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PJ37-W3-ITARO

INTEGRATED TMA, AIRPORT AND RUNWAY OPERATIONS

This Demonstration Report (DEMOR) – Part I belonging to Contractual Deliverable D1.5, 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 the Demonstration Report (DEMOR-Part I), hence is the core part of the contractual deliverable (D1.5), of the SESAR 2020 project PJ37-W3-ITARO. This document comprises an overview of the executed '*VLD-like*' exercises in the project. It provides a comprehensive description of these exercises followed by an analysis of the results of exercises. Furthermore, based on the analysis, the objectives defined in the corresponding Demonstration Plan (Deliverable D1.4) [2] are reviewed and assessed.

The PJ37-W3-ITARO project combines two different innovation aspects. The first are the Very Large Demonstration '*VLD-like*' exercises as part of the Innovation Action (IA). The second aspect, resulting from the Industrial Research (IR)-part of the project, will be mentioned here for the sake of completeness only, but are further detailed in the complementary projects PJ.01-W2-08B and PJ.07-W2-39. The aim of these latter activities is to support further maturing of these particular Wave 2 SESAR Solutions.

The current version of the full DEMOR, that is composed of five different parts, consists of the Parts I, II, III, IV and V. Part I is the core text that provides an overview all exercises and SESAR Solutions involved, and provides results on the two RTS arrival demonstration exercises and the RNAV/RNP-CDO-IM Flight Trial (PJ.37-W3-01A) and the RTS departure demonstration exercise (PJ.37-W3-01B). Part II deals with the Safety aspects of the integrated Solutions, Part III covers the Human Performance, Part IV the Environmental Assessment and Part V the Performance Assessment.

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1 Executive summary

The present document constitutes the Demonstration Report (DEMOR)-Part I, i.e., the contractual deliverable D1.5, of the SESAR2020 project PJ37-W3-ITARO. This document comprises an overview of the executed ‘VLD-like’ exercises in the project. It provides a comprehensive description of these ‘exercises, followed by an analysis of the results of the exercises. Furthermore, based on the analysis, the objectives defined in the corresponding Demonstration Plan (Deliverable D1.4) [2] are reviewed and assessed.

The PJ37-W3-ITARO project combines two different innovation aspects. The first are the Very Large Demonstration ‘(VLD)-like’ exercises as part of the Innovation Action (IA). The second aspect, resulting from the Industrial Research (IR)-part of the project, will be mentioned here for sake of completeness only but further detailed in the complementary projects PJ.01-W2-08B and PJ.07-W2-39. The aim of these latter activities is to support further maturing these particular Wave 2 SESAR Solutions.

The executed ‘VLD-like’ exercises relate to the following Solution ‘tracks’:

- PJ.37-W3-01A ITARO Arrivals Solution track
 - Two RTS exercises relate to the integration of RNP-based arrival and approach operations, Interval Management (IM), Continuous Descent Operations (CDOs). These exercises include the Optimised Runway Delivery (ORD) tool, RECAT-EU-Pairwise Separations (PWS) and Runway Occupancy Time (ROT) related spacing impact. CDO and IM are generally initiated outside the TMA, CDOs preferably at the Top of Descent. Hence the further unification of arrival management will need an extended horizon, i.e., Extended-AMAN tool adaptation. Consequently, a precise delivery of aircraft into the terminal airspace is part of the exercises. In particular, controller aspects (e.g., Controller Working Position (CWP) HMI, working procedures, workload, acceptance) and ATC tool-integration were looked at during both RTSs, as well as assessing the impact on the environment. The work combined the SESAR Solutions PJ.01-05, PJ.02-01-01, PJ.02-01-04, PJ.02-08.03 with CDOs and RNP-based operations, and the overall aim was to achieve the maturity level TRL7 ongoing for the Solutions PJ.02-01-01, PJ.02-01-04 and PJ.02.08-03.
 - The previous mentioned RTSs were supported by a real-life flight demonstration that combined Interval Management, Continuous Descent Operations and RNP-based TMA operations, but mainly addressed from the cockpit perspective. The work combined the SESAR Solution PJ.01-05 with CDOs and RNP-based operations, and the overall aim was to achieve the V3 ongoing maturity level for PJ.01-05.
 - This solution track also aims to bring the development of the Dutch Airspace Redesign Programme (DARP) closer to deployment.
- PJ.37-W3-01B ITARO Departures Solution track
 - Another focus is on outbound traffic, on validating the operational feasibility of extending the Optimised Separation Delivery (OSD) tool for Departures with reduced and higher granularity non-wake separations which are dependent on the capacity of the TMA. Hence NATS and INDRA prepared for an RTS (integrated demonstration) on the Heathrow Tower simulator. Here the overall aim was to achieve the TRL7 ongoing maturity level.



The current version of the full DEMOR, that is composed of five different parts, consists of the Parts I, II, III, IV and V. Part I is the core text that provides an overview all exercises and SESAR Solutions involved, and provides results on the two RTS arrival demonstration exercises and the RNAV/RNP-CDO-IM Live Trial (PJ.37-W3-01A) and the RTS departure demonstration exercise (PJ.37-W3-01B). Part II deals with the Safety aspects of the integrated Solutions, Part III covers the Human Performance, Part IV the Environmental Assessment and Part V the Performance Assessment.



2 Introduction

2.1 Purpose of the document

This document constitutes the Demonstration Report (DEMOR)-Part I, hence is the core part of the contractual deliverable D1.5, of the SESAR2020 project PJ37-W3-ITARO. This document comprises an overview of the executed ‘VLD-like’ exercises as part in the project. It provides a comprehensive description of these exercises followed by an analysis of the results of exercises. Furthermore, based on the analysis, the objectives defined in the corresponding Demonstration Plan (DEMOP) [2] are reviewed and assessed.

2.2 Scope

This DEMO Report for SESAR2020 project PJ37-W3-ITARO describes the results and analysis of a number of ‘VLD-like’ exercises executed by NLR/DLR and NATS/INDRA. It details the demonstration objectives, success criteria, and the set-up of each exercise. This general part of the DEMOR (Part I) is supplemented by the parts on Safety Assessment (Part II), Human Performance Assessment (Part III), Environmental Assessment (Part IV) and Performance Assessment (Part V). These supplemental documents are developed for both the arrival (PJ.37-W3-01A) and departure (PJ.37-W3-01B) domain.

PJ37-W3-ITARO also performed validation activities to support two SESAR2020 Wave 2 Solutions (PJ.01-W2-08B and PJ.07-W2-39). The validation results for those complementary exercises are not described in this DEMO Report, but are included in the complementary projects PJ.01-W2-08B and PJ.07-W2-39.

The remainder of this document solely focusses on and therefore solely describes the ‘VLD-like’ demonstration activities and outcomes of PJ37-W3-ITARO.

2.3 Intended readership

The intended readers of this document are the PJ37-W3-ITARO team members working on the demonstration exercises, PJ37-W3-ITARO management, the SESAR3 Joint Undertaking: PJ.01 Wave 2 Project Coordinator and members, PJ.19 Content Integration, PJ.22 Validation and Demonstration Engineering, and PJ.20 Master Plan Maintenance.

2.4 Background

The individual SESAR Solutions that were combined in PJ37-W3-ITARO have been validated to either V2 or V3. This has been performed in various SESAR2020 Wave 1 projects, in particular SESAR2020 PJ.01 and SESAR2020 PJ.02. The combined SESAR Solution were validated in an environment based on a number of SESAR Solutions that were part of the Pilot Common Project (PCP), and therefore have been validated in SESAR1. This included PBN Operations in high-density terminal airspace, Time Based Separation (TBS) based on the recategorization of wake criteria (RECAT-EU), and Extended Arrival Management horizon (E-AMAN).

2.4.1 PJ.37-W3-01A ITARO Arrivals Solution Track

The PJ37-W3-01A ITARO Arrivals Solution track builds on previous work conducted in SESAR2020 Wave 2 PJ.01-05 and PJ.02-01-01, PJ.02-01-04 and PJ.02-08-03. Table 2-1 gives an overview of the addressed solutions in the PJ.37-W3-01A ITARO Arrivals Solution Track.

Solution	Description
PJ.01-05 ¹	Provides an airborne surveillance application Flight-deck Interval Management (FIM) aimed to sustain or increase runway throughput in a PBN-based terminal airspace environment, in which aircraft fly fixed approach routes from defined TMA entry fixes down to the landing runway.
PJ.02-01-01	Provides an ATC support tool to enable safe, consistent and efficient delivery of the required separation or spacing between arrival pairs on final approach to the runway threshold.
PJ.02-01-04	Provides an application of the efficient aircraft type pairwise wake separation rules for final approach. It consists of both the 103x103 aircraft type-based wake separation minima (for the most common aircraft in ECAC area) and the 20 wake category (20-CAT) based wake separation minima for arrival pairs involving all the remaining aircraft types.
PJ.02-08-03	Aims to reduce the in-trail separation on final approach with the aim of increasing runway throughput by taking into account the Runway Occupancy Time (ROT).

Table 2-1: Overview of the addressed solutions in the PJ.37-W3-01A ITARO Arrivals Solution Track.

All aforementioned PJ.02 solutions aimed to optimise separation schemes for arrivals in order to increase runway throughput through the application of Static Pairwise Wake Separations (S-PWS) and ROT, this ensemble of new minimum separation/spacing criteria is complemented by the ORD tool of PJ.02-01-01 to support the controller in safely and efficiently applying the new separation/spacing criteria. These SESAR solutions were combined for a first time and validated mainly through Real Time Simulations (RTS) in preparation of a future VLD. The solution track also aims to bring the development of the Dutch Airspace Redesign Programme (DARP) closer to deployment.

2.4.2 PJ.37-W3-01B ITARO Departures Solution Track

The PJ37-W3-01B ITARO Departure Solution track builds on previous work conducted in SESAR2020 Wave 1 and Wave 2 and can be split in to two parts: (1) Optimised Separation Delivery (OSD) tool support and (2) integration of TMA information into the eOSD tool through Tower Platform RTS. Table 2-2 gives an overview of addressed solutions for Optimised Separation Delivery (OSD) tool support.

¹ The solution is combined with a form of optimised descent operations, namely fixed profile descents

Solution	Description
PJ.02-01-02	Provides an Optimised Separation Delivery (OSD) tool, which uses information on when the lead aircraft is airborne to calculate the earliest airborne time for the follower aircraft for satisfying the wake separation scheme.

Table 2-2: Overview of the addressed solution(s) for extended Optimised Separation Delivery (eOSD) tool support.

The PJ.37-W3-01B ITARO Departures Solution track did incorporate a TMA data-feed to ensure that the optimised non-wake SID separations do not put an excessive demand onto TMA sectors.

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 are provided.
- Chapter 3 gives an overview of the Very Large Demonstration ('VLD-like'). In this chapter the scope is set by the SESAR Solution(s) addressed in this 'VLD-like' project. Furthermore, this chapter provides a summary of Demonstration Plan and the operating method that is validated in the demonstrations.
- Chapter 4 presents the demonstration results. A summary of demonstration results is given followed by a detailed analysis per demonstration objective. This chapter concludes with a statement on the confidence in results of demonstration exercises.
- Chapter 5 gives an overview of conclusions and recommendations based on the results of demonstration exercises. The recommendations relate to (for example) industrialization and deployment, regulation and standardisation initiatives, and updates for the ATM Master Plan L2.
- Chapter 6 gives a summary on the Communications and Dissemination activities addressed by this 'VLD-like' project.
- Chapter 7 provides an overview of referenced documents.
- The Appendices give a report per demonstration exercise.

2.6 Glossary of terms

Term	Definition	Source of the definition
Arrival Manager (AMAN)	A planning system to improve arrival flows at one or more airports by calculating the optimised approach / landing sequence and Target Landing Times (TLDT) and, where needed, times for specific fixes for each flight, taking multiple constraints and preferences into account.	SESAR CONOPS 2019 [1]

Assigned Spacing Goal	The time or distance interval between the IM aircraft and target aircraft assigned by the air traffic controller as part of the IM operation. The assigned spacing goal is determined by the air traffic controller issuing the IM clearance and the type and value(s) of the assigned spacing goal are selected to achieve the air traffic controller's goal of establishing an efficient flow while maintaining separation from all traffic.	ICAO Doc 9994 Manual on Airborne Surveillance Applications
Continuous Descent Operation (CDO) Optimised Descent Profile (ODP)	An operation, enabled by airspace design, procedure design and ATC facilitation, in which an arriving aircraft descends continuously, to the greatest possible extent, by employing minimum engine thrust, ideally in a low drag configuration, prior to the final approach fix /final approach point. Note 1 - An optimal CDO/ODP starts from the top of descent and uses descent profiles that minimize non predicted segments of level flight, specifically at constant speed, to reduce noise, fuel burn, emissions and controller/pilot communications, while increasing predictability to pilots and controllers and flight stability. Note 2 - A CDO/ODP initiated from the highest possible level in the en-route or arrival phases of flight will achieve the maximum reduction in fuel burn, noise and emissions.	ICAO Doc 9931 CDO Manual
Extended (E-TMA) TMA	Describes the airspace encompassing both the TMA and the airspace beyond, which has been designed to service the need for a seamless transition between the TMA and FRA (and vice versa).	SESAR CONOPS 2019 [1]
Extended Separation (eOSD) Optimised Delivery	Extended version of the Optimised Separation Delivery tool developed in PJ.02-01-02 to provide support to the Tower Runway Controller for the application of refined, more granular route spacings on departure, as well as wake turbulence separations.	
Fixed Profile Descent (FPD)	A descent profile normally associated with a published standard instrument arrival (STAR) and initial and intermediate segments of a published instrument approach procedure (IAP), and designed to allow maximum practical use of a CDO. The descent profile is comprised of geometric	

	descent profile segments that maximize altitude, minimize thrust required to remain on the path, terminate the path at the desired end location and satisfy the altitude and vertical angle restrictions along the closed path design. Note – FPD is one method of facilitating CDO.	
IM aircraft	An aircraft approved by the State of the Operator that is equipped with FIM Equipment that is instructed to perform an IM Operation.	ICAO Doc 9994 Manual on Airborne Surveillance Applications
Optimised Profile Descent (OPD)	A descent profile normally associated with a published arrival (STAR) and designed to allow maximum practical use of a CDO. It starts from top of descent, taking into consideration the limitations of the local airport, airspace and environment, traffic and aircraft capabilities, and ATC. To the extent possible the descent profile is comprised of idle-power performance descent profile segments and geometric descent profile segments that maximize altitude, minimize thrust required to remain on the path, terminate the path at the desired end location and satisfy the altitude and speed constraints along the closed path design. Note – OPD is one method of facilitating CDO.	ICAO Doc 9931 CDO Manual
Pair Wise Separation (PWS)	Procedure designed for use between arrivals on final approach or between departures from the runway, based on an optimum adjusting of the needed separation between two aircraft taking into account their respective characteristics and giving Controllers more dynamic separation options.	SESAR CONOPS 2019 [1]
Performance Based Navigation (PBN)	Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace. Note.— Performance requirements are expressed in navigation specifications in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept	ICAO Doc 9613 PBN Manual

Systemised Airspace Management (SYSMAN)	Based on the iACM (Indra Airspace Capacity Manager), the product that aims to help ANSPs to adapt demand and capacity strategically, enabling ANSPs to optimize operational and environmental performances, the SYSMAN “Systemised Airspace Manager” prototype is an extension with new functionality aiming at the balancing of demand among routes on a Systemised airspace.	
Target aircraft	A designated aircraft from which the IM aircraft achieves and/or maintains an assigned spacing goal.	ICAO Doc 9994 Manual on Airborne Surveillance Applications

Table 2-3: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
4D	Four Dimensional
A/C	Aircraft
ABI	Advance Boundary Information (message)
ABP	Achieve-by Point
ACC	Area Control Centre
A-CDM	Airport Collaborative Decision Making
ACE	ATC Cost Efficiency
ACM	Airspace Capacity Manager
ACPO	Aircraft Control Position Officer
ACT	Activation (message), Acceptability
ADI	Average Departure Interval
ADIS	Airport Display Information System
ADS-B	Automatic Dependent Surveillance - Broadcast
AF	ATM Functionality
AIP	Aeronautical Information Publication
AMAN	Arrival Manager
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
AO	Aerodrome Operations (EATMA Capability)

AOM	Airspace Organisation and Management (EATMA Capability)
APP	Approach Controller
AROT	Arrival Runway Occupancy Time
ARR	Arrival Controller
ASA	Airborne Surveillance Application(s)
ASAS	ASA System
A-SMGCS	Advanced Surface Movement Guidance and Control System
ASPA	Airborne Spacing
ASS	Assumption
ASTAR	Airborne Spacing for Terminal Arrival Routes
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATE	Air Traffic Engineer
ATM	Air Traffic Management
AU	Airspace User
BADA	Base of Aircraft Data
BD/ML	Big Data/Machine Learning
CAP	Capacity
CAT	Category
CDE	Communication, Dissemination and Exploitation
CDO	Continuous Descent Operation
CFT	Customer Functionality Test
CMS	Central Maintenance Services
CO2	Carbon dioxide
CONOPS	Concept of Operations
CP1	Common Project One
CRT	Criteria
CTC	NATS Corporate and Technical Centre
CTOT	Calculated Take-Off Time
CTR	Controlled Traffic Region (aka Control Zone)
CWP	Controller Working Position
DARP	Dutch Airspace Redesign Programme

DCB	Demand and Capacity Balancing
DDI-D	Dynamic Departure Indicator - Distance
DDI-T	Dynamic Departure Indicator - Timer
deg	degree(s)
DEMOP	Demonstration Plan
DEMOR	Demonstration Report
DMAN	Departure Manager
E-AMAN	Extended Arrival Management
EASA	European Union Aviation Safety Agency
EAT	Expected Approach Time
EATMA	European ATM Architecture
EC	European Commission
ECAC	European Civil Aviation Conference
EFB	Electronic Flight Bag
EFPS	Electronic Flight Progress Strip
EoP	End of Participation
EoR	End of Run
EOR	Established On RNP
eOSD	extended Optimised Separation Delivery
ER/APP	En-Route/Approach
ESA	European Space Agency
E-TMA	Extended TMA
ETO	Estimated Time Over
EU	European Union
EXE	Exercise
FAF	Final Approach Fix
FAR	Fixed Approach Route
FATO	Final Approach and Take-Off Area
FDE	Flight Data Entry
FIM	Flight-deck Interval Management
FIR	Flight Information Region
FL	Flight Level

