reference scenario 10, two flight pairs have been compared. The vertical and horizontal profiles of the pairs are, among themselves, almost identical. However, the speed profiles and thus usage of flaps/slats (as a function of speed) are different. As can be seen in Figure 9, where two B39M flights are compared, the solution flight gives, in some places around the route, 2 to 3dB lower noise levels. This, in part, is due to the reference flight taking longer to traverse the route elongating exposure. Also, due to having lower approach speeds the reference flight selects flaps at an earlier stage than the solution flight, which leads to higher noise levels. The same can be seen in Figure 10, where two B38M flights are compared.

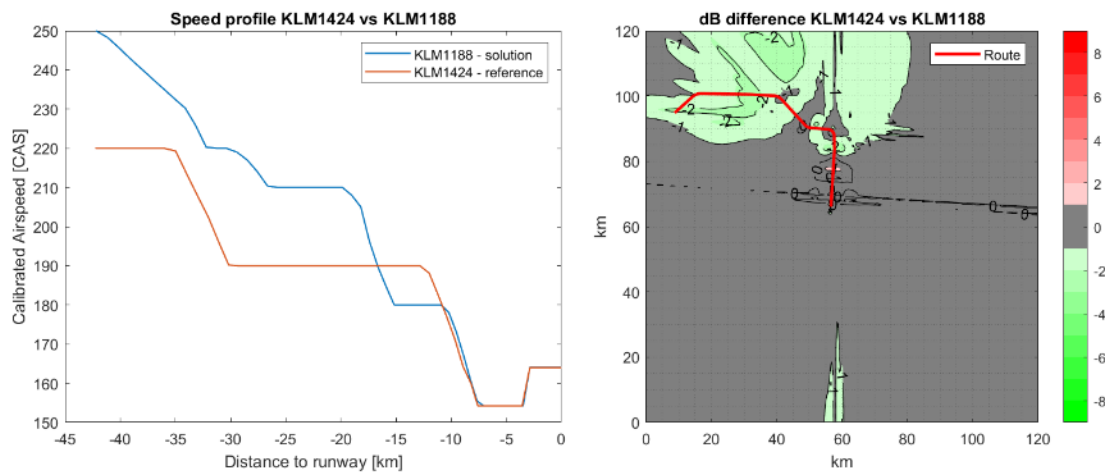


Figure 9 Speed [CAS] and Noise difference [delta_dB] plots between solution and reference flight (B39M aircraft type) on SUGOL_1Y transition

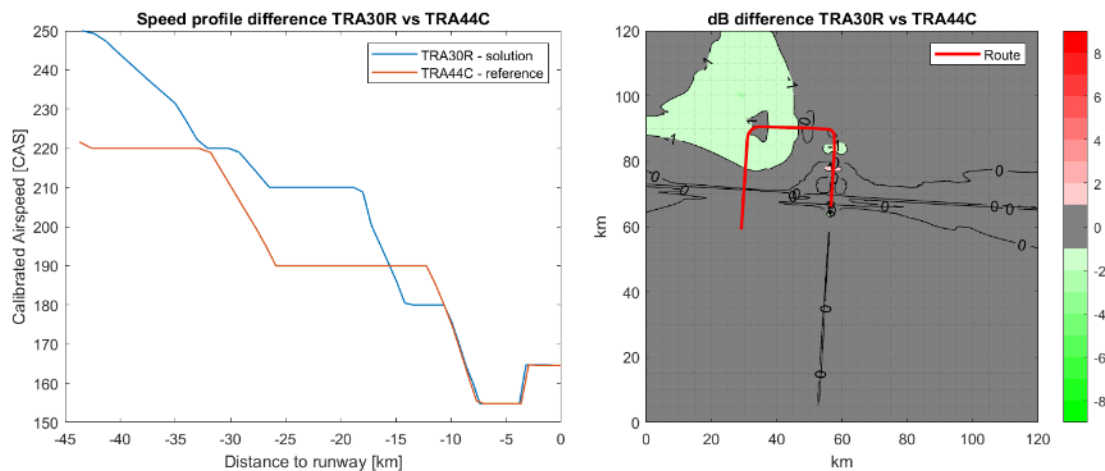


Figure 10 Speed [CAS] and Noise difference [delta_dB] plots between solution and reference flight (B38M aircraft type) on RIVER_1Y transition

These results indicate that noise exposure in areas surrounding the airport can be lowered by maintaining high speeds during the approach phase.

4.4.5.2 EXE-PJ.37-W3-002

Demonstration objective OBJ-37-W3-DEMOP-NOI1-0001 "The noise profile will not increase against the reference scenario" has been assessed as OK as the 55 dB noise contour area between the runs vary $\pm 1\%$ between the reference and solution runs. Differences are too small to conclude that the 55 dB noise contour area has improved or worsened.