FLE	Flight Efficiency
FMP	Flow Management Position
FMS	Flight Management System
FPD	Fixed Profile Descent
FRA	Free Route Airspace
FT	Flight Trial
ft	foot (feet)
GA	Go-Around
GBAS	Ground Based Augmentation System
GLS	GBAS Landing System
GMC	Ground Movement Controller
GND	Ground
GNSS	Global Navigation Satellite System
GS	Group Supervisor
HF	Human Factors
HLOR	High Level Operational Requirements
HMI	Human Machine Interface
HP	Human Performance
hPa	hectopascal(s)
HUP	Human Performance
IA	Innovation Action
iACM	INDRA's Airspace Capacity Manager
IAF	Initial Approach Fix
IBP	Industrial Based Platform
ICAO	International Civil Aviation Organization
ID	Identification
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IM	Interval Management
INTEROP	Interoperability Requirements
IR	Industrial Research
ITARO	Integrated TMA, Airport and Runway Operations

KIAS	Knots Indicated Airspeed
km/h	kilometres per hour
KPA	Key Performance Area
KPI	Key Performance Indicator
kt	knot(s)
Lat	Latitude
LHR	London Heathrow
LOA	Letters of Agreement
Long	Longitude
LOS	Loss of Separation
LPV	Localizer Performance with Vertical Guidance
LSS	Large Scale Shakedown
MDI	Minimum Departure Interval
MDT	Manned Data Test
MET	Meteorological
min	minute(s)
MM:SS	minutes:seconds
MOPS	Minimum Operational Performance Standards
MR	Metric Requirement
MRS	Minimum Radar Separation
MTOW	Maximum Take-Off Weight
N/A	Not Applicable
NARSIM	NLR ATC Research Simulator
NBAT	Not Before Airborne Time
NM	Nautical Mile(s)
OBJ	Objective
OI	Operational Improvement
OIM	Operational Instructions Manual
OPF	Operational Feasibility
ORD	Optimised Runway Delivery
OSD	Optimised Separation Delivery
OSD	Operational Services and Environment Definition

PANS-ATM	Procedures for Air Navigation Services - Air Traffic Management
PBN	Performance Based Navigation
PCP	Pilot Common Project
PER	Performance
PinS	Point-in-Space
PRD	Predictability
PRO	Procedure
PTP	Planned Termination Point
PUN	Punctuality
PWS	Pair Wise Separation
PWS-D	Pair Wise Separation for Departures
Q'naire	Questionnaire
QNH	Q-code Nautical Height (height above sea level)
R&D	Research and Development
R/T	Radiotelephony
RECAT	Re-categorisation
REF	Reference
REG	Regulation
RF	Radius-to-Fix
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP APCH	RNP Approach
RNP AR APCH	RNP Authorization Required Approach
ROT	Runway Occupancy Time
RPAS	Remotely Piloted Aircraft System
RRS	Reduced Runway Separation
RSP	Required Surveillance Performance
RSVA	Reduced Separation in the Vicinity of the Aerodrome
RTS	Real Time Simulation
RWY	Runway
s	second(s)
SAF	Safety

SA	Situational Awareness
SASHA	Situation Awareness for SHAPE (Eurocontrol HP repository)
SBAS	Satellite Based Augmentation System
SDO	Stepped Descent Operation
sec	second(s)
SESAR	Single European Sky ATM Research Programme
Sep	Separation
SID	Standard Instrument Departure
SIM	Simulator
S3JU	SESAR3 Joint Undertaking (Agency of the European Commission)
SOL	Solution
SPR	Safety and Performance Requirements
S-PWS	Static Pair Wise Separation
SQEP	Suitable Qualified Experienced Personnel
SSE	Safety Significant Events
STAR	Standard Instrument Arrival
STO	Simulation Training Officer
SUT	System Under Test
SYSMAN	Systemised Airspace Management
TA	Transversal Area
TBC	To Be Confirmed
TBD	To Be Determined
TBO	Trajectory Based Operations
TBS	Time Based Separation
TDI	Target Distance Indicator
TEAM	Tactical Enhanced Arrival Mode
TLDT	Target Landing Time
TLOR	Top Level Operational Requirements
TMA	Terminal Control Area (aka Terminal Manoeuvring Area)
TOC	TMA-Oost Controller
TOD	Top of Descent
TP	Trajectory Prediction

TRL	Technology Readiness Level
TS	Traffic Synchronisation (EATMA Capability)
TSAT	Target Start-Up Approval Time
TSC	Touch Screen Controller (an avionics-grade display)
TTOT	Target Take-Off Time
TWEC	TMA-West Controller
TWR	Tower
UAC	Upper Area Control Centre
UCO	Under Control
UDPP	User Driven Prioritisation Process
UDT	Unmanned Data Test
V&V	Verification and Validation
VALP	Validation Plan
VALR	Validation Report
VFR	Visual Flight Rules
VLD	Very Large Demonstration
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VOIP	Voice over Internet Protocol
VS	Vertical Separation
WDS	Weather Dependent Separation
WT	Wake Turbulence
WTC	Wake Turbulence Category
WTS	Wake Turbulence Separation
XMAN	Cross-border Arrival Management

Table 2-4: List of acronyms

3 Very Large Demonstration (VLD) Scope

In the scope of the VLD-like PJ37-W3-ITARO activities Real-Time Simulations were performed for both departure as well as the arrival domain, of an ensemble of SESAR Solutions, which were individually developed to maturity level V2 or V3, but were not validated when integrated together in a realistic environment. Furthermore, a flight trial was executed to further validate aircraft/avionics aspects of Flight-deck Interval Management (FIM) in relation with TMA Fixed Approach Routes (FAR) and Fixed Profile Descents (a form of Optimised Descent Operations).

3.1 Very Large Demonstration Purpose

The aim of the Real-Time Simulations which were performed for both the arrival and departure domains was to validate the integration of a system of combined, individually validated SESAR Solutions. One of the aims of the 'VLD-like' activities was to prepare for a future VLD related to the integration of the SESAR solutions under investigation.

For the arrival domain, Amsterdam Airport Schiphol and the Dutch FIR was chosen as it is a very high-density airport and airspace. This environment is deemed credible to validate the integration of several arrival-related SESAR Solutions. Furthermore, it is in line with the development and deployment plans of the Dutch Airspace Redesign Programme (DARP).

For the departure domain, London Heathrow airport and the London TMA airspace environment were chosen for the same reasons.

The technologies in the test environment for the reference scenario were based on already introduced (typically by NATS) or near-term introduction of technologies, in particular Time-Based Separation, RECAT-EU, PBN operations in busy TMA, Extended AMAN horizon and Optimised Separation Delivery tool.

3.2 SESAR Solution(s) addressed by VLD

The SESAR solutions that have been demonstrated in PJ.37-W3-ITARO and their respective operational improvements (OIs) under demonstration by PJ.37-W3-01A (arrivals solutions) are given in Table 3-1 and by PJ.37-W3-01B (departures solutions) in Table 3-2. The tables present a subset of enablers associated with the OI Steps which are of relevance for the demonstrations. Optional enablers are not addressed to limit the scope of the exercises, for example the use of data link in TS-0108 (enablers A/C-31a, AGDL-STD-01 and APP-ATC-144) is not relevant for a TMA environment. Furthermore, for PJ.37-W3-01A (arrivals solutions) the integration focusses on the APP controllers, no integration aspects related to tower controllers were anticipated, therefore the enablers related to tower controllers are not addressed (e.g., enabler AERODROME-ATC-68 for AO-0328).

The descriptions of the solutions and OIs were extracted from SESAR EATMA Dataset DS23 Draft.

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
PJ.01-05 Airborne Spacing Flight-deck Interval Management	Airborne spacing flight-deck interval management refers to new Interval Management (IM) operations involving more complex geometries where a designated target aircraft may not be flying direct to the merge point.	TS-0108 Airborne Spacing Flight-deck Interval Management (ASPA FIM)	A/C-15b (Develop) Aircraft functions for Interval Management
			A/C-48a (Use) Air broadcast of aircraft position/vector (ADS-B OUT) compliant with DO260B
			A/C-67 (Use) ADS-B IN
			APP ATC 61 (Develop) Ground functions for Interval Management
			ASAS-STD-02 ICAO provisions for Interval Management
			HUM-002 (Develop) Human factors flight crew – Interval Management
PJ.02-01-01 Optimised Runway Delivery (ORD) on Final Approach	The solution is an ATC support tool to enable safe, consistent and efficient delivery of the required separation or spacing between arrival pairs on final approach to the runway landing threshold.	AO-0328 Optimised Runway Delivery (ORD) on Final Approach	HUM-003 (Develop) Human factors ATCOs – Interval Management
			APP ATC 120 (Develop) Approach ATC System to support Optimised Runway Delivery on Final Approach
			APP ATC 156 (Optional) ATC System to Support Time-Based Separation in Final Approach
			APP ATC 169 (Optional) Approach ATC System to support Optimised Runway Delivery on Approach based on Aircraft ROT categorisation
			APP ATC 99 (Use) ATC System to use Real-Time Meteo Information

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
			Received From Met Systems
PJ.02-01-04 Wake Turbulence Separations (for Arrivals) based on Static Aircraft Characteristics	The solution consists of the efficient aircraft type pairwise wake separation rules for final approach. It consists of both the 103x103 aircraft type-based wake separation minima (for the most common aircraft in ECAC area) and the 20 wake category (20-CAT) based wake separation minima for arrival pairs involving all the remaining aircraft types.	AO-0306 Static Pairwise Separations (S-PWS) for Arrivals	APP ATC 118 (Develop) ATC System to support static pair-wise wake separation (S-PWS) on approach REG-0523 (Develop) Regulatory provisions (AMC) for static pair-wise separation minima (S-PWS) AERODROME-ATC-42a (Develop) Airport ATC tool to support static pair-wise wake separation (S-PWS) in final approach
PJ.02-08-03 Increased Runway Throughput based on local ROT characterization.	The solution intends to reduce the in-trail separation on final approach with the aim of increasing runway throughput by taking into account the Runway Occupancy Time (ROT).	AO-0337 Increased Runway Throughput based on local ROT characterization	APP ATC 169 (Develop) Approach ATC System to support Optimised Runway Delivery on Approach based on Aircraft ROT categorisation AERODROME-ATC-55 (Use) Airport ATC analyser tool for predicting ROT

Table 3-1: SESAR Solution(s) under Demonstration PJ.37-W3-01A, extracted from EATMA Dataset

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)
PJ.02-01-02 Optimised spacing delivery for departure	OSD is the ATC support to enable safe, consistent and efficient delivery of the required separation or spacing between departure pairs from the follower aircraft becoming airborne.	AO-0329² Optimised Separation Delivery for Departure	AERODROME-ATC-69 (Develop) ATC system to support optimised departure separation

Table 3-2: SESAR Solution(s) under Demonstration PJ.37-W3-01B, extracted from EATMA Dataset

The following solutions and/or Operational Improvements (OI) have been identified to be part of the Reference Scenario for the exercises related to PJ.37-W3-01A in Table 3-3, as these were developed in SESAR 1 and/or are part of the Pilot Common Project (PCP), which has been superseded by the Common Project One (CP1). Table 3-4 presents solutions which are both part of the reference as well as the solution scenario. The current implementations of Time Based Separation (TBS) and more refined wake turbulence categories (RECAT-EU) include an Optimised Runway Delivery (ORD) tool, therefore the ORD tool itself is also implemented in the reference scenario. As the currently implemented ORD tools already consider Runway Occupancy Times (ROT), PJ.02-08-03 is also included in the reference scenario. Summary Table 3-6 provides an overview of the OI steps that were further validated in PJ.37.

SESAR Solution in Reference Scenario for PJ.37-W3-01A	OI step
#5 Extended Arrival Management (E-AMAN) horizon	TS-0305-A Arrival Management Extended to En-Route Airspace - single TMA
N/A Re-CATegorisation (RECAT-EU)	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 ³ transition to ILS/GLS/LPV

² Elements within this OI are being used and the scope is being broadened in order to obtain maximum performance benefits in this VLD-like activity.

³ RNP refers as well to the usage of Fixed Approach Routes (FAR) with a fixed profile descent

SESAR Solution in Reference Scenario for PJ.37-W3-01A		OI step
#64		AO-0303
Time Based Separation (TBS)		Time Based Separation for Final Approach - full concept

Table 3-3: Solutions and/or operational improvements which are part of the reference scenario for integrated solution-PJ.37-W3-01A, related to the CP1 AF-1 and AF-2 functionalities. These solutions are extracted from SESAR 1 and/or the PCP/CP1.

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

Table 3-4: Solutions which are part of the reference and solution scenario for integrated solution-PJ.37-W3-01A.

The following solutions and/or operational improvements (OI) have been identified to be part of the Reference Scenario for the exercises related to PJ.37-W3-01B. The OIs are assumed to be in place and no further maturing of those OIs are anticipated. PJ.02-01-02 in its basic form is included in the reference scenario, whereas the extensions to the (basic) OSD tool are part of the solution scenario (eOSD tool).

SESAR Solution in Reference Scenario for PJ.37-W3-01B		OI step
PJ.02-01-02		AO-0329 ⁴
		Optimised Separation Delivery for Departure
PJ.02-01-06		AO-0323
		S-PWS
Re-CATegorisation (RECAT-EU)		AO-0326
		Optimisation of Separation Minima on Approach and Departure thanks to European Wake Turbulence Categorisation (RECAT EU)

Table 3-5: Solutions and/or operational improvements which are part of the reference scenario for integrated solution-PJ.37-W3-01B.

⁴ Elements within this OI are being used and the scope is being broadened in order to obtain maximum performance benefits in this VLD-like activity.

OI step	Current Maturity Level	Target Maturity Level
TS-0108 Airborne Spacing Flight-deck Interval Management (ASPA FIM)	V2	V3 ongoing
AO-0328 Optimised Runway Delivery (ORD) on Final Approach	V3	TRL7 ongoing
AO-0306 Static Pairwise Separations (S-PWS) for Arrivals	V3	TRL7 ongoing
AO-0337 Increased Runway Throughput based on local ROT characterization	V3	TRL7 ongoing
AO-0329 Optimised Separation Delivery for Departure	V3	TRL7 ongoing

Table 3-6: Current and target OI step maturity level.

3.2.1 Deviations with respect to the SESAR Solution(s) definition

No deviations of the SESAR Solutions, which have been tested, were needed for the demonstration activities.

One of the main purposes of the integrated demonstration activities was to identify whether, if any, requirements need to be adapted, added or deleted for the individual SESAR Solutions. This will be reported in Chapter 5 of this DEMOR.

3.3 Summary of Demonstration Plan

The PJ37-W3-ITARO project contains four different demonstration exercises that were executed within PJ37-W3-ITARO. An overview of the PJ37-W3-ITARO work packages, solutions, exercises, and coupling to external SESAR H2020 Wave 2 projects is provided in Table 3-7. The sections hereafter address the PJ.37-W3-01A - Arrival Operations and PJ.37-W3-01B - Departure Operations.

Work Package (WP)	Solution to be validated	Exercise ID	Description	OI's to be validated in exercise
WP02	PJ.37-W3-01A	EXE-PJ.37-W3-001	NLR real time simulation 1 for the integrated arrival management process solution, for the Schiphol TMA operations .	AO-0306 (S-PWS) AO-0328 (ORD) AO-0337 (ROT) TS-0108 (FIM)
		EXE-PJ.37-W3-002	NLR real time simulation 2 for the integrated arrival management process solution, for the Schiphol TMA operations .	AO-0306 (S-PWS) AO-0328 (ORD) AO-0337 (ROT) TS-0108 (FIM)
		EXE-PJ.37-W3-003	NLR flight test to validate interval management, combined with CDO and FAR	TS-0108 (FIM)

Work Package (WP)	Solution to be validated	Exercise ID	Description	OI's to be validated in exercise
	PJ.37-W3-01B	EXE-PJ.37-W3-004	NATS real time simulation for the integrated departure management process solution	AO-0329 (OSD)

Table 3-7: PJ37-W3-ITARO exercises overview including relevant solutions per exercise.

3.3.1 PJ.37-W3-01A - Arrival Operations

3.3.1.1 Demonstration Plan Purpose

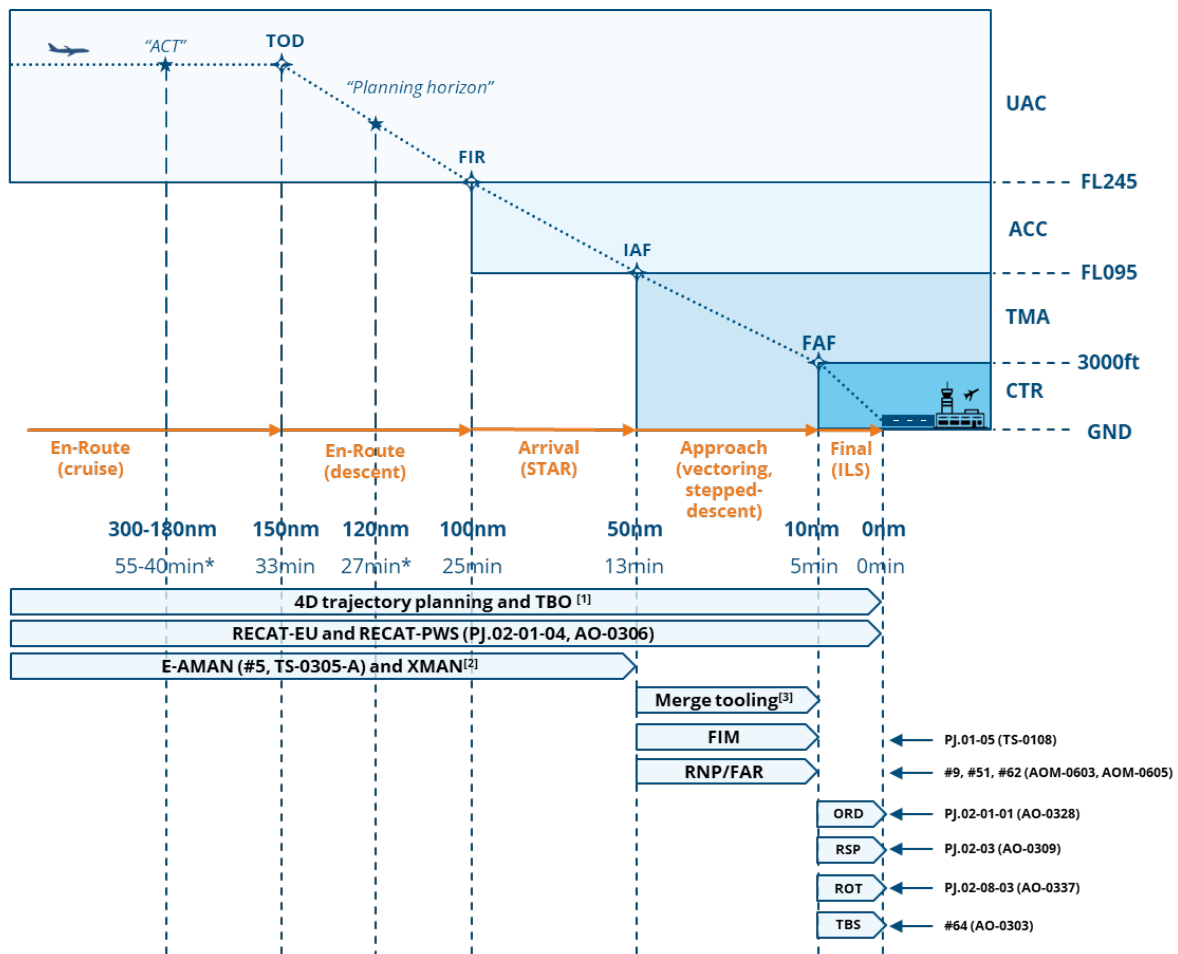
The purpose of solution track PJ.37-W3-01A is to demonstrate the benefits of integrated TMA and runway throughput solutions. This was demonstrated via three different exercises; two sets of Real-Time Simulation (RTS) activities and a flight trial (FT), namely:

- EXE-PJ.37-W3-001 relates to RTS1 for PJ.37-W3-01A and aims to test the integrated applicable SESAR solutions within PJ.37-W3-01A for the Schiphol Terminal Manoeuvring Area (TMA). The RTS was performed on the NLR's Air traffic management Real-time SIMulator (NARSIM).
- EXE-PJ.37-W3-002 relates to RTS2 for PJ.37-W3-01A and aims to test the integrated applicable SESAR solutions within PJ.37-W3-01A also for the Schiphol TMA. The RTS was performed on NARSIM.
- EXE-PJ.37-W3-003 relates to the flight trial for PJ.37-W3-01A and aims to live-test the integrated applicable SESAR solutions within PJ.37-W3-01A with an in-flight aircraft pair. The flight trial was done with research aircraft from NLR and DLR.

The Real-Time simulations were executed at the NLR premises in Amsterdam using the NLR's Air traffic management Real-time SIMulator (NARSIM) augmented with SESAR solution technologies.

3.3.1.2 Operating method description

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 7-1, 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 3-1: 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.

Since E-AMAN, TBS, RECAT-EU, RNP, and FARs with a fixed descent profile are already part of the reference scenario, most of the required infrastructure for the solution scenario is already present in the reference scenario. The introduction of IM and ORD, 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).

3.3.1.3 Summary of Demonstration Objectives and success criteria

See DEMO Plan section 4.4.1, entitled "PJ.37-W3-01A – Arrival operations". This section provides the demonstration objectives and criteria grouped by themes like acceptability objectives, human performance objectives, operational feasibility objectives, performance objectives and safety objectives.

3.3.1.4 Demonstration Assumptions

See DEMO Plan section 4.5.1, entitled " PJ.37-W3-01A – Arrival operations". This section provides the demonstration assumptions for the Arrival exercises EXE-PJ.37-W3-001, EXE-PJ.37-W3-002, and EXE-PJ.37-W3-003.

3.3.1.5 Demonstration Exercises List

3.3.1.5.1 EXE-PJ.37-W3-001

[EXE]

Identifier	EXE-PJ.37-W3-001
Title	Real time simulation 1 for the integrated arrival management process solution for the Schiphol TMA operations
Description	To validate the SESAR Solutions RECAT-PWS/ROT (Wave 1 PJ02-01-04 and PJ02-08-03), IM (Wave 1 PJ.01-05), and ORD tool extended on RNP routes (Wave 1 PJ.02-01-01) in an integrated concept of operations, which also encompasses SESAR 1 / PCP Solutions (such as Extended Arrival Management horizon (#05), Time-Based Separation (#64), RECAT-EU and Enhanced Terminal Airspace using RNP Based Operations(#62, #09, #51)) within the TMA.
Demonstration Technique	Real Time Simulation (RTS)
KPA/TA Addressed	<Human Performance> <Capacity> <Operational Efficiency> <Environment> <Safety>
Number of flights	
Start Date	14 January 2022
End Date	18 February 2022
Demonstration Coordinator	NLR
Demonstration Platform	The NLR ATC Research Simulation facility (NARSIM)
Demonstration Location	Amsterdam
Status	<Completed>
Dependencies	No on-going project dependencies

[EXE Trace]

Linked Element Type	Identifier
<SESAR Solution>	Wave 1 PJ02-01-04
<SESAR Solution>	Wave 1 PJ02-08-03
<SESAR Solution>	Wave 1 PJ.01-05
<SESAR Solution>	Wave 1 PJ.02-01-01
<Demo Objective>	OBJ-37-W3-DEMOP-HUP1-0003 OBJ-37-W3-DEMOP-HUP1-0004 OBJ-37-W3-DEMOP-HUP1-0005 OBJ-37-W3-DEMOP-HUP1-0006 OBJ-37-W3-DEMOP-HUP1-0007 OBJ-37-W3-DEMOP-HUP1-0008 OBJ-37-W3-DEMOP-HUP1-0009 OBJ-37-W3-DEMOP-HUP1-0010 OBJ-37-W3-DEMOP-HUP1-0011 OBJ-37-W3-DEMOP-HUP1-0012 OBJ-37-W3-DEMOP-HUP1-0013 OBJ-37-W3-DEMOP-HUP1-0014 OBJ-37-W3-DEMOP-HUP1-0015 OBJ-37-W3-DEMOP-CAP1-0001 OBJ-37-W3-DEMOP-CAP1-0002 OBJ-37-W3-DEMOP-PRD1-0001 OBJ-37-W3-DEMOP-NOI1-0001 OBJ-37-W3-DEMOP-ENV1-0001 OBJ-37-W3-DEMOP-SAF1-0001 OBJ-37-W3-DEMOP-SAF1-0003 OBJ-37-W3-DEMOP-SAF1-0004 OBJ-37-W3-DEMOP-SAF1-0005

Table 3-8: EXE-PJ.37-W3-001

3.3.1.5.2 EXE-PJ.37-W3-002

[EXE]

Identifier	EXE-PJ.37-W3-002
Title	Real time simulation 2 for the integrated arrival management process solution for the Schiphol TMA environment.
Description	To validate the SESAR Solutions RECAT-PWS/ROT (Wave 1 PJ02-01-04 and PJ02-08-03), IM (Wave 1 PJ.01-05), and ORD tool extended on RNP routes (Wave 1 PJ.02-01-01) in an integrated concept of operations, which also encompasses SESAR 1 / PCP Solutions (such as Extended Arrival Management horizon (#05), Time-Based Separation (#64), RECAT-EU and Enhanced Terminal Airspace using RNP Based Operations(#62, #09, #51)) within the TMA.
Demonstration Technique	Real Time Simulation (RTS)
KPA/TA Addressed	<Human Performance> <Capacity> <Operational Efficiency> <Environment> <Safety>
Number of flights	
Start Date	5 October 2022
End Date	21 December 2022
Demonstration Coordinator	NLR
Demonstration Platform	The NLR ATC Research Simulation facility (NARSIM)
Demonstration Location	Amsterdam
Status	<Completed>
Dependencies	No on-going project dependencies

[EXE Trace]

Linked Element Type	Identifier
<SESAR Solution>	Wave 1 PJ02-01-04
<SESAR Solution>	Wave 1 PJ02-08-03
<SESAR Solution>	Wave 1 PJ.01-05
<SESAR Solution>	Wave 1 PJ.02-01-01
<Demo Objective>	OBJ-37-W3-DEMOP-HUP1-0003 OBJ-37-W3-DEMOP-HUP1-0004 OBJ-37-W3-DEMOP-HUP1-0005 OBJ-37-W3-DEMOP-HUP1-0006

OBJ-37-W3-DEMOP-HUP1-0007
OBJ-37-W3-DEMOP-HUP1-0008
OBJ-37-W3-DEMOP-HUP1-0009
OBJ-37-W3-DEMOP-HUP1-0010
OBJ-37-W3-DEMOP-HUP1-0011
OBJ-37-W3-DEMOP-HUP1-0012
OBJ-37-W3-DEMOP-HUP1-0013
OBJ-37-W3-DEMOP-HUP1-0014
OBJ-37-W3-DEMOP-HUP1-0015
OBJ-37-W3-DEMOP-CAP1-0001
OBJ-37-W3-DEMOP-CAP1-0002
OBJ-37-W3-DEMOP-PRD1-0001
OBJ-37-W3-DEMOP-NOI1-0001
OBJ-37-W3-DEMOP-ENV1-0001
OBJ-37-W3-DEMOP-SAF1-0001
OBJ-37-W3-DEMOP-SAF1-0003
OBJ-37-W3-DEMOP-SAF1-0004
OBJ-37-W3-DEMOP-SAF1-0005

Table 3-9: EXE-PJ.37-W3-002.**3.3.1.5.3 EXE-PJ.37-W3-003**

[EXE]

Identifier	EXE-PJ.37-W3-003
Title	Flight test to validate interval management, combined with CDO and FAR
Description	To increase the maturity level of Interval Management operations on RNP routes/procedures and continuous descent operations (i.e. fixed profile descents) in high density TMA environments by performing flight trials with an aircraft equipped with the RNP, RNAV, VNAV and Flight-deck Interval Management (FIM) capability.
Demonstration Technique	Live Trial
KPA/TA Addressed	<Human Performance><Capacity><Safety>
Number of flights	2 shakedown flights

	3 engineering flights, together with PH-WIS 8 measurement flights, together with D-BDLR
Start Date	22 April 2022 (shakedown and engineering flights) 9 June 2022 (shakedown flight) 14 June 2022 (measurement flights)
End Date	26 April 2022 (shakedown and engineering flights) 17 June 2022 (measurement flights)
Demonstration Coordinator	NLR
Demonstration Platform	NLR's Cessna Citation II test aircraft (PH-LAB), Privately owned Cessna CitationJet CJ4 (PH-WIS) and DLR's Dassault Falcon 2000LX iSTAR test aircraft (D-BDLR).
Demonstration Location	Groningen Airport Eelde (EHGG)
Status	<Completed>
Dependencies	No on-going project dependencies

[EXE Trace]

Linked Element Type	Identifier
<SESAR Solution>	Wave 1 PJ.01-05
<Demo Objective>	OBJ-37-W3-DEMOP-HUP1-0001 OBJ-37-W3-DEMOP-HUP1-0015 OBJ-37-W3-DEMOP-HUP1-0016 OBJ-37-W3-DEMOP-CAP1-0003 OBJ-37-W3-DEMOP-SAF1-0006 OBJ-37-W3-DEMOP-SAF1-0007

Table 3-10: EXE-PJ.37-W3-003

3.3.2 PJ.37-W3-01B - Departure Operations

3.3.2.1 Demonstration Plan Purpose

The purpose of solution track PJ.37-W3-01B - Departure Operations was to investigate the application of reduced, more granular route spacings on departure with an extended OSD tool. The RTS considered

segregated⁵ runway operations in the Heathrow environment. The concept also assessed the integration of an emulated TMA data-feed into the extended OSD tool, which dynamically adjusted the departure flow rate into the TMA dependent on the predicted TMA workload.

This RTS builds on the validation activities conducted in SESAR Wave 1 PJ.02-01-02 [12] to assess the Optimised Separation Delivery (OSD) tool for departure (AO-0329), which was validated to V3 maturity. The PJ.37-W3-01B solution track extends the functionality of the Wave 1 OSD tool to support the Tower Runway Controller apply refined, more granular route spacings. The simulation also builds on validation activities conducted in SESAR Wave 2 PJ.01-W2-08B4 **Error! Reference source not found.**, which has been validated at V2 maturity level (with acceptable risks to be addressed in future work) by including an emulated TMA data-feed from the SYSMAN tool into the extended OSD tool in order to dynamically adjust the departure flow rate along individual Standard Instrument Departure (SID) routes if the workload in the TMA is predicted to become too high.

The RTS was executed using the Heathrow Tower environment and involved Heathrow Tower controllers and a TMA expert observer from NATS. The simulation was led by NATS and supported by INDRA, who provided expert advice on the TMA data-feed requirements.

3.3.2.2 Operating method description

This section presents the operating method description for the PJ.37-W3-01B Departures Solution track.

3.3.2.2.1 Procedures and tool support for applying reduced and more granular SID spacings

The PJ.37-W3-01B solution track assumes that the Tower Runway Controller will tactically sequence the aircraft queuing at the runway holding bays for departure using the same methods as in current operations, which includes consideration of any separation or spacing constraints in place (e.g. wake separations, route separations and any applicable flow controls, i.e. Minimum Departure Intervals (MDIs) or Average Departure Intervals (ADIs) and also the Calculated Take Off Time (CTOT) for the aircraft.

With the reduced and more granular route spacings employed by the PJ.37-W3-01B solution track, which are dependent on a number of factors, including the departure runway in use, SID pairing, leader and follower aircraft types, and wind conditions along the initial departure path, it is no longer possible for the Tower Runway Controller to mentally derive the required route spacing between a departure pair. Extended OSD tool support is therefore provided for a follower departure aircraft from when it is given the clearance instruction to line-up.

The extended OSD tool calculates the earliest airborne time for the follower aircraft, which is the “Not Before Airborne Time” for separation and spacing constraints. The departure time spacing is displayed to the Tower Runway Controller in the form of a digital countdown timer on their CWP and zero seconds on the countdown timer corresponded to the applicable “Not Before Airborne Time”. It is a “Not Before Airborne Time” as there may be other more constraining separation or spacing constraints

⁵ Note that although segregated runway operations are used in the RTS, up to six arrivals an hour are allowed on Runway 09R under the Tactically Enhanced Arrivals Mode (TEAM).

unknown by the extended OSD tool support that still need to be manually applied by the Tower Runway Controller, such as speed group separations.

In EXE-PJ.37-W3-004, two separate countdown timers were provided: a wake countdown timer (as developed in PJ.02-01-02) and a route countdown timer, which also accounts for any applicable flow restrictions along the follower aircraft's SID. However, depending on the preference of the airport where the extended OSD tool is to be implemented, the information may be combined into a single countdown timer.

In the PJ.37-W3-01B Solution track, the countdown timer is started when the Tower Runway Controller triggers that the lead aircraft has become airborne on their electronic display. This is achieved by either toggling the 'Airborne/Hide' button or moving the Flight Data Entry (FDE) strip below the runway strip in the runway bay of the Electronic Flight Progress Strip (EFPS) display. However, in the case of EXE-PJ.37-W3-004, since there was no direct link between the EFPS display and the extended OSD tool, the countdown timer was started when the radar position updates indicated that the aircraft was airborne.

The Tower Runway Controller uses the zero on the countdown timer as the earliest time for the "airborne time" of the follower aircraft, and mentally subtracts both the anticipated pilot reaction time and roll time for the follower aircraft, to establish the earliest time the take-off clearance may be issued.

Note that with route separations, there is a need for the extended OSD tool to take into account the "airborne time" of not just the lead departure aircraft ahead, but also the previous departure aircraft ahead (for same and similar SIDs). This may be the case if there are flow restrictions applied along a particular SID, which increase the required departure separations applied.

When a departure pair is not constrained by a wake separation, or a route separation, then either a Reduced Separation in the Vicinity of the Aerodrome (RSVA) is applied, or the 3NM Minimum Radar Separation (MRS) is applied. In this scenario, there is not a requirement to apply a procedural 60s time separation minimum (unless there is a failure of the Aerodrome Traffic Monitor radar system) and no extended OSD tool support is provided.

When a departure pair is constrained by a route separation, but conditions for applying a reduced form of separation are met, then the Tower Runway Controller may choose to reduce the departure separation in place of following the countdown timer. This is common practice for SIDs which currently have 2-minute separation requirements and diverge early, where the Tower Runway Controller can observe the lead aircraft turning away from the departure path of the follower.

The departure time spacing provided by the extended OSD tool should ensure that the target route distance spacing is achieved by the defined leader and follower aircraft spacing delivery points (which will be agreed at a local airport level as it will be dependent on factors such as the local airport surveillance infrastructure, topology, meteorological conditions, runway configurations/layout and SID structure).

The Tower Runway Controller uses their radar screen to check that the minimum target distance spacing has been achieved before transferring the aircraft to the TMA Departure Controller.

An EATMA diagram describing the activity view (NOV-5) of the process for determining the departure spacing/separation to be delivered can be found in Appendix E1 and the associated system functionality and flow model (NSV-4) diagram can be found in Appendix E2.

A detailed description of the PJ.37-W3-01B Departures Operating Method can be found in the DEMO Plan Part I [2].