In Table 15, the number of aircraft to be considered in the noise analysis are presented. To compare the different runs, only the flights that have been completed in the runs to be compared are evaluated. The traffic sample considered and their wake category in the analysis is presented in Table 16 to Table 18 and in Figure 11 and Figure 12. In addition, the 55dB noise contour areas of the different runs are compared. The results presents a difference of $\pm 1\%$ in the noise contour areas between the difference runs.

Run #	Nr of good flights – 18R	Nr of good flights – 18C	Flights considered in this analysis	WTC				55dB contour area [km ²]
				H	M	L	J	
1	29	26	54	10	43	0	1	505
3	28	27						509 (+0.8%)
4	29	26						505 (0%)

Table 22: OBJ-37-W3-DEMOP-NOI1-0001 55 dB noise contour areas for run #1, #3 and #4

Run #	Nr of good flights – 18R	Nr of good flights – 18C	Flights considered in this analysis	WTC				55dB contour area [km ²]
				H	M	L	J	
4	29	26	38	8	30	0	0	493
2	20	18						491 (-0.4%)

Table 23: OBJ-37-W3-DEMOP-NOI1-0001 55 dB noise contour areas for run #2 and #4

Run #	Nr of good flights – 18R	Nr of good flights – 18C	Flights considered in this analysis	WTC				55dB contour area [km ²]
				H	M	L	J	
8	29		29	1	28	0	0	346
9	31							350 (+1.2%)

Table 24: OBJ-37-W3-DEMOP-NOI1-0001 55 dB noise contour areas for run #8 and #9

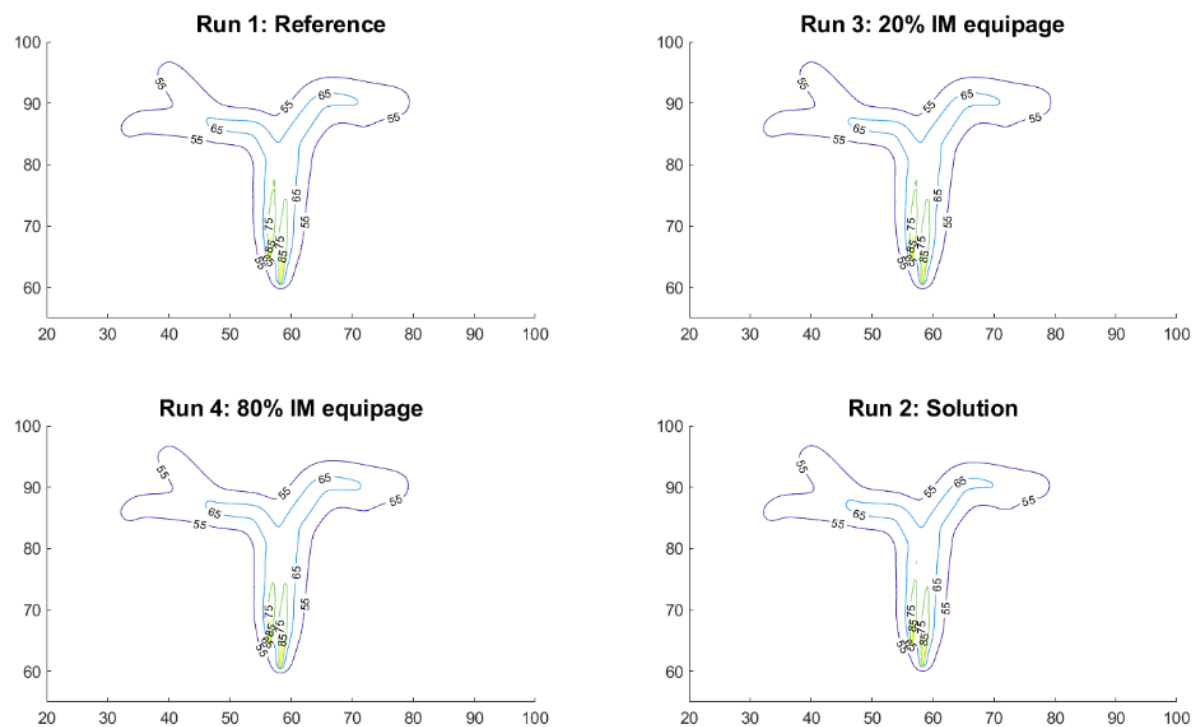


Figure 11: OBJ-37-W3-DEMOP-NOI1-0001 Lden noise contour areas for run #1 – #4 for 1 year of operation