3.3.2.2.2 Procedures and tool support for managing departure flow rate into TMA

A TMA airspace management tool, such as SYSMAN (based on INDRA's Airspace Capacity Management tool (iACM) **Error! Reference source not found.**), will be used to enable the TMA Group Supervisor (GS) and/or Airspace Capacity Manager (ACM) to view predicted demand and capacity at Fixed Reference Points along selected TMA departure routes and also for Fixed Reference Routes, over a locally configurable time interval. In addition, a view of sector capacity demand will also be used to inform the GS/FMP of the overall traffic picture. This will enable them to assess the effect of the reduced route spacings on TMA traffic complexity.

The TMA airspace management tool will predict when a departure route becomes overloaded, which occurs when the flow rate past a fixed Reference Point on the departure route is predicted to exceed a defined threshold.

The TMA airspace management tool will warn the user of imminent time intervals causing over-demand and the tool user will have the ability to propose a new route flow rate to avoid the route congestion/bunching. It will be possible to use a sandbox to test the effect of changing the departure flow rate along specific routes before deciding to implement the flow restriction.

Once the user is happy with the changes shown in the sandbox as a result of entering a flow rate through the MDI measure, the sandbox will be committed and the SYSMAN will consider it as accepted. The TMA airspace management tool would then read the information from the SYSMAN database and generate the messages to be delivered to the extended OSD tool via a data-feed.

The GS/ACM would coordinate with the Tower Supervisor via telephone to inform them of the impending change to the departure flow rate along the affected SIDs. The Tower Supervisor would communicate this information to the affected actors, such as Air Departure Controller and Ground Movement Controller. In the case of Heathrow, the Tower Supervisor would input the details of the change to the departure flow rate into the information bar on the EFPS display.

The extended OSD tool would use the information provided by the TMA data-feed to apply the appropriate departure separations along the affected SID(s) over the required timeframe.

The reduction in departure flow would remain in place for the duration predicted by the TMA tool for the route overload.

An EATMA diagram describing the activity view (NOV-5) of the process for determining the flow rate measures can be found in Appendix E3 and the associated system functionality and flow model (NSV-4) diagram can be found in Appendix E4.

3.3.2.3 Summary of Demonstration Objectives and success criteria

See DEMO Plan section 4.4.1, entitled "PJ.37-W3-01B – Departure operations ". This section provides the demonstration objectives and criteria grouped by themes such as Human Performance, Operational Feasibility, Performance and Safety.

3.3.2.3.1 Human Performance Objectives

The assumptions which hold for the PJ.37-W3-01B simulation EXE-PJ.37-W3-004 are summarised in the following table:

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
HUP	OBJ-37-W3-DEMOP-HUP1-0017	Assess the ability of controllers to follow operating methods	V3. Tasks are effectively achieved.
	OBJ-37-W3-DEMOP-HUP1-0018	Assess the credibility of potential human errors, the associated risk and identify mitigations if appropriate	V3. Number of errors in the solution not significantly higher than in reference scenario, taking into account error type & operational impact.
	OBJ-37-W3-DEMOP-HUP1-0019	Assess the extent to which task performance is impacted by the concept solution	V3. Tasks are effectively achieved
	OBJ-37-W3-DEMOP-HUP1-0009	Assess the impact on workload by the concept solution	V3. Level of workload within acceptable limits ('acceptable limits' to be defined with regard to the tool used for the assessment).
	OBJ-37-W3-DEMOP-HUP1-0021	Assess the impact on situation awareness by the concept solution	V3. User is able to perceive and interpret task relevant information and anticipate future events/actions.
	OBJ-37-W3-DEMOP-HUP1-0022	Assess the extent to which automating SID separation calculations enables controllers to make quicker decisions	V3. Task allocation is found to be consistent with good deliverables of 16.5.1 Please note: deliverable 16.5.2 is SESAR's Guidance Materials on HP Automation Support (Edit 00.01.00). This document provides guidance material on automation design and evaluation that HF specialists can apply to airborne and ground operational and technical projects involving automation.
	OBJ-37-W3-DEMOP-HUP1-0023	Assess the extent automating airborne time detection improves human performance	V3. The task allocation is consistent with deliverable of 16.5.2. Please note: deliverable 16.5.2 is SESAR's Guidance Materials on HP Automation Support (Edit 00.01.00). This document provides guidance material on automation design and evaluation that HF specialists can apply to airborne and ground operational and technical projects involving automation.
	OBJ-37-W3-DEMOP-HUP1-0024	Assess users' mode switching capability	V3. There are no excessive cognitive demands or potential for error in transition tasks.

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
	OBJ-37-W3-DEMOP-HUP1-0026	Assess the extent to which actors can acquire mental models	V3. Understanding of the technical system's behaviour is consistent with the operator's task demands.
	OBJ-37-W3-DEMOP-HUP1-0027	Assess the extent to which the accuracy of the system meets HP requirements	V3. Information accuracy experienced as sufficient by the end user.
	OBJ-37-W3-DEMOP-HUP1-0028	Assess the extent to which the timeliness of the system meets HP requirements	V3. Timeliness of information is judged as being sufficient.
	OBJ-37-W3-DEMOP-HUP1-0029	Assess the credibility of the benefit and identify how to realise the benefit if appropriate	V3. Information provided allows task achievement.
	OBJ-37-W3-DEMOP-HUP1-0030	Assess the credibility of the issue, the associated risk and identify mitigations if appropriate	V3. Information provided allows task achievement.
	OBJ-37-W3-DEMOP-HUP1-0031	Assess the extent to which the user interface impacts human performance and service delivery	V3. End user experiences integrated interface including any new system components as sufficiently usable.
	OBJ-37-W3-DEMOP-HUP1-0033	Assess the extent to which the concept solution complies with the relevant HP Principles	V3. Number and/or severity of errors is within acceptable limits.
	OBJ-37-W3-DEMOP-HUP1-0034	Assess the impact the user interface has on individual situation awareness levels	V3. End user is able to perceive and interpret task relevant information and anticipate future events/actions
	OBJ-37-W3-DEMOP-HUP1-0035	Assess the impact the user interface has on team situation awareness levels	V3. Team is able to perceive and interpret task relevant information and anticipate future events/actions.
	OBJ-37-W3-DEMOP-HUP1-0036	Assess the credibility of an interference risk	V3. Interferences between existing and required new knowledge & skills are identified.

Table 3-11: Human Performance Demonstration Objectives.

3.3.2.3.2 Operational Feasibility Demonstration Objective

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
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OPF	OBJ-37-W3-DEMOP-OPF1-0001	To provide evidence that the ITARO Departures Solution is operationally feasible for the Aerodrome when integrated in a realistic environment in segregated mode.	The ITARO Departures Solution is shown to be operationally feasible for the Aerodrome when the IBP is tested in a realistic environment. The extended OSD Tool design and usability is considered appropriate by users.
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Table 3-12: Operational Feasibility Demonstration Objective.

3.3.2.3.3 Capacity Demonstration Objective

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
CAP	OBJ-37-W3-DEMOP-CAP1-0004	To assess the improvement in departure runway capacity due to the ITARO Departures Solution versus the Reference Scenario.	Evidence shows an increase in maximum hourly operational runway throughput for departures in the Solution Scenario versus the Reference Scenario.

Table 3-13: Capacity Demonstration Objective related to PJ.37-W3-01B.

3.3.2.3.4 Operational Efficiency Demonstration Objectives

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
OPE	OBJ-37-W3-DEMOP-PRD1-0001	To assess the improvement in predictability per flight for the Aerodrome due to the ITARO Departures Solution versus the Reference Scenario.	Evidence shows a decrease in taxi out variability for departing aircraft in the Solution Scenario versus the Reference Scenario.
	OBJ-37-W3-DEMOP-PRD1-0002	To assess the predictability per flight for the TMA due to the ITARO Departures Solution versus the Reference Scenario.	Evidence shows a more consistent delivery of aircraft into the TMA in the Solution Scenario versus the Reference Scenario.
	OBJ-37-W3-DEMOP-PUN1-0001	To assess the impact on ANSP-attributed holding delay at the Aerodrome as a result of the ITARO Departures Solution versus the Reference Scenario.	There is evidence to show that the ANSP-attributable delay at the Aerodrome is reduced in the Solution scenario versus the reference scenario.

Table 3-14: Operational Efficiency Demonstration Objective related to PJ.37-W3-01B.

3.3.2.3.5 Environment Demonstration Objective

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
ENV	OBJ-37-W3-DEMOP-ENV1-0002	To assess the impact of the ITARO Departures Solution on the average fuel burn per flight versus the Reference Scenario.	There is evidence to show there is a reduction in the average fuel burn per flight, and therefore average CO2 emissions per flight in the Solution Scenario versus the Reference Scenario.

Table 3-15: Environment Demonstration Objective related to related to PJ.37-W3-01B.

3.3.2.3.6 Cost Efficiency Demonstration Objective

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
CEF	OBJ-37-W3-DEMOP-CEF1-0001	To assess the increase to Aerodrome ATCO productivity in terms of flights handled per unit time in the ITARO Departures Solution versus the Reference Scenario.	Evidence shows an increase in the number of flights handled by an Aerodrome ATCO per hour in the Solution Scenario versus the Reference Scenario.

Table 3-16: Cost Efficiency Demonstration Objective related to PJ.37-W3-01B.

3.3.2.3.7 Safety Demonstration Objectives

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
SAF	OBJ-37-W3-DEMOP-SAF1-0008	To assess the impact of the ITARO Departures Solution on operational safety in the Tower compared to the Reference Scenario.	CRT-37-W3-DEMOP-SAF1-0008: There is evidence that the level of safety for the Tower controllers' operations is maintained and not negatively impacted with the ITARO Departures Solution compared to the Reference Scenario. CRT-37-W3-DEMOP-SAF1-0008: There is evidence that the ITARO Departures Solution does not increase the number of minor wake under-separations and decreases the number of large wake under-separations (i.e., those with potential for severe wake encounters and / or loss of separation) compared to the Reference Scenario CRT-37-W3-DEMOP-SAF1-0008: There is evidence that the ITARO Departures Solution does not increase the number of route under spacing events relative to the target distance spacing and compared to the Reference Scenario.

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
	OBJ-37-W3-DEMOP-SAF1-0009	To assess the impact on safety by the associated procedures	CRT-37-W3-DEMOP-SAF1-0009: Evidence is gathered regarding the impact on safety and associated procedures that the ITARO Departures Solution has.
	OBJ-37-W3-DEMOP-SAF1-0010	Understand the equipment requirements, e.g., corrupt data, hardware failures.	CRT-37-W3-DEMOP-SAF1-0010: Evidence is gathered regarding equipment requirements and the ITARO Departures Solution

Table 3-17: Safety Demonstration Objectives related to PJ.37-W3-01B.

3.3.2.4 Demonstration Assumptions

The assumptions which hold for the PJ.37-W3-01B Departure simulation EXE-PJ.37-W3-004 are summarised in the following table:

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
ASS-37-W3-DEMOR-004-001	Aircraft performance capabilities	Technology	Median performance characteristics as defined by aircraft type in the RTS are sufficiently representative of real aircraft performance.	For realistic simulation environment, and for the ATCOs to effectively assess the algorithm.	High
ASS-37-W3-DEMOR-004-002	Generalisation	RTS Design	Heathrow scenarios (Runways 27R and 09R) are representative of other aerodromes.	To enable RTS results to be extrapolated to other aerodromes.	Medium
ASS-37-W3-DEMOR-004-003	Data Collection	Experimental Design	Where statistical tests cannot be performed due to low sample size, it is assumed that outcomes are still valid indications of real effects associable with the solution.	To enable reliable Validation findings to be drawn from the RTS results, taking into consideration any limitations of the demonstration.	High

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
ASS-37-W3-DEMOR-004-004	Traffic Sample Design	Validation Analysis	The simulation start up point of aircraft in the traffic samples are at specific points along the taxiway rather than starting at the stand and follow the actual order taken from operational data. This is the same for both reference and solution scenarios (as the same traffic sample is used for both).	Even though the traffic sample is not representative of the real world in that the aircraft are not controlled from the stand to the runway the conditions are kept the same between reference and solutions therefore it is assumed that it is a fair comparison conducted in the experimental design.	Medium
ASS-37-W3-DEMOR-004-005	Simulation Configuration	RTS Design	Deviations of CWP setup and other hardware used in the RTS are not introducing significant errors into results, in particular when conducting relative research (reference vs. solution scenario)	To enable an accurate, reliable, informed and meaningful assessment of the concept.	High

Table 3-18: Demonstration Assumptions list for EXE-PJ.37-W3-004.

3.3.2.5 Demonstration Exercises List

3.3.2.5.1 EXE-PJ.37-W3-004

[EXE]

Identifier	EXE-PJ37-W3-004
Title	ITARO for departures in segregated runway operations
Description	Real Time Simulation demonstration of reduced and refined route spacings on departure and their integration with an extended

	departure Optimised Separation Delivery tool with a TMA data feed on a single runway in segregated mode (London Heathrow). The objective is to assess the impact on departure capacity in both nominal, non-nominal and failure conditions. A Human Performance and Safety analysis will also be conducted as part of the activities.
Demonstration Technique	<Real Time Simulation>
KPA/TA Addressed	<Human Performance>, <Capacity>, <Operational Efficiency>, <Environment>, <Cost Efficiency>, <Safety>
Number of flights	N/A
Start Date	January 2022 (note the testing phase started in January 2022 and continued through to August 2022. The actual demonstration exercise began in September 2022).
End Date	September 2022
Demonstration Coordinator	NATS
Demonstration Platform	NATS Ace simulation environment
Demonstration Location	Demonstration held at NATS Heathrow with connection to CTC. Demonstration environment is London Heathrow.
Status	<completed>
Dependencies	Demonstration platform availability and controller availability

[EXE Trace]

Linked Element Type	Identifier
<SESAR Solution>	PJ.02-01-02
<Demo Objective>	OBJ-37-W3-DEMOP-HUP1-0017 OBJ-37-W3-DEMOP-HUP1-0018 OBJ-37-W3-DEMOP-HUP1-0019 OBJ-37-W3-DEMOP-HUP1-0009 OBJ-37-W3-DEMOP-HUP1-0021 OBJ-37-W3-DEMOP-HUP1-0022 OBJ-37-W3-DEMOP-HUP1-0023 OBJ-37-W3-DEMOP-HUP1-0024 OBJ-37-W3-DEMOP-HUP1-0026

OBJ-37-W3-DEMOP-HUP1-0027
OBJ-37-W3-DEMOP-HUP1-0028
OBJ-37-W3-DEMOP-HUP1-0029
OBJ-37-W3-DEMOP-HUP1-0030
OBJ-37-W3-DEMOP-HUP1-0031
OBJ-37-W3-DEMOP-HUP1-0033
OBJ-37-W3-DEMOP-HUP1-0034
OBJ-37-W3-DEMOP-HUP1-0035
OBJ-37-W3-DEMOP-HUP1-0036
OBJ-37-W3-DEMOP-OPF1-0001
OBJ-37-W3-DEMOP-CAP1-0004
OBJ-37-W3-DEMOP-PRD1-0002
OBJ-37-W3-DEMOP-PRD1-0003
OBJ-37-W3-DEMOP-PUN1-0001
OBJ-37-W3-DEMOP-ENV1-0002
OBJ-37-W3-DEMOP-CEF1-0001
OBJ-37-W3-DEMOP-SAF1-0008
OBJ-37-W3-DEMOP-SAF1-0009
OBJ-37-W3-DEMOP-SAF1-0010

Table 3-19: Demonstration

3.4 Deviations

3.4.1 Deviations with respect to the S3JU Project Handbook

No deviation with respect to the SJU Project Handbook have been identified.

3.4.2 Deviations with respect to the Demonstration Plan

For deviations with respect to the Demonstration Plan please refer to individual Demonstration exercises. See Appendices A.2, B.2, C.2 and D.2.

4 Demonstration Results

4.1 Summary of Arrival Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0001	The IM execution is found acceptable by the flight crew of the test aircraft	CRT-37-W3-DEMOP-HUP1-0001	No acceptance issues are identified both during the test flights and debriefings by the flight crew of the IM aircraft	The pilots found the IM operations acceptable to be used in operation. The HMI was acceptable to the majority of the pilots with some improvements identified. The pilots found the IM speed guidance acceptable.	OK
OBJ-37-W3-DEMOP-HUP1-0003	The arrival management process is found acceptable by the ATCOs present in the RTS.	CRT-37-W3-DEMOP-HUP1-0003	No acceptance issues are identified both during the RTS and debriefings by the ATCOs involved in the simulations.	The acceptability of the concept was partially OK. ATCOs mentioned that they felt confident provided that speeds of flights reduce gradually towards final, and that traffic is delivered accurately (plus or minus 30 seconds but preferably more accurate). The ATCOs felt that only when the above criteria were met, the concept could safely work, and they did not find that very realistic to expect.	POK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0004	Assess completeness and acceptability of working procedures (regarding transition between IM/merge tool and PWS/ORD tool whilst operating RNAV/RNP transition procedures followed by instrument approach procedures).	CRT-37-W3-DEMOP-HUP1-0004	V3. Operating methods are found to cover identified normal operating conditions.	The working procedures were not fully complete and acceptable to ATCOs. ATCOs concerns pertained mainly dealing with unexpected events in combination with a high traffic volume.	POK
OBJ-37-W3-DEMOP-HUP1-0005	Assess working procedures for normal mode of operations are clear and consistent.	CRT-37-W3-DEMOP-HUP1-0005	V3. The content of the operating methods has been determined to be clear and consistent by end users and native speakers/linguistic experts.	The working procedures are not absolutely clear and consistent. Some further refinement on the integration of algorithms was deemed necessary.	POK
OBJ-37-W3-DEMOP-HUP1-0006	Assess the ability of controller to follow working procedures.	CRT-37-W3-DEMOP-HUP1-0006	V3. [GND only] Number of errors in the solution not significantly higher than in reference scenario, taking into account error type & operational impact.	The RTS results are not really conclusive with regard to the potential for human error, as the number of errors observed was too low to compare. No errors were observed. Overall, high amounts of traffic and high speeds make it difficult to monitor the traffic at all route segments in the same way it is done in current operations. Also, the task of having to change IM targets should be avoided.	POKI

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0007	Assess the types, likelihood and effect of errors that occur, in particular due to the simultaneous presentation ORD and Merge tool indicators.	CRT-37-W3-DEMOP-HUP1-0007	V3. Recovery means for errors in the solution minimise operational impact.	It was concluded that the combined presentation of the Target Distance Indicators (TDI) and merge tool indications do not lead to confusion and the probability of human error is not increased.	OK
OBJ-37-W3-DEMOP-HUP1-0008	Assess the extent to which task performance is reduced by the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0008	V3. Tasks are effectively achieved	Task performance was rated high. Overall it was concluded that merging and spacing were performed timely. Nevertheless, meanwhile monitoring the traffic turning in for final was difficult.	POK
OBJ-37-W3-DEMOP-HUP1-0009	Assess the impact on ATCO workload by the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0009	V3. Level of workload within acceptable limits ('acceptable limits' to be defined with regard to the tool used for the assessment).	The average workload ratings seem to be at acceptable levels. Nevertheless, ATCOs mentioned that small disturbances have an impact on workload and that insufficient time remained to monitor the traffic turning towards final. The reduction of MRS to 2.0 does not seem to contribute to ATCO workload.	POK
OBJ-37-W3-DEMOP-HUP1-0010	Assess the impact on ATCOs level of trust in the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0010	V3. Potential issues related to trust and the preliminary mitigation identified are acceptable.	The results of the RTS were not really conclusive. The ATCOs' confidence in the concept was rated neutral to positive, with the remark that in the simulation the pilots were very collaborative and timely following up instructions, which is not the case in current day operations.	POK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0011	Assess the impact on individual ATCO situation awareness levels by the integrated arrival concept	CRT-37-W3-DEMOP-HUP1-1011	V3. [GND only] Level of situational awareness not lower in the solution than in the reference scenario.	The average ATCO Situation Awareness rating is sufficient (4.5 or higher, scale 0-6), with slightly higher values for the reference. A lower accuracy of delivery seems to have a negative impact on SA. A lower percentage of flight capable of IM does not seem to have a negative impact.	OK
		CRT-37-W3-DEMOP-HUP1-2011	V3. End user is able to perceive and interpret task relevant information and anticipate future events/actions.	ATCOs mentioned not to have sufficient time e.g., to monitor the traffic on final. Having insufficient time could be an indicator that anticipating and planning ahead is limited.	POK
OBJ-37-W3-DEMOP-HUP1-0012	Assess the extent to which the integrated arrival concept complies with the relevant HP Principles.	CRT-37-W3-DEMOP-HUP1-0012	V3. Visual displays are consistent with design standards or regulations. Rationales are provided in case of deviations from standards.	Several potential improvement were identified to the route design, the HMI and the concept, some of which were implemented in RTS 2. These improvement relate to the HF principles of reducing the information to the absolute necessary, and only using alerting colours when certain parameters are deviating from the expected. Overall it is concluded that the HMI was adequately improved for RTS 2.	OK
OBJ-37-W3-DEMOP-HUP1-0013	Assess the extent to which the user interface reduces human performance and service delivery.	CRT-37-W3-DEMOP-HUP1-0013	V3. [GND only] Usability rating for the integrated interface not lower in the solution than in the reference scenario.	The HMI usability was rated positively. Overall it was concluded that the HMI does not negatively impact the human performance.	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0014	Assess the impact on team ATCO situation awareness levels by the integrated arrival concept	CRT-37-W3-DEMOP-HUP1-0014	V3. Team is able to perceive and interpret task relevant information and anticipate future events/actions.	It was concluded that Team SA may reduce slightly in comparison to current day operations but will remain at sufficient levels.	OK
OBJ-37-W3-DEMOP-HUP1-0015	The integrated tool does not deteriorate the arrival management process	CRT-37-W3-DEMOP-HUP1-0015	Under nominal conditions, there shall be no need to fall back on the use of vectoring operations while using the integrated tool.	<u>Flight Trial:</u> Air traffic controllers never intervened with radar vectors or intermediate level-offs. The fixed routes with a fixed descent profile were always adhered to (11 test flights, 61 test runs). <u>RTS:</u> Based on the RTS, it is concluded that the integration is complex. Small changes meant to improve the integration proved to have unexpected results. Nevertheless, it is expected that if flights are delivered accurately into the TMA the concept could work, allowing continuous descents at high throughput.	OK (Flight Trial) POK (RTS)



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0016	The IM execution is feasible while performing RNP/RNAV procedures with a defined vertical profile	CRT-37-W3-DEMOP-HUP1-0016	Under nominal conditions, there is no need to deviate from the defined horizontal or vertical path or deviate from the IM speeds (for prolonged periods of time)	During all runs the aircraft successfully adhered to the defined vertical profile (2.0-deg or 2.5-deg) and nominal speed profile for the lead aircraft and IM speeds for the trail aircraft.	OK
OBJ-37-W3-DEMOP-CAP1-0001	The runway throughput level shall remain at the same level or increase against the reference scenario	CRT-37-W3-DEMOP-CAP1-0001	There is no negative effect on the runway throughput by using the integrated tool in nominal operations against the reference scenario.	The simulations did not identify negative effects on the runway throughput by using the integrated tool in nominal operations against the reference scenario. The runway throughput for each runways does not vary much when increasing the IM equipage rate. When increasing the traffic load, the throughput increases as expected as long as the traffic is operating nominally.	OK
OBJ-37-W3-DEMOP-CAP1-0002	The airspace capacity shall remain at the same level or increase against the reference scenario	CRT-37-W3-DEMOP-CAP1-0002	There is no negative effect on the airspace capacity by using the integrated tool in nominal operations against the reference scenario.	The simulations did not identify negative effects on the airspace capacity by using the integrated tool in nominal operations against the reference scenario. Airspace capacity on fixed routes is evaluated using runway throughput and number of aircraft under control (UCO) by a controller. Increasing traffic load resulted in more aircraft UCO, however peak number of aircraft UCO is similar to lower traffic load.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-CAP1-0003	The delivery of aircraft on final shall be improved	CRT-37-W3-DEMOP-CAP1-0003	The use of the on-board FIM capability shall provide a highly accurate (< 9.3 sec spacing error, 95%) delivery of the IM aircraft on final, for both in-trail and merging operations to the same runway.	98% of the runs complied with the 9.3-second tolerance at the Planned Termination Point, which was located at the Final Approach Point (based on 11 test flights, 49 test runs).	OK
OBJ-37-W3-DEMOP-PRD1-0001	The predictability of arriving traffic shall remain at the same level or increase against the reference scenario.	CRT-37-W3-DEMOP-PRD1-0001	There is no negative effect on the predictability of the traffic in the TMA by using the integrated tool	The simulations did not identify negative effects by the integrated tool on the predictability as the average difference between the actual and planned time in the TMA for the solution runs is within seconds compared to the reference run. With increasing IM equipage rate the spread in the difference between the actual and planned time in the TMA decreased.	OK
OBJ-37-W3-DEMOP-NOI1-0001	The noise profile will not increase against the reference scenario	CRT-37-W3-DEMOP-NOI1-0001	The use of the integrated tool does not increase the noise profile in the nominal simulation against the reference scenario.	In the nominal simulation, the 55 dB noise contour area in the solution run has decreased with less than 1%. Differences are too small to conclude that the 55 dB noise contour area has improved.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-ENV1-0001	The CO2 emissions will not increase against the reference scenario	CRT-37-W3-DEMOP-ENV1-0001	The use of the integrated tool does not increase the CO2 emission in the nominal simulation against the reference scenario.	In the nominal simulation, the solution run with the integrated tool emits 6.7% less CO2 than the reference run.	OK
OBJ-37-W3-DEMOP-SAF1-0001	The number of go-arounds due to insufficient spacing shall not be greater than in the reference scenario	CRT-37-W3-DEMOP-SAF1-0001	The use of the integrated tool shall not increase the number of controller-instructed go-arounds.	The data supported by the questionnaires showed that the combination of tools did not cause more go-arounds occurring.	OK
OBJ-37-W3-DEMOP-SAF1-0003	The interoperability of the different tools in the integrated tool shall not introduce safety issues.	CRT-37-W3-DEMOP-SAF1-0003	Ensure that the functionalities of all solutions complement one another without negative interference.	The RTS showed some illogical pairings and an unpredictable operation, to which the ATCOs were not alerted. Therefore, the safety objective is not fully met.	POK
OBJ-37-W3-DEMOP-SAF1-0004	There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts).	CRT-37-W3-DEMOP-SAF1-0004	The use of the integrated tool and the Airborne Spacing Flight Deck Interval Management does not lead to an increased number of separation losses in the nominal solution as compared against the reference scenario.	During the RTS, the number of LOSs during solution runs was similar to the number of LOSs in reference runs. The concerns of the controllers could not be related to the combination of tools.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-SAF1-0005	The perceived controllability of the operation by ATCO shall not degrade due to the use of the integrated tool.	CRT-37-W3-DEMOP-SAF1-0005	The tool gives the ATCO the means to intervene. The use of the tool does not lead to a perceived loss of controllability of the operation by the ATCO in relation to the conventional operation. This is assessed through a qualitative analysis.	With time, the controllers became more familiar with the integrated tool, resulting in increased trust and increased perceived controllability. However, some disturbances led to a rapid loss of control and the need to halt the simulation. The concerns warrant further attention in future testing and simulations.	POK
OBJ-37-W3-DEMOP-SAF1-0006	The use of IM operations shall not result in any unsafe condition during the live trial	CRT-37-W3-DEMOP-SAF1-0006	No major safety issues are identified both during the test flights and debriefings by the flight crew of the IM aircraft	Safety was not an issue during the flight trial based on pilot feedback.	OK
OBJ-37-W3-DEMOP-SAF1-0007	The FIM system performs its intended function during the live trial (airworthiness related objective)	CRT-37-W3-DEMOP-SAF1-0007	No functional issues related to the FIM system standard (ED-236A) are identified during the test flights (e.g. non-compliance or other issues with relevant ED-236A requirements).	The vast majority of the FIM functions worked as intended. A gap is the limited ADS-B In range observed during the flight trial, this was attributed to the specific antenna installation Furthermore, a very limited number of updated/new FIM MOPS requirements still need to be implemented.	POK



4.2 Detailed analysis of Arrival Demonstration Results per Demonstration objective

4.2.1 Human Performance Demonstration Objective

4.2.1.1 OBJ-37-W3-DEMOP-HUP1-0001

Identifier	OBJ-37-W3-DEMOP-HUP1-0001	KPA Category	HUP
Title	Not Specified		
Objective	The IM execution is found acceptable by the flight crew of the test aircraft		
Success Criterion	CRT-37-W3-DEMOP-HUP1-0001	No acceptance issues are identified both during the test flights and debriefings by the flight crew of the IM aircraft	
Results	The pilots found the IM operations acceptable to be used in operation. The HMI was acceptable to the majority of the pilots with some improvements identified. The pilots found the IM speed guidance acceptable.		OK
Reference	Appendix C.3.2 paragraph 1. Pilot questionnaire data.		

This objective is evaluated in EXE-PJ.37-W3-003. For detailed analysis, refer to Appendix C.3.2 paragraph 1.

4.2.1.2 OBJ-37-W3-DEMOP-HUP1-0003

Identifier	OBJ-37-W3-DEMOP-HUP1-0003	KPA Category	HUP
Title	Not Specified		
Objective	The arrival management process is found acceptable by the ATCOs present in the RTS.		
Success Criterion	CRT-37-W3-DEMOP-HUP1-0003	No acceptance issues are identified both during the RTS and debriefings by the ATCOs involved in the simulations.	
Results	The post-run question on the acceptability of the concept was on average rated 4.5 (scale 1-7), however with high variation in the ratings. One ATCO rated the statement 1 or 2 in four instances. The explanation provided pertained to different reasons: the low equipage level (20%), the sequence of delivery into TMA (as a result of less accurate EAT adherence) and simulator issues in nominal runs. Concluding, the acceptability is only sufficient providing that the flights are delivered accurately, pilots are timely following up instructions and the equipage level is substantial. For the ATCOs the concept is too dependent on these factors, which in their perception is not realistic (e.g., pilots following up instructions so quick).		POK
Reference	Human Performance Assessment Report [4] Appendix A.3.2, paragraph 1 Appendix B.3.2, paragraph 1 RTS1 and 2 questionnaires and debriefing		

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.



4.2.1.3 OBJ-37-W3-DEMOP-HUP1-0004



Identifier	OBJ-37-W3-DEMOP-HUP1-0004	KPA Category	HUP
Title	Not Specified		
Objective	Assess completeness and acceptability of working procedures (regarding transition between IM/merge tool and PWS/ORD tool whilst operating RNAV/RNP transition procedures followed by instrument approach procedures).		
Success Criterion	CRT-37-W3-DEMOP-HUP1-0004	V3. Operating methods are found to cover identified normal operating conditions. Measured indicator: post-run questionnaire on acceptability in normal operating conditions.	

Results	In RTS 1, all controllers rated the completeness and acceptability of the working procedures 4 (on a scale of 1 to 5) in the post-experiment questionnaire. It is concluded that both completeness and acceptability of working procedures are at an acceptable level. Nevertheless, there is room for further improvement. In RTS 2, the ATCOs rated the completeness 2.7 and acceptability 3 (scale 1-5). The completeness and acceptability apparently reduced in comparison to the first RTS. In RTS 2 the concept was evaluated against more challenging situations that required more controller actions. For example, merging a go-around, which was rather challenging in the high volume of traffic. Also, reduced equipage levels and some unexpected simulation and technology behaviours may have had an effect. Overall, working procedures seem not fully acceptable and complete. Certain aspects require further attention, e.g. how to deal with (inevitable) unexpected traffic behaviour, that still fall under normal operations and ATCOs found it illogical to use IM when only 20% of the traffic was equipped. <table><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr><tr><td rowspan="4">1.2.1-1: Working procedures regarding transition between IM/merge tool and PWS/ORD tool are neither complete nor acceptable.</td><td>REC-37-W3-HUP-R4.1: Design arrival routes such that turns are 135 degree or larger and that routes to parallel runways are not exactly mirrored (avoid head-on base legs). <i>Validated in RTS2.</i></td></tr><tr><td>REC-37-W3-HUP-R4.2: Standardise the altitude at IAF or start the RNP approach at the merge point. <i>Standardised altitude was validated in RTS2.</i></td></tr><tr><td>REC-37-W3-HUP-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. <i>This was validated in RTS 2.</i></td></tr><tr><td>REC-37-W3-HUP-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.</td></tr></table>	HP Issue / Benefit	Recommendation	1.2.1-1: Working procedures regarding transition between IM/merge tool and PWS/ORD tool are neither complete nor acceptable.	REC-37-W3-HUP-R4.1: Design arrival routes such that turns are 135 degree or larger and that routes to parallel runways are not exactly mirrored (avoid head-on base legs). <i>Validated in RTS2.</i>	REC-37-W3-HUP-R4.2: Standardise the altitude at IAF or start the RNP approach at the merge point. <i>Standardised altitude was validated in RTS2.</i>	REC-37-W3-HUP-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. <i>This was validated in RTS 2.</i>	REC-37-W3-HUP-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.	POK
HP Issue / Benefit	Recommendation								
1.2.1-1: Working procedures regarding transition between IM/merge tool and PWS/ORD tool are neither complete nor acceptable.	REC-37-W3-HUP-R4.1: Design arrival routes such that turns are 135 degree or larger and that routes to parallel runways are not exactly mirrored (avoid head-on base legs). <i>Validated in RTS2.</i>								
	REC-37-W3-HUP-R4.2: Standardise the altitude at IAF or start the RNP approach at the merge point. <i>Standardised altitude was validated in RTS2.</i>								
	REC-37-W3-HUP-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. <i>This was validated in RTS 2.</i>								
	REC-37-W3-HUP-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.								
Reference	Human Performance Assessment Report [4] Appendix A.3.2, paragraph 2 Appendix B.3.2, paragraph 2 RTS1 and 2 questionnaires and debriefing								



This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.



4.2.1.4 OBJ-37-W3-DEMOP-HUP1-0005

Identifier	OBJ-37-W3-DEMOP-HUP1-0005		KPA Category	HUP					
Title	Not Specified								
Objective	Assess working procedures for normal mode of operations are clear and consistent.								
Success Criterion	CRT-37-W3-DEMOP-HUP1-0005	V3. The content of the operating methods has been determined to be clear and consistent by end users and native speakers/linguistic experts. Measured indicator: Post-experiment questionnaire: Clear and consistent procedures.							
Results	In RTS 1, the controllers rated the clarity and consistency of the procedures at 3 or 4 (scale 1 to 5) in the post-experiment questionnaire. The average on clarity was 3.7 and on consistency 3.3, which indicates the controllers rated it neutral to positive. In RTS2, the ATCO rating regarding clarity and consistency of the procedures did not increase compared to RTS 1. In contrary, the consistency was slightly reduced to 2.8. It is believed that the inconsistency due to technology aspects, that resulted in some flights increasing speeds at final approach, led to this decreased rating. Also, the reduced equipage levels in RTS2 have had an effect. Overall, working procedures clarity and consistency were neutrally rated in RTS 2. It seems that the procedures were clear and consistent for normal operations under the conditions in RTS1, but require further attention for situations with largely reduced accuracy of delivery, IM speed behaviour between merge point and final approach fix (in IM maintain phase) and mixed equipage levels. <table><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr><tr><td rowspan="2">1.2.4-1: Working procedures regarding the transition from IM to PWS/ORD operations are not clear and consistent</td><td>REC-37-W3-HUP-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. <i>This was validated in RTS 2.</i></td></tr><tr><td>REC-37-W3-HUP-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.</td></tr></table>			HP Issue / Benefit	Recommendation	1.2.4-1: Working procedures regarding the transition from IM to PWS/ORD operations are not clear and consistent	REC-37-W3-HUP-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. <i>This was validated in RTS 2.</i>	REC-37-W3-HUP-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.	POK
HP Issue / Benefit	Recommendation								
1.2.4-1: Working procedures regarding the transition from IM to PWS/ORD operations are not clear and consistent	REC-37-W3-HUP-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. <i>This was validated in RTS 2.</i>								
	REC-37-W3-HUP-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.								
Reference	Human Performance Assessment Report [4] Appendix A.3.2, paragraph 3								

Appendix B.3.2, paragraph 3

RTS1 and 2 questionnaires and debriefing

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.