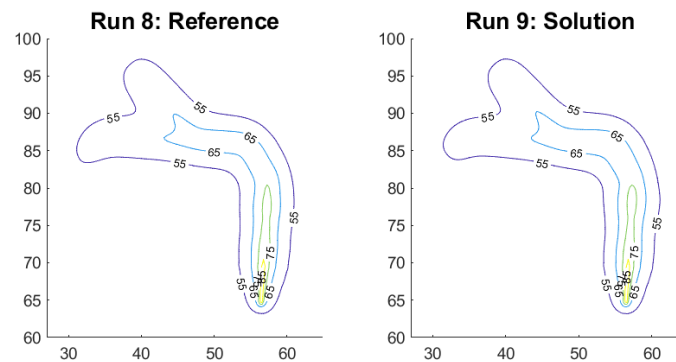


Figure 12: OBJ-37-W3-DEMOP-NOI1-0001 Lden noise contour areas for run #8 – #9 for 1 year of operation

To identify what caused the slight differences in noise contour areas, Figure 13 presents the noise level differences between simulation runs. In the figures, all differences between -1 and 1 dB are coloured grey, as these differences are minimal and can be disregarded as scenario specific. Red areas in the figures indicate that the second mentioned simulation run in the figure title shows higher noise levels, while green areas indicate lower noise levels. As noise levels are dependent on factors like altitude, speed, thrust, aircraft attitude and aircraft configuration it is not always, and especially for very small differences, clear what is the main contributor to that difference.

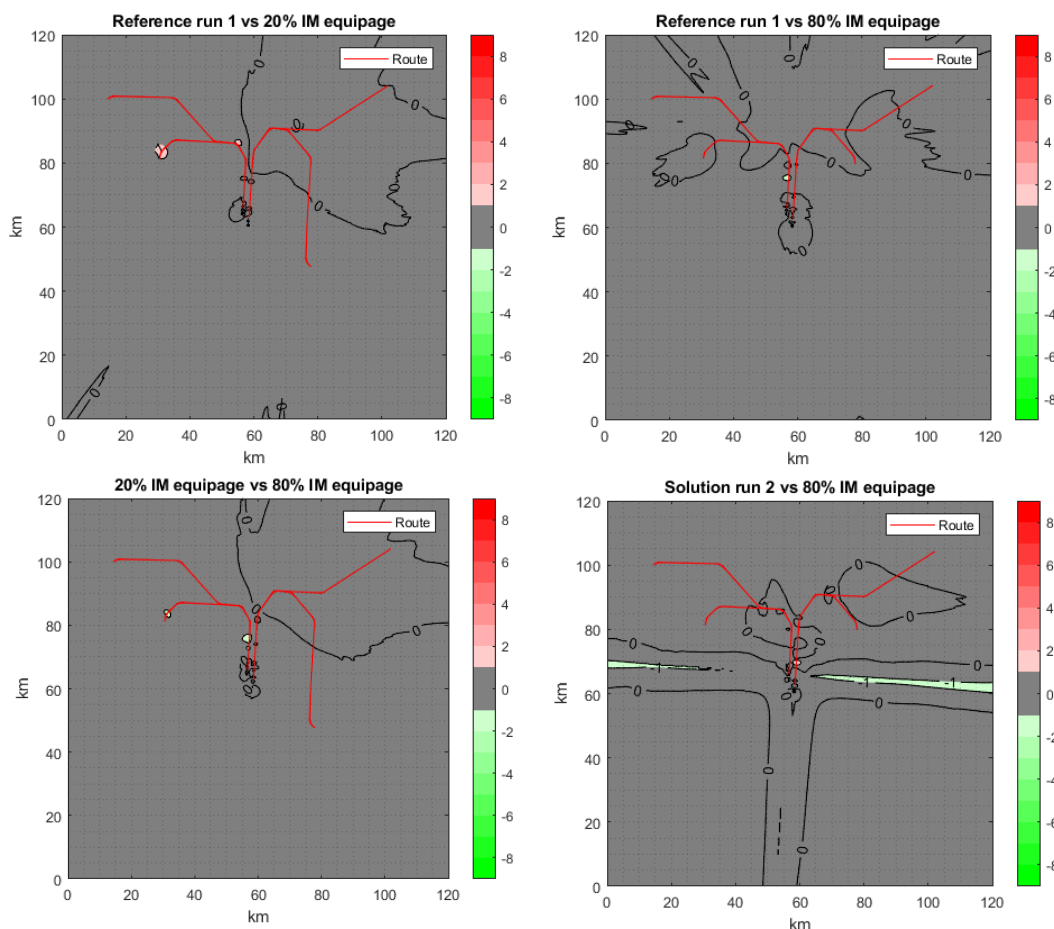


Figure 13 Noise difference [delta_dB] plots between run #1 - #4

Comparing reference run #1 and the 20% IM equipage run #3, only small differences arise, namely a 1-2 dB difference around the $x = 30$ km, $y = 85$ km coordinate. Overall speeds in the reference run are higher than in run #3. This means that in run #3 aircraft will be more likely to select higher flap settings at an earlier stage. With higher flap settings, aircraft usually need higher thrust settings to maintain speed, leading to locally elevated noise levels. When looking at the different altitude profiles, reference run #1 shows one level segment at the identified (x, y) coordinate. This could lead to somewhat higher noise levels at that point.