4.2.1.5 OBJ-37-W3-DEMOP-HUP1-0006

Identifier	OBJ-37-W3-DEMOP-HUP1-0006		KPA Category	HUP					
Title	Not Specified								
Objective	Assess the ability of controller to follow working procedures.								
Success Criterion	CRT-37-W3-DEMOP-HUP1-0006	V3. [GND only] Number of errors in the solution not significantly higher than in reference scenario, taking into account error type & operational impact. Measured indicator: Acceptability and feasibility of operating methods, questionnaires and debriefings.							
Results	In RTS 1, the acceptability of the concept was rated on average 4.8 for the reference and 3.8 for the solution (scale 1-7). ATCOs stated there was insufficient time to also monitor the traffic that is turning in for the final stretch. The high speeds at final seem to increase the above mentioned aspect. These findings concern both reference and solution. In addition, changing IM targets (only performed in rare cases) was found too cumbersome. For RTS 2, the average acceptability rating of the concept was rated positively for all conditions, except for the runs with equipage of 20%. ATCOs mentioned that 20% equipage is too low for the concept to be useful. The previous stated finding also applies but to a lesser extent as speeds were in general lower and the routes towards the parallel runways were no longer head-on. Overall, the ATCOs were able to follow the procedures. However, high amounts of traffic and high speeds make it difficult to monitor the traffic at all route segments in the same way it is done in current operations. Also, the task of changing IM targets should be avoided. <table><thead><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr></thead><tbody><tr><td rowspan="2">1.2.5-1: New working procedures & practices associated with the transition from IM to PWS/ORD are not usable / suitable or acceptable, i.e. they cannot be followed and executed in an accurate, efficient and timely manner.</td><td>REC-37-W3-HUP-R6.1: In case of changes in the inbound sequence it is recommended to update the inbound planning (AMAN/Supervisor) or cancel the IM for one (or several) flights, instead of changing IM targets.</td></tr><tr><td>REC-37-W3-HUP-R6.2: It is recommended to take a closer look at responsibilities such as monitoring the traffic at final, with high volumes of traffic. Can this reasonably be expected from the ATCO?</td></tr></tbody></table>			HP Issue / Benefit	Recommendation	1.2.5-1: New working procedures & practices associated with the transition from IM to PWS/ORD are not usable / suitable or acceptable, i.e. they cannot be followed and executed in an accurate, efficient and timely manner.	REC-37-W3-HUP-R6.1: In case of changes in the inbound sequence it is recommended to update the inbound planning (AMAN/Supervisor) or cancel the IM for one (or several) flights, instead of changing IM targets.	REC-37-W3-HUP-R6.2: It is recommended to take a closer look at responsibilities such as monitoring the traffic at final, with high volumes of traffic. Can this reasonably be expected from the ATCO?	POK
HP Issue / Benefit	Recommendation								
1.2.5-1: New working procedures & practices associated with the transition from IM to PWS/ORD are not usable / suitable or acceptable, i.e. they cannot be followed and executed in an accurate, efficient and timely manner.	REC-37-W3-HUP-R6.1: In case of changes in the inbound sequence it is recommended to update the inbound planning (AMAN/Supervisor) or cancel the IM for one (or several) flights, instead of changing IM targets.								
	REC-37-W3-HUP-R6.2: It is recommended to take a closer look at responsibilities such as monitoring the traffic at final, with high volumes of traffic. Can this reasonably be expected from the ATCO?								
Reference	Human Performance Assessment Report [4]								

Appendix A.3.2, paragraph 4

Appendix B.3.2, paragraph 4

RTS1 and 2 questionnaires and debriefing

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.



4.2.1.6 OBJ-37-W3-DEMOP-HUP1-0007



Identifier	OBJ-37-W3-DEMOP-HUP1-0007		KPA Category	HUP
Title	Not Specified			
Objective	Assess the types, likelihood and effect of errors that occur, in particular due to the simultaneous presentation ORD and Merge tool indicators.			
Success Criterion	CRT-37-W3-DEMOP-HUP1-0007	V3. Recovery means for errors in the solution minimise operational impact. Measured indicator: post-run questionnaire: confusion, task performance, end-of-day questionnaire: expected impact on potential for human error.		

Results	In RTS 1, ATCOs did not indicate to have experienced any confusion between the tools in the post-run ratings of the Solution concept (for the Reference this was indicated once (1 in 8 runs)). One of the three ATCOs rated the HMI's robustness against error negatively. In addition, task performance self-ratings were not reduced in the solution compared to the reference. ATCO ratings on task performance were sufficiently stable and on average 5.9 (scale 1 – 7). Also confidence levels were high. In RTS 2, the combined presentation did not lead to confusion. ATCOs did not mention this as a problem. Increased confusion was reported in runs where simulation/automation generated illogical sequences and IM settings. In addition, the effect of the concept on task performance and potential for human error was rated neutrally to slightly negative in comparison to the current concept of operations (vectoring). It was concluded that the combined presentation of ITD, FTD and merge tool indications do not lead to confusion and the probability of human error is not significantly increased. It however remains an important point for attention. <table><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr><tr><td rowspan="2">1.3.1-1: The combined presentation of ITD and FTD indications and merge tool indications may lead to human errors.</td><td>REC-37-W3-HUP-R7.1: Design the HMI, such that: - It is clear which flights are IM capable and which are not; Validated in RTS2 - It is clear which flights are applying IM (validated in RTS2), and whether it is applied correctly (to the flight preceding on the route); - it is clear which flights are established on RNP; Validated in RTS2 - that ATCO can change the sequence with a minimal number of actions </td></tr><tr><td>REC-37-W3-HUP-R7.2: When the actual sequence is different from the planned sequence, the planning is preferably updated (automatically) ensuring the right IM target for each flight. If a mix-up of IM targets is a possible occurrence, the controller could be made aware of such mix-ups.</td></tr></table>	HP Issue / Benefit	Recommendation	1.3.1-1: The combined presentation of ITD and FTD indications and merge tool indications may lead to human errors.	REC-37-W3-HUP-R7.1: Design the HMI, such that: - It is clear which flights are IM capable and which are not; Validated in RTS2 - It is clear which flights are applying IM (validated in RTS2), and whether it is applied correctly (to the flight preceding on the route); - it is clear which flights are established on RNP; Validated in RTS2 - that ATCO can change the sequence with a minimal number of actions	REC-37-W3-HUP-R7.2: When the actual sequence is different from the planned sequence, the planning is preferably updated (automatically) ensuring the right IM target for each flight. If a mix-up of IM targets is a possible occurrence, the controller could be made aware of such mix-ups.	OK
HP Issue / Benefit	Recommendation						
1.3.1-1: The combined presentation of ITD and FTD indications and merge tool indications may lead to human errors.	REC-37-W3-HUP-R7.1: Design the HMI, such that: - It is clear which flights are IM capable and which are not; Validated in RTS2 - It is clear which flights are applying IM (validated in RTS2), and whether it is applied correctly (to the flight preceding on the route); - it is clear which flights are established on RNP; Validated in RTS2 - that ATCO can change the sequence with a minimal number of actions						
	REC-37-W3-HUP-R7.2: When the actual sequence is different from the planned sequence, the planning is preferably updated (automatically) ensuring the right IM target for each flight. If a mix-up of IM targets is a possible occurrence, the controller could be made aware of such mix-ups.						
Reference	Human Performance Assessment Report [4] Appendix A.3.2, paragraph 5						

Appendix B.3.2, paragraph 5

RTS1 and 2 questionnaires and debriefing

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.



4.2.1.7 OBJ-37-W3-DEMOP-HUP1-0008



Identifier	OBJ-37-W3-DEMOP-HUP1-0008	KPA Category	HUP
Title	Not Specified		
Objective	Assess the extent to which task performance is reduced by the integrated arrival concept.		
Success Criterion	CRT-37-W3-DEMOP-HUP1-0008	V3. Tasks are effectively achieved. Measured indicator: Questionnaires post-run, observation	

Results	In RTS 1, merging and spacing was performed in a timely manner. The post-run ratings of 'the successfulness in achieving the task' was rated 5.9 (scale 1-7) for both conditions, which is concluded to be acceptable. Nevertheless, one ATCO mentioned it was difficult to monitor the aircraft turning in for final and meanwhile dealing with aircraft separation before the merge point. In addition, ATCOs mentioned it to be cumbersome to change all IM targets when a sequence change was required. They tended to prefer to revert to vectoring. ATCOs did not report of any confusion on what to do. The tasks were not unclear. For RTS 2, the above mentioned results apply. It was concluded that merging and spacing were performed timely and tasks were not unclear. Nevertheless, meanwhile monitoring the traffic turning in for final was difficult. <table><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr><tr><td>1.3.2-1: Merging and spacing tasks cannot be undertaken in a timely manner whilst transitioning from IM/merge tool to PWS/ORD tool (e.g. scanning the merging and spacing of a/c; updating the spacing according to the envisaged arrival flow cannot be done in a timely manner)</td><td>REC-37-W3-HUP-R8.1: Consider automated adherence monitoring of the NTZ. REC-37-W3-HUP-R8.2: The concept should ensure the gradual reduction of speeds of arriving traffic.</td></tr><tr><td>1.3.2-2 The tasks of the ATCO are not clear with regard to actions required in relation to the IAC concept, for the transition from IM/merge tool to PWS/ORD tool, on RNAV/RNP-based fixed approach</td><td></td></tr></table>	HP Issue / Benefit	Recommendation	1.3.2-1: Merging and spacing tasks cannot be undertaken in a timely manner whilst transitioning from IM/merge tool to PWS/ORD tool (e.g. scanning the merging and spacing of a/c; updating the spacing according to the envisaged arrival flow cannot be done in a timely manner)	REC-37-W3-HUP-R8.1: Consider automated adherence monitoring of the NTZ. REC-37-W3-HUP-R8.2: The concept should ensure the gradual reduction of speeds of arriving traffic.	1.3.2-2 The tasks of the ATCO are not clear with regard to actions required in relation to the IAC concept, for the transition from IM/merge tool to PWS/ORD tool, on RNAV/RNP-based fixed approach		OK
HP Issue / Benefit	Recommendation							
1.3.2-1: Merging and spacing tasks cannot be undertaken in a timely manner whilst transitioning from IM/merge tool to PWS/ORD tool (e.g. scanning the merging and spacing of a/c; updating the spacing according to the envisaged arrival flow cannot be done in a timely manner)	REC-37-W3-HUP-R8.1: Consider automated adherence monitoring of the NTZ. REC-37-W3-HUP-R8.2: The concept should ensure the gradual reduction of speeds of arriving traffic.							
1.3.2-2 The tasks of the ATCO are not clear with regard to actions required in relation to the IAC concept, for the transition from IM/merge tool to PWS/ORD tool, on RNAV/RNP-based fixed approach								

	procedures (including initial, intermediate and final approach segments). This may result in tasks not adequately performed, hence not timely.	
Reference	Human Performance Assessment Report [4] Appendix A.3.2, paragraph 6 Appendix B.3.2, paragraph 6 RTS1 and 2 questionnaires and debriefing	

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.



4.2.1.8 OBJ-37-W3-DEMOP-HUP1-0009



Identifier	OBJ-37-W3-DEMOP-HUP1-0009		KPA Category	HUP
Title	Not Specified			
Objective	Assess the impact on ATCO workload by the integrated arrival concept.			
Success Criterion	CRT-37-W3-DEMOP-HUP1-0009	V3. Level of workload within acceptable limits ('acceptable limits' to be defined with regard to the tool used for the assessment). Measured indicator: Workload (modified NASA-TLX), post-run questionnaire and end-of-day questionnaire		

Results	In RTS 1, the NASA-TLX ratings of controllers in the overall analysis result in an average rating of 35 (on scale 0-100) and no significant differences between the solution and the reference. The post-experiment controller ratings showed that the controllers expected a positive influence of the solution concept on workload in comparison to the current way of working (m=4 (on scale 1-5)). Meanwhile it was said it was impossible to also check if the turn towards final was performed properly the scenarios with RWY 18/18. In RTS 2, the NASA-TLX ratings were between 30 and 40. The ratings of the runs with 100% equipage were increased compared to all other runs, contrary to what was expected. This is most likely due to simulation problems. For runs with more variation and with a go-around the workload rating was increased, as expected, but only slightly. For MRS 2.0 no increase was measured. For equipages of 20% and 80%, no increases in average ratings were found. The strong wind did not lead to increased workload, neither in the reference nor in the 100% equipage run, while the number of aircraft per hour remained at the level of 40/40. Concluding, the average workload ratings seem to be at acceptable levels. Nevertheless, ATCOs mentioned that that small disturbances have an impact on workload and that insufficient time remained to monitor the traffic turning towards final. The reduction of MRS to 2.0 does not seem to contribute to ATCO workload. <table><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr><tr><td rowspan="2">1.3.3-1: The level of APP ATCO workload has increased due to negative interaction between IM and PWS/ORD (increased executive control, increased time for monitoring conformance to instruction and monitoring spacing).</td><td>REC-37-W3-HUP-R9.1: Divide the work of the FDR between two ATCOs (TWEC/TOC). <i>Validated in RTS 2.</i></td></tr><tr><td>REC-37-W3-HUP-R9.2: Expand Non Transition Zone (automated monitoring) for traffic established on RNP (18/18). <i>Validated in RTS 2</i></td></tr></table>	HP Issue / Benefit	Recommendation	1.3.3-1: The level of APP ATCO workload has increased due to negative interaction between IM and PWS/ORD (increased executive control, increased time for monitoring conformance to instruction and monitoring spacing).	REC-37-W3-HUP-R9.1: Divide the work of the FDR between two ATCOs (TWEC/TOC). <i>Validated in RTS 2.</i>	REC-37-W3-HUP-R9.2: Expand Non Transition Zone (automated monitoring) for traffic established on RNP (18/18). <i>Validated in RTS 2</i>	OK
HP Issue / Benefit	Recommendation						
1.3.3-1: The level of APP ATCO workload has increased due to negative interaction between IM and PWS/ORD (increased executive control, increased time for monitoring conformance to instruction and monitoring spacing).	REC-37-W3-HUP-R9.1: Divide the work of the FDR between two ATCOs (TWEC/TOC). <i>Validated in RTS 2.</i>						
	REC-37-W3-HUP-R9.2: Expand Non Transition Zone (automated monitoring) for traffic established on RNP (18/18). <i>Validated in RTS 2</i>						
Reference	Human Performance Assessment Report [4] Appendix A.3.2, paragraph 7 Appendix B.3.2, paragraph 7 RTS1 and 2 questionnaires and debriefing						

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.



4.2.1.9 OBJ-37-W3-DEMOP-HUP1-0010



Identifier	OBJ-37-W3-DEMOP-HUP1-0010		KPA Category	HUP				
Title	Not Specified							
Objective	Assess the impact on ATCOs level of trust in the integrated arrival concept.							
Success Criterion	CRT-37-W3-DEMOP-HUP1-0010	V3. Potential issues related to trust and the preliminary mitigation identified are acceptable. Measured indicator: level of confidence in post-run and end-of-day questionnaire						
Results	In RTS 1, the average ATCO rating of confidence in the combination of tools was around 5.7 in the end-of-day questionnaire (on scale 1-9). ATCO's mentioned that the confidence is strongly related to the confidence in the pilots to follow the routes, which will in reality be different. In RTS 2, the average confidence in the combination of tools was 4.8 (scale 1-9, in the end-of-day questionnaire, but was also once rated value 1 and 2 (in day 2). ATCOs mentioned it was caused by the unexpected behaviour due to simulator issues, which makes it hard to draw conclusions. The ATCO confidence (in their own performance) was high in the post-run ratings. Overall the results were partially OK. The ATCOs' confidence in the concept was rated neutral to positive, with the remark that in the simulation the pilots were very collaborative and timely following up instructions, which is not the case in current day operations. <table><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr><tr><td>1.3.4-1: ATCOs do not trust the new working practices and related tools in relation to the transition from IM to PWS/ORD. This may lead to them adding extra buffers, interventions, not using the TDI's appropriately or not using all/most opportunities for IM procedures.</td><td>REC-37-W3-HUP-R10.1: Trust should develop with more experience. Test the concept with, for example: - Go-arounds: Validated in RTS2 - Provide a gap for runway inspection - Change sequence (e.g. emergency): Validated in RTS2 - Runway closure - Runway change </td></tr></table>			HP Issue / Benefit	Recommendation	1.3.4-1: ATCOs do not trust the new working practices and related tools in relation to the transition from IM to PWS/ORD. This may lead to them adding extra buffers, interventions, not using the TDI's appropriately or not using all/most opportunities for IM procedures.	REC-37-W3-HUP-R10.1: Trust should develop with more experience. Test the concept with, for example: - Go-arounds: Validated in RTS2 - Provide a gap for runway inspection - Change sequence (e.g. emergency): Validated in RTS2 - Runway closure - Runway change	POK c
HP Issue / Benefit	Recommendation							
1.3.4-1: ATCOs do not trust the new working practices and related tools in relation to the transition from IM to PWS/ORD. This may lead to them adding extra buffers, interventions, not using the TDI's appropriately or not using all/most opportunities for IM procedures.	REC-37-W3-HUP-R10.1: Trust should develop with more experience. Test the concept with, for example: - Go-arounds: Validated in RTS2 - Provide a gap for runway inspection - Change sequence (e.g. emergency): Validated in RTS2 - Runway closure - Runway change							
Reference	Human Performance Assessment Report [4]							

Appendix A.3.2, paragraph 8

Appendix B.3.2, paragraph 8

RTS1 and 2 questionnaires and debriefing

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.



4.2.1.10 OBJ-37-W3-DEMOP-HUP1-0011



Identifier	OBJ-37-W3-DEMOP-HUP1-0011		KPA Category	HUP						
Title	Not Specified									
Objective	Assess the impact on individual ATCO situation awareness levels by the integrated arrival concept									
Success Criterion	CRT-37-W3-DEMOP-HUP1-1011	V3. [GND only] Level of situational awareness not lower in the solution than in the reference scenario. Measured indicator: SASHA ratings (post-run questionnaires)								
	CRT-37-W3-DEMOP-HUP1-2011	V3. End user is able to perceive and interpret task relevant information and anticipate future events/actions. Measured indicator: ATCO feedback in post-run debriefings								
Results	In RTS 1, The post-run situation awareness (SA) ratings show differences between the solution (4.6) and reference (5.1) (on the SASHA scale 0-6). Thus the SA is slightly reduced in the solution concept. Especially the statement 'there was a risk of forgetting something important' is responsible for the difference. ATCOs mentioned that when an IM alert was given they were searching for the reason. In RTS 2, the average SA ratings varied between 4.4 and 5.2 (scale 0 – 6). For the 20% equipage the rating was highest and lowest for 100% equipage with increased variation at TMA entry. On average the ATCO SA seems sufficient. Partial equipage of the traffic does not seem to give severe problems of SA. The variation of accuracy of TMA entry seems to have a higher impact on SA. <table><thead><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr></thead><tbody><tr><td rowspan="3">1.3.5-1: ATCO level of SA may reduce due to negative interaction between PWS/ORD tool and IM/merge tool, e.g. indications of ORD and merge tools are mixed up.</td><td>REC-37-W3-HUP-R11.1: Improve IM alert: <i>Validated in RTS2</i></td></tr><tr><td>REC-37-W3-HUP-R11.2: Improve HMI to provide an indication when a flight is established on RNP: <i>Validated in RTS2</i></td></tr><tr><td>REC-37-W3-HUP-R11.3: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: <i>Validated in RTS2</i></td></tr></tbody></table>			HP Issue / Benefit	Recommendation	1.3.5-1: ATCO level of SA may reduce due to negative interaction between PWS/ORD tool and IM/merge tool, e.g. indications of ORD and merge tools are mixed up.	REC-37-W3-HUP-R11.1: Improve IM alert: <i>Validated in RTS2</i>	REC-37-W3-HUP-R11.2: Improve HMI to provide an indication when a flight is established on RNP: <i>Validated in RTS2</i>	REC-37-W3-HUP-R11.3: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: <i>Validated in RTS2</i>	OK
HP Issue / Benefit	Recommendation									
1.3.5-1: ATCO level of SA may reduce due to negative interaction between PWS/ORD tool and IM/merge tool, e.g. indications of ORD and merge tools are mixed up.	REC-37-W3-HUP-R11.1: Improve IM alert: <i>Validated in RTS2</i>									
	REC-37-W3-HUP-R11.2: Improve HMI to provide an indication when a flight is established on RNP: <i>Validated in RTS2</i>									
	REC-37-W3-HUP-R11.3: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: <i>Validated in RTS2</i>									
Reference	Human Performance Assessment Report [4]									

Appendix A.3.2, paragraph 9

Appendix B.3.2, paragraph 9

RTS1 and 2 questionnaires and debriefing

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.

4.2.1.11 OBJ-37-W3-DEMOP-HUP1-0012

Identifier	OBJ-37-W3-DEMOP-HUP1-0012		KPA Category	HUP					
Title	Not Specified								
Objective	Assess the extent to which the integrated arrival concept complies with the relevant HP Principles.								
Success Criterion	CRT-37-W3-DEMOP-HUP1-0012	V3. Visual displays are consistent with design standards or regulations. Rationales are provided in case of deviations from standards. Measured indicator: Information requirements, Post-run questionnaire.							
Results	In RTS 1, ATCOs did not indicate to have experienced any confusion between the tools in the post-run ratings of the Solution concept (for the Reference this was indicated once (1 in 8 runs)). The consistency of the design of the tools was rated negative by two of the three controllers. The inconsistencies between the ghost and the IM activation was mentioned to be confusing at first. In addition, the end-of-day questionnaires revealed that the potential for Human Error might increase with the Solution concept. In RTS 2, the results show similar trends (with several negative ratings due to the more unpredictable speed behaviour of IM, after the merge point). Overall it is concluded that visual displays are consistent with design standards and regulations and that the HMI was adequately improved for RTS 2. The inconsistencies due to the IM implementations need to be resolved. <table><thead><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr></thead><tbody><tr><td rowspan="2">2.3.3-1: Controllers may misidentify /mistake IM information and merge tool indicators with ORD tool indicators (and other information) on the radar screen due to their visual channels already heavily loaded.</td><td>REC-37-W3-HUP-R12.1: Improve HMI to provide an indication when a flight is (not) established on RNP: <i>Validated in RTS2.</i></td></tr><tr><td>REC-37-W3-HUP-R12.2: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: <i>Validated in RTS2.</i></td></tr></tbody></table>			HP Issue / Benefit	Recommendation	2.3.3-1: Controllers may misidentify /mistake IM information and merge tool indicators with ORD tool indicators (and other information) on the radar screen due to their visual channels already heavily loaded.	REC-37-W3-HUP-R12.1: Improve HMI to provide an indication when a flight is (not) established on RNP: <i>Validated in RTS2.</i>	REC-37-W3-HUP-R12.2: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: <i>Validated in RTS2.</i>	OK
HP Issue / Benefit	Recommendation								
2.3.3-1: Controllers may misidentify /mistake IM information and merge tool indicators with ORD tool indicators (and other information) on the radar screen due to their visual channels already heavily loaded.	REC-37-W3-HUP-R12.1: Improve HMI to provide an indication when a flight is (not) established on RNP: <i>Validated in RTS2.</i>								
	REC-37-W3-HUP-R12.2: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: <i>Validated in RTS2.</i>								
Reference	Human Performance Assessment Report [4]								

Appendix A.3.2, paragraph 10

Appendix B.3.2, paragraph 10

RTS1 and 2 questionnaires and debriefing

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.

4.2.1.12 OBJ-37-W3-DEMOP-HUP1-0013

Identifier	OBJ-37-W3-DEMOP-HUP1-0013		KPA Category	HUP				
Title	Not Specified							
Objective	Assess the extent to which the user interface reduces human performance and service delivery.							
Success Criterion	CRT-37-W3-DEMOP-HUP1-0013	V3. [GND only] Usability rating for the integrated interface not lower in the solution than in the reference scenario. Measured indicator: HMI usability						
Results	In RTS 1, the usability of the HMI was not unacceptable, nevertheless several HMI improvements were identified and implemented for RTS 2. In RTS 2, the HMI usability of 4.7 to 6.0 on average (scale 1-7). The usability of the combined information was acceptable. Overall it was concluded that the HMI does not negatively impact the human performance and supported the ATCOs in performing their tasks. The usability of the HMI was acceptable to the ATCOs <table><thead><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr></thead><tbody><tr><td>2.3.6-2: The usability of the (combined) IM information, merge tool and ORD tool indications is not acceptable for APP ATCOs including input devices, output devices/displays, and alarms & alerts, (e.g. as there is too much clutter on the screen).</td><td>REC-37-W3-HUP-R13.1: Improve HMI: <i>Validated in RTS2.</i></td></tr></tbody></table>			HP Issue / Benefit	Recommendation	2.3.6-2: The usability of the (combined) IM information, merge tool and ORD tool indications is not acceptable for APP ATCOs including input devices, output devices/displays, and alarms & alerts, (e.g. as there is too much clutter on the screen).	REC-37-W3-HUP-R13.1: Improve HMI: <i>Validated in RTS2.</i>	OK
HP Issue / Benefit	Recommendation							
2.3.6-2: The usability of the (combined) IM information, merge tool and ORD tool indications is not acceptable for APP ATCOs including input devices, output devices/displays, and alarms & alerts, (e.g. as there is too much clutter on the screen).	REC-37-W3-HUP-R13.1: Improve HMI: <i>Validated in RTS2.</i>							
Reference	Human Performance Assessment Report [4] Appendix A.3.2, paragraph 11 Appendix B.3.2, paragraph 11 RTS1 and 2 questionnaires and debriefing							



This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.



4.2.1.13 OBJ-37-W3-DEMOP-HUP1-0014

Identifier	OBJ-37-W3-DEMOP-HUP1-0014		KPA Category	HUP				
Title	Not Specified							
Objective	Assess the impact on team ATCO situation awareness levels by the integrated arrival concept							
Success Criterion	CRT-37-W3-DEMOP-HUP1-0014	V3. Team is able to perceive and interpret task relevant information and anticipate future events/actions. Measured indicator: ATCO ratings of Team SA						
Results	In RTS 1, the team SA was not significantly different between the two conditions considering the post-run ratings as well as the post-experiment ratings. It seemed that specifically for the role of the Feeder ATCO the Team SA was reduced in the Solution and also in comparison to the team SA as experienced by the Arrival ATCOs. In RTS 2, the team SA was rated on average 5.7 (scale 1-7) in the post-run questionnaire. Nevertheless, the expected effect of the concept on Team SA was on average rated slightly reduced (2.6 on scale 1-5, end-of-day questionnaire) compared to current day operations. In RTS2, the Team SA of the Feeder ATCO was not lower compared to the Arrival ATCOs. It was concluded that Team SA was high, but may reduce slightly in comparison to current day operations. <table><thead><tr><th>HP Issue / Benefit</th><th>Recommendation</th></tr></thead><tbody><tr><td>2.3.9-1: The design of the HMI should support the level of individual situation awareness for all terminal controllers in order to support sufficient levels of team SA. Failure to do so could impact the efficiency and effectiveness of the team.</td><td>REC-37-W3-HUP-R14.1: Show the ghost only for flights almost in TMA. Validated in RTS2.</td></tr></tbody></table>			HP Issue / Benefit	Recommendation	2.3.9-1: The design of the HMI should support the level of individual situation awareness for all terminal controllers in order to support sufficient levels of team SA. Failure to do so could impact the efficiency and effectiveness of the team.	REC-37-W3-HUP-R14.1: Show the ghost only for flights almost in TMA. Validated in RTS2.	OK
HP Issue / Benefit	Recommendation							
2.3.9-1: The design of the HMI should support the level of individual situation awareness for all terminal controllers in order to support sufficient levels of team SA. Failure to do so could impact the efficiency and effectiveness of the team.	REC-37-W3-HUP-R14.1: Show the ghost only for flights almost in TMA. Validated in RTS2.							
Reference	Human Performance Assessment Report [4]							

Appendix A.3.2, paragraph 12

Appendix B.3.2, paragraph 12

RTS1 and 2 questionnaires and debriefing

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.

4.2.1.14 OBJ-37-W3-DEMOP-HUP1-0015

Identifier	OBJ-37-W3-DEMOP-HUP1-0015	KPA Category	HUP
Title	Not Specified		
Objective	The integrated tool does not deteriorate the arrival management process		
Success Criterion	CRT-37-W3-DEMOP-HUP1-0015	Under nominal conditions, there shall be no need to fall back on the use of vectoring operations while using the integrated tool.	
Results	<u>Flight Trial:</u> Air traffic controllers never intervened with radar vectors or intermediate level-offs. The fixed routes with a fixed descent profile was always adhered to (11 test flights, 61 test runs). <u>RTS:</u> In RTS 1, the number of flights vectored was not higher in the solution in comparison to the reference. In the condition with strong wind the ATCOs decided to apply a larger separation distance. In RTS 2, abnormal system behaviour was deteriorating the arrival management process in a few runs. This abnormal behaviour was in itself an integration issue but is believed to be solvable in next iterations. Overall it is concluded that the integration is complex. Small changes meant to improve the integration proved to have unexpected results. Nevertheless, it is expected that if flights are delivered accurately into the TMA the concept could work, allowing continuous descents at high throughput.		OK (Flight Trial) POK (RTS)
Reference	<u>Flight Trial:</u> Appendix C.3.2 paragraph 2. Pilot questionnaire data, observations, logged aircraft data (trailing & leading aircraft state data, FIM equipment data) <u>RTS:</u> Human Performance Assessment Report [4] Appendix A.3.2, paragraph 13		

Appendix B.3.2, paragraph 13

RTS1 and 2 observations and simulation data logs

This objective is evaluated in EXE-PJ.37-W3-003. For detailed analysis, refer to Appendix C.3.2 paragraph 2.

This objective is also evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to the Human Performance Assessment Report [4], Appendix A.3.2 and Appendix B.3.2.

4.2.1.15 OBJ-37-W3-DEMOP-HUP1-0016

Identifier	OBJ-37-W3-DEMOP-HUP1-0016		KPA Category	HUP
Title	Not Specified			
Objective	The IM execution is feasible while performing RNP/RNAV procedures with a defined vertical profile			
Success Criterion	CRT-37-W3-DEMOP-HUP1-0016	Under nominal conditions, there is no need to deviate from the defined horizontal or vertical path or deviate from the IM speeds (for prolonged periods of time)		
Results	During all runs the aircraft successfully adhered to the defined vertical profile (2.0-deg or 2.5-deg) and nominal speed profile for the lead aircraft and IM speeds for the trail aircraft.			OK
Reference	Appendix C.3.2 paragraph 3. Pilot questionnaire data, observations, logged aircraft data (trailing & leading aircraft state data, FIM equipment data).			

This objective is evaluated in EXE-PJ.37-W3-003. For detailed analysis, refer to Appendix C.3.2 paragraph 3.

4.2.2 Capacity Demonstration Objective

4.2.2.1 OBJ-37-W3-DEMOP-CAP1-0001

Identifier	OBJ-37-W3-DEMOP-CAP1-0001	KPA Category	CAP
Title	Not Specified		
Objective	The runway throughput level shall remain at the same level or increase against the reference scenario		
Success Criterion	CRT-37-W3-DEMOP-CAP1-0001	There is no negative effect on the runway throughput by using the integrated tool in nominal operations against the reference scenario.	
Results	There is no negative effect on the runway throughput by using the integrated tool in nominal operations against the reference scenario. The runway throughput for each runway does not vary much when increasing the IM equipage rate. When increasing the traffic load, the throughput increases as expected as long as the traffic is operating nominally.		OK
Reference	Appendix A.3.2 paragraph 14 for EXE-PJ.37-W3-001. Appendix B.3.2 paragraph 14 for EXE-PJ.37-W3-002. Simulation data (traffic logs per timestamp)		

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to Appendix A.3.2 paragraph 14 for EXE-PJ.37-W3-001 and Appendix B.3.2 paragraph 14 for EXE-PJ.37-W3-002. Recommendations in the first exercise have been implemented in the second exercise. Thus the result reflects the outcome of the second exercise.

4.2.2.2 OBJ-37-W3-DEMOP-CAP1-0002

Identifier	OBJ-37-W3-DEMOP-CAP1-0002	KPA Category	CAP
Title	Not Specified		
Objective	The airspace capacity shall remain at the same level or increase against the reference scenario		
Success Criterion	CRT-37-W3-DEMOP-CAP1-0002	There is no negative effect on the airspace capacity by using the integrated tool in nominal operations against the reference scenario	
Results	There is no negative effect on the airspace capacity by using the integrated tool in nominal operations against the reference scenario. Airspace capacity on fixed routes is evaluated using runway throughput and number of aircraft under control (UCO) by a controller. Increasing traffic load resulted in more aircraft UCO, however peak number of aircraft UCO is similar to lower traffic load.		OK
Reference	Appendix A.3.2 paragraph 15 for EXE-PJ.37-W3-001. Appendix B.3.2 paragraph 15 for EXE-PJ.37-W3-002. Simulation data (traffic logs per timestamps)		

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to Appendix A.3.2 paragraph 15 for EXE-PJ.37-W3-001 and Appendix B.3.2 paragraph 15 for EXE-PJ.37-W3-002. Recommendations in the first exercise have been implemented in the second exercise. Thus the results reflects the outcome of the second exercise.

4.2.2.3 OBJ-37-W3-DEMOP-CAP1-0003

Identifier	OBJ-37-W3-DEMOP-CAP1-0003		KPA Category	CAP
Title	Not Specified			
Objective	The delivery of aircraft on final shall be improved			
Success Criterion	CRT-37-W3-DEMOP-CAP1-0003	The use of the on-board FIM capability shall provide a highly accurate (< 9.3 sec spacing error, 95%) delivery of the IM aircraft on final, for both in-trail and merging operations to the same runway.		
Results	98% of the runs complied with the 9.3-second tolerance at the Planned Termination Point, which was located at the Final Approach Point (based on 11 test flights, 49 test runs)			OK
Reference	Appendix C.3.2 paragraph 4 Logged aircraft data (trailing aircraft state data, FIM equipment data)			

This objective is evaluated in EXE-PJ.37-W3-003. For detailed analysis, refer to Appendix C.3.2 paragraph 4.

4.2.3 Operational Efficiency Demonstration Objective

4.2.3.1 OBJ-37-W3-DEMOP-PRD1-0001

Identifier	OBJ-37-W3-DEMOP-PRD1-0001		KPA Category	OPE
Title	Not Specified			
Objective	The predictability of arriving traffic shall remain at the same level or increase against the reference scenario.			
Success Criterion	CRT-37-W3-DEMOP-PRD1-0001	There is no negative effect on the predictability of the traffic in the TMA by using the integrated tool.		
Results	The integrated tool does not have a negative effect on the predictability as the average difference between the actual and planned time in the TMA for the solution runs is within seconds compared to the reference run. With increasing IM equipage rate the spread in the difference between the actual and planned time in the TMA decreased.			OK
Reference	Appendix A.3.2 paragraph 16 for EXE-PJ.37-W3-001. Appendix B.3.2 paragraph 16 for EXE-PJ.37-W3-002.			

Simulation data (traffic logs and arrival manager logs per timestamps)
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This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to Appendix A.3.2 paragraph 16 for EXE-PJ.37-W3-001 and Appendix B.3.2 paragraph 16 for EXE-PJ.37-W3-002. In the first simulation, the average difference between the actual and planned time in the TMA was smaller in the solution runs. In the second simulation, the difference between the reference and solution run was within seconds of each other. The results to this objective reflects the outcome of the second exercise.