Comparing reference run #1 and the 80% IM equipage run #4, speeds for run #4 are somewhat higher than for run #3. This is the most probable reason that the difference around the $x = 30$ km, $y = 85$ km coordinate is less pronounced than with run #3.

Comparing 20% IM equipage run #3 and the 80% IM equipage run #4 the figure shows two small green areas where run #4 has lower noise levels. This also stems from the fact that speeds in run #4 are higher than for run #3.

Comparing the solution run #2 with 100% IM equipage and the 80% IM equipage run #4, run #4 has two areas of around 1 dB lower noise levels to the sides of the runway, where noise levels are already low. Right in front of the runway, where noise levels are higher, there is an area of 1 dB higher noise levels. Speeds in run #4 have more spread, but are mainly lower at the point where noise levels are elevated. Again due to lower speeds higher flap settings are triggered at an earlier point, giving rise to elevated noise levels.

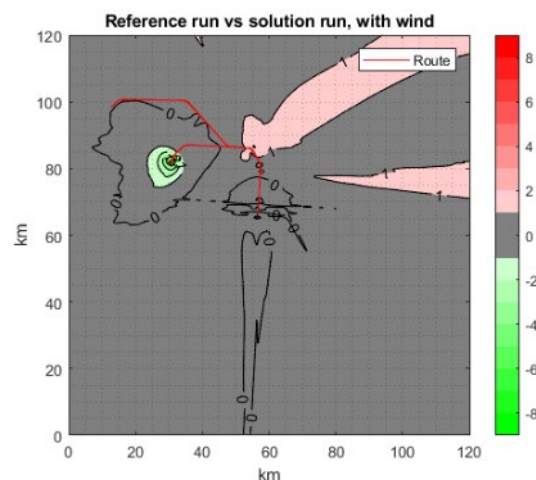


Figure 14 Noise difference [delta_dB] plots between run #8 - #9

Figure 14 shows the difference between reference run #8 and solution run #9 results. Both runs include strong headwind on final approach. Around the $x = 30$ km, $y = 80$ km coordinate, an area of 1-4 dB lower noise levels for the solution run against the reference run is found. This is due to an aircraft in the solution run flying a level segment and diverting somewhat from the normal route. The red areas, where the solution run had larger noise level than the reference run, are perpendicular to the two turns before ILS interception. Because speeds in the solution run #9 are much lower than in the reference run, flaps are selected at an earlier point, resulting in higher noise levels. The increased noise level experienced arise due to the aircraft turning and directing noise more outward. Also difference

in speed can result in differing bank angles. Due to differences in directivity of noise at different bank angles, local noise differences can occur. However noise differences are limited.

It can be concluded that differences between matching scenarios are limited. 55 Lden area differences are 1% or lower. Differences in local noise levels are also very limited. Most differences are between 0 and 1 dB, only few localized differences are between 1 and 2 dB and in one case a difference of 4 dB occurs. The 4 dB difference however was due to one flight that flew a level segment, while its counterpart in the matching scenario did not. This is not inherent to a certain IM equipage percentage. The few localized differences are most probably mainly due to speed differences between two scenarios. Aircraft having higher speeds require flap selections at a later moment along the route. With increased flap settings, drag increases and thus the need for more thrust, which results in higher noise levels.

4.5 Overall conclusion on the environmental impact of the Solution

Both exercises are Real-Time Simulations (RTS) with a focus on the safety and human performance aspects of the integrated solution. Thus a limited number of simulations have been performed. The outcome of this analysis will provide an indication of the impact of the integrated arrival solution. Fast-Time Simulations (FTS) evaluating a large number of scenarios is required to more accurately assess the impact of the integrated solution.

However, it can be concluded that due to CDO operations, which results in efficient vertical profiles, in combination with the FIM, which step-wise reduces aircraft speed while meeting the spacing goals, a positive effect is noticed on fuel usage.

At lower altitudes where noise is of importance, in case the aircraft performs their CDO profile as defined in combination with the fixed routes, no major differences are observed in the 55 dB noise contour areas. Few localized differences were identified but this is most probably caused by speed differences between simulation runs. Aircraft having higher speeds require flap selections at a later moment along the route. With increased flap settings, drag increases and thus the need for more thrust, which results in higher noise levels.

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