4.2.4 Environment Demonstration Objective

4.2.4.1 OBJ-37-W3-DEMOP-NOI1-0001

Identifier	OBJ-37-W3-DEMOP-NOI1-0001	KPA Category	ENV
Title	Not Specified		
Objective	The noise profile will not increase against the reference scenario.		
Success Criterion	CRT-37-W3-DEMOP-NOI1-0001	The use of the integrated tool does not increase the noise profile in the nominal simulation against the reference scenario.	
Results	In nominal simulation, the 55 dB noise contour area in the solution run decreased with less than 1%. Differences are too small to conclude that the 55 dB noise contour area has improved, however the area did not increase.		OK
Reference	Appendix A.3.2 paragraph 17 for EXE-PJ.37-W3-001. Appendix B.3.2 paragraph 17 for EXE-PJ.37-W3-002. Detailed analysis is provided in DEMOR Part IV – Environment Assessment Report [5]. ECAC Doc29 guidance standard of computing noise contours around airports Simulation data (traffic logs per timestamps)		

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to DEMOR Part IV – Environment Assessment Report [5] Chapter 4.4. Recommendations in the first exercise have been implemented in the second exercise. Thus the results reflects the outcome of the second exercise.

4.2.4.2 OBJ-37-W3-DEMOP-ENV1-0001

Identifier	OBJ-37-W3-DEMOP-ENV1-0001		KPA Category	ENV
Title	Not Specified			
Objective	The CO2 emissions will not increase against the reference scenario			
Success Criterion	CRT-37-W3-DEMOP-ENV1-0001	The use of the integrated tool does not increase the CO2 emission in the nominal simulation against the reference scenario.		
Results	In the nominal simulation, the solution run with the integrated tool emitted 6.7% less CO2 than the reference run.			OK
Reference	Appendix A.3.2 paragraph 18 for EXE-PJ.37-W3-001. Appendix B.3.2 paragraph 18 for EXE-PJ.37-W3-002. Detailed analysis is provided in DEMOR Part IV – Environment Assessment Report [5]. Simulation data (traffic logs per timestamps)			

This objective is evaluated in EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002. For detailed analysis, refer to DEMOR Part IV – Environment Assessment Report, Track PJ.37-W3-01A [5] Chapter 4.3. Recommendations in the first exercise have been implemented in the second exercise. Thus the results reflects the outcome of the second exercise.

4.2.5 Safety Demonstration Objective

The tables below provide an analysis of the RTS1 and RTS2 results per safety demonstration objective. For justification and full details, please see DEMOR Part II - Safety Assessment Report, Track PJ.37-W3-01A [3] Appendix A -Analysis of Safety Objectives.

4.2.5.1 OBJ-37-W3-DEMOP-SAF1-0001

Identifier	OBJ-37-W3-DEMOP-SAF1-0001		KPA Category	Safety
Title	Not Specified			
Objective	The number of go-arounds due to insufficient spacing shall not be greater than in the reference scenario			
Success Criterion	CRT-37-W3-DEMOP-SAF1-0001	The use of the integrated tool shall not increase the number of controller-instructed go-arounds.		
Results	Based on the data in RTS1, the fact that more go-arounds occurred in solution runs than in reference runs cannot be related to the new combination of tools. The questionnaires did not reveal a concern regarding this objective either. Therefore, it was concluded that the number of go-arounds due to insufficient spacing is not increased by the combination of tools. This conclusion was confirmed during RTS2, which did not include any go-arounds due to insufficient spacing. Recommendations REC-37-W3-SAF-R1.1: For a more accurate representation of the safety objectives being studied, incorporate a runway controller in future simulations to manage traffic on the final approach segment and collaborate with the arrival (ARR) controller in instances that may result in go-arounds REC-37-W3-SAF-R1.2: In future simulations it is recommended to incorporate an ACC controller. If a go-around occurs, the ACC or the APP controller should delay the traffic that is still further away from the runway, in order to create some space in the sequence.			OK (Full)
Reference	Post-run questionnaire			
	Data analysis on KPI-01			

Table 4-1: Results for OBJ-37-W3-DEMOP-SAF1-0001: The number of go-arounds due to insufficient spacing shall not be greater than in the reference simulation

4.2.5.2 OBJ-37-W3-DEMOP-SAF1-0003

Identifier	OBJ-37-W3-DEMOP-SAF1-0003		KPA Category	Safety
Title	Not Specified			
Objective	The interoperability of the different tools in the integrated tool shall not introduce safety issues.			
Success Criterion	CRT-37-W3-DEMOP-SAF1-0003	Ensure that the functionalities of all solutions complement one another without negative interference.		
Results	The FIM system's task is to create spacing between aircraft on fixed routes, but its efficiency depends on the accuracy of the EAT provided by E-AMAN. During a simulation, the actual flight sequence was sometimes different from the planned sequence, resulting in illogical pairings and unpredictable operation. This highlights the need for reliable EAT on the TMA boundary for the FIM system to work properly. However, the likelihood of the E-AMAN system providing unreliable EAT in real-life operations is small and the consequences are likely to be low as the ACC controller and flight crew may detect and resolve any issues before the aircraft arrives in the TMA. Nevertheless, ATCOs are not informed if the pairing is illogical, resulting in the safety objective not being fully met. The overall score for this system is "Partial OK." Recommendations REC-37-W3-SAF-R3.1: For future simulations or demonstrations, implement a safety mechanism to alert ATCOs in case of any compatibility issues between the FIM system/algorithm and the E-AMAN system/algorithm, such as illogical aircraft pairings. REC-37-W3-SAF-R3.2: Consider expanding the coverage of the FIM system to include the ACC airspace, in addition to the TMA airspace. This could provide more time and space for the system to maintain appropriate spacing between aircraft and to create gaps in case an aircraft needs to re-sequenced. REC-37-W3-SAF-R3.3: Enhance the realism of future simulations or demonstrations by incorporating more realistic speed profiles of aircraft. Refining the FIM algorithms and ensuring seamless transitions between them may be necessary to achieve this.			Partial OK (POK)
Reference	Post-run questionnaire Remarks end-of-run debrief-sessions Remarks end-of-experiment debrief session			

Table 4-2: Results for OBJ-37-W3-DEMOP-SAF1-0003: The interoperability of the different tools in the integrated tool shall not introduce safety issues



4.2.5.3 OBJ-37-W3-DEMOP-SAF1-0004



Identifier	OBJ-37-W3-DEMOP-SAF1-0004		KPA Category	Safety
Title	Not Specified			
Objective	There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts).			
Success Criterion	CRT-37-W3-DEMOP-SAF1-0004	The use of the integrated tool and the Airborne Spacing Flight Deck Interval Management does not lead to an increased number of separation losses in the nominal solution as compared against the reference scenario.		
Results	The data of RTS1 showed that for both MRS and ROT, the solution runs did not seem to have more cases of LOS than the reference runs, and even showed much fewer. In the questionnaires and the debriefing the controllers did have a few concerns with wake turbulence separation losses, however. During RTS2, the number of LOSs during solution runs was similar to the number of LOSs in reference runs under comparable circumstances. The controllers did have a few concerns regarding LOSs, but these seemed to be mainly due to the high traffic density, the perceived controllability and the use of FIM, rather than due to the combination of tools. Therefore, the results of RTS2 appeared to confirm the RTS1 conclusion. Recommendations REC-37-W3-SAF-R4.1: To include a runway controller in the simulations, who controls the traffic on the final approach segment, and who can coordinate with the arrival (ARR) controller regarding situations that may lead up to losses of separation due to WTS, MRS, and ROT. This would provide a more realistic picture regarding the safety objectives studied. REC-37-W3-SAF-R4.2: The previous recommendation would also create the opportunity to study a safety objective that was omitted from the analysis in this report: OBJ-37-W3-DEMOP-SAF1-0002 (The variability in Clearance to Land margin decreases for ROT constrained pairs). REC-37-W3-SAF-R4.3: The objectives studied looked at safety up to the level of potential for loss of separation, limited by the nature of real time simulations. In order to assess the risk of a mid-air collision and the risk of wake turbulence related accidents, as is required in SESAR safety reference material (SRM), in a follow on project it is recommended to use Dynamic Risk Modelling to assess the safety benefits of the combination of tools more accurately.			OK (Full)
Reference	Post-run questionnaire			

Data analysis on KPI-02, KPI-03

Table 4-3: Results for OBJ-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)

4.2.5.4 OBJ-37-W3-DEMOP-SAF1-0005

Identifier	OBJ-PJ.37-W3-DEMOP-SAF1-0005		KPA Category	Safety
Title	Not Specified			
Objective	The perceived controllability of the operation by ATCO shall not degrade due to the use of the integrated tool.			
Success Criterion	CRT-37-W3-DEMOP-SAF1-0005	The tool gives the ATCO the means to intervene. The use of the tool does not lead to a perceived loss of controllability of the operation by the ATCO in relation to the conventional operation. This is assessed through a qualitative analysis.		
Results	At the beginning of RTS1, the controllers did feel less in control during the solution runs, compared to the reference runs. However, this seemed to be mainly due to the use of a single tool rather than to the combination of tools. Moreover, post-experiment they indicated to have grown more positive regarding the solution runs. The execution of RTS2 helped the controllers to become more familiar with and obtain more experience with the integrated tool, resulting in increased trust. However, some simulation issues arose during the runs, leading to concerns about the perceived controllability in real-world operations. Some of these disturbances were related to the integration of AMAN and FIM. The concerns warrant further attention in future testing and simulations. Therefore, at this moment we cannot conclude that objective OBJ-37-W3-DEMOP-SAF1-0005 is fully met. Recommendations REC-37-W3-SAF-R5.1: Assess the similarity of simulation issues encountered during RTS2 to real-world operational scenarios. In future testing and simulations, include these types of events in scenarios to gauge the operational efficiency and durability of the tools used. REC-37-W3-SAF-R5.2: Evaluate the ability of controllers to handle non-typical operational disruptions that occur frequently in real-world practice. Incorporate these events into scenarios for future testing and simulations to assess the efficiency and stability of the tools and overall operation during such situations.			Partial OK (POK)
Reference	Post-run questionnaire RTS2 End of Day questionnaire Additional input from Post-experiment questions on perceived workload, situation awareness and potential for human error.			

Table 4-4: Results for OBJ-37-W3-DEMOP-SAF1-0005: The perceived controllability of the operation by ATCO shall not degrade due to the use of the integrated tool

4.2.5.5 OBJ-37-W3-DEMOP-SAF1-0006

Identifier	OBJ-37-W3-DEMOP-SAF1-0006	KPA Category	SAF
Title	Not Specified		
Objective	The use of IM operations shall not result in any unsafe condition during the live trial		
Success Criterion	CRT-37-W3-DEMOP-SAF1-0006	No major safety issues are identified both during the test flights and debriefings by the flight crew of the IM aircraft	
Results	Safety was not an issue during the flight trial based on pilot feedback.		OK
Reference	Appendix C.3.2 paragraph 5. Pilot questionnaire data, observations, logged aircraft data		

Table 4-5: Results for OBJ-37-W3-DEMOP-SAF1-0006: The use of IM operations shall not result in any unsafe condition during the live trial

This objective is evaluated in EXE-PJ.37-W3-003. For detailed analysis, refer to Appendix C.3.2 paragraph 5.



4.2.5.6 OBJ-37-W3-DEMOP-SAF1-0007



Identifier	OBJ-37-W3-DEMOP-SAF1-0007	KPA Category	SAF
Title	Not Specified		
Objective	The FIM system performs its intended function during the live trial (airworthiness related objective)		
Success Criterion	CRT-37-W3-DEMOP-SAF1-0007	No functional issues related to the FIM system standard (ED-236A) are identified during the test flights (e.g. non-compliance or other issues with relevant ED-236A requirements).	

Results	The vast majority of the FIM functions worked as intended. A gap is the limited ADS-B In range observed during the flight trial, this was attributed to the specific antenna installation Furthermore, a very limited number of updated/new FIM MOPS requirements still need to be implemented. Recommendations REC-37-W3-SAF-R7.1: It is recommended to address the ADS-B IN system performance gap by setting up a test/exercise to demonstrate adequate ADS-B In range performance, with an improved antenna installation and possibly a decreased RF interference at the aircraft level. As part of this demonstration on an aircraft, the RF performance should be verified after installation and before starting the flight test. REC-37-W3-SAF-R7.2: It is recommended to update the FIM software to comply with the new traffic alignment requirements of the FIM MOPS. REC-37-W3-SAF-R7.3: It is recommended that the FIM software should be improved to be more robust regarding waypoint sequencing and should have an easier option for restoring waypoints that should not have been sequenced. REC-37-W3-SAF-R7.4: It is recommended to update the FIM software to ignore what traffic reports after it sequences the PTP for time-based IM clearances. However, this is not a critical issue and it is therefore proposed to address/discuss it in the standards (FIM MOPS requirement IM.011) whenever the FIM MOPS will be revised for others reasons. REC-37-W3-SAF-R7.5: It is recommended to update the FIM software to comply with the updated traffic path conformance requirements of the FIM MOPS. REC-37-W3-SAF-R7.6: It is recommended to perform a live trial in Europe with a (limited) number of airliner's aircraft being equipped with a FIM system that is approved under TSO-C195c (and therefore complies with the system requirements of EUROCAE ED-236A Change 1 / RTCA DO-361A Change 1) and an ATC centre/sector actively supporting and using IM operations. This operational trial could seamlessly be continued (i.e. deployed) in that ATC environment. Prerequisite is the availability and usage of a PBN route structure in that part of the airspace.	POK
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Reference	Appendix C.3.2 paragraph 6. Pilot questionnaire data, observations, logged aircraft data.
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Table 4-6: Results for OBJ-37-W3-DEMOP-SAF1-0007: The FIM system performs its intended function during the live trial (airworthiness related objective)

This objective is evaluated in EXE-PJ.37-W3-003. For detailed analysis, refer to Appendix C.3.2 paragraph 6.

4.3 Summary of Departure Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0017	Assess the ability of controllers to follow operating methods	CRT-37-W3-DEMOP-HUP1-0017	V3. Tasks are effectively achieved.	ATCOs could follow the operating methods without significant WL increase or SA issues, even in failure and degraded mode cases, but they expressed a preference for additional support, e.g., a fallback matrix for failure mode. Potential issue in applying operating methods for 'inter' wake categories were quoted: "I only looked at the countdown timer when I believed a wake separation was required. This works in a RECAT-EU scenario but if there were 'inter' wake category separations I am not sure I would have realised". Questionnaire feedback indicated that participants tended to ignore the tool during an 'event'.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0018	Assess the credibility of potential human errors, the associated risk and identify mitigations if appropriate	CRT-37-W3-DEMOP-HUP1-0018	V3. Number of errors in the solution not significantly higher than in reference scenario, taking into account error type & operational impact.	During the stakeholder workshop, ATCOs stated they felt like the extended OSD tool supported them in better completing their tasks and that training and experience with the tool would significantly decrease any potential human performance and human error related risks	OK
OBJ-37-W3-DEMOP-HUP1-0019	Assess the extent to which task performance is impacted by the concept solution	CRT-37-W3-DEMOP-HUP1-0019	V3. Tasks are effectively achieved	The post-RTS questionnaire data analysis showed that all entries agreed (30.5%) and strongly agreed (69.5%) that controlling tasks can be achieved in a timely manner. During the stakeholder workshop, ATCOs stated that they do not feel like the decrease of separations would impact other tasks or their timeliness and that they could perform their tasks effectively. However, ATCOs did suggest that being supported by a type of departure manager (DMAN) would be useful, as tasks could be achieved more efficiently in a timelier manner by knowing departure information in advance: “having the knowledge about departure sequence would be helpful and less distracting”. Additionally, they consider that not having to work out the time and instead following the timer would generate a taskload decrease leading to a reduction in cognitive workload. As such, they felt they could reallocate resources to other relevant activities	OK

OBJ-37-W3-DEMOP-HUP1-0009	Assess the impact to workload by the concept solution	CRT-37-W3-DEMOP-HUP1-0009	V3. Level of workload within acceptable limits ('acceptable limits' to be defined with regard to the tool used for the assessment).	Most entries (44.1%) indicated moderate average WL levels and moderate-high peak WL levels (47.1%). Participants stated that workload was more manageable thanks to support given by MDI restriction on the tool and the workload level was overall more manageable with the tool. The TMA data feed scenario yielded the best results, pointing to a shift towards the lower end of the WL scale as opposed to baseline and no TMA feed. Additionally, they consider that not having to work out the time and instead following the timer would generate a taskload decrease that would even allow them to have the mental capacity/availability to do something else. Lastly, participants felt using the tool would decrease WL during the hours of darkness (when operations would imply using the lighting screen – not tested in the RTS), as opposed to current operations During the stakeholder workshop, the ATCOs acknowledged that in failure modes an immediate spike in workload could ensue, which normally would then flatten, with no significantly greater impact than today's operations. Participants pointed out that the separation delivery tool can be highly beneficial especially in a restriction and departure heavy period, but that system failure in such a situation could be problematic. As such, they agreed that the business of operations, level of ATCO experience and the fallback matrix would play a defining role in the flattening of that curve. Having a very restrictive	OK
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Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				fallback matrix to follow during failure mode could work, but it would be difficult to follow during very busy times and it would increase workload. The impact of potential skill fade on manual operations fallback was also raised. Controllers expressed a preference for having a clear indication regarding the nature of the displayed time (whether it relates to a route separation or flow restriction), as not having the difference clearly expressed could lead to a workload increase. A negligible increase in WL due to communication and coordination aspects with the ground controller was quoted	



OBJ-37-W3-DEMOP-HUP1-0021	Assess the impact on situation awareness by the concept solution	CRT-37-W3-DEMOP-HUP1-0021	V3. User is able to perceive and interpret task relevant information and anticipate future events/actions.	During the stakeholder workshop participants explained that when using the tool, they were thinking less about the geometry and situation, so they felt the SA would be better without the tool. While this would not be problematic during nominal operations (ATCOs felt like the RWY throughput increase would not significantly influence their SA), they considered it could raise issues in the system failure case, especially for inexperienced ATCOs. They stated that while the tool unlocks future features, trying to unwind in that scenario could sometimes be impossible (“the more helpful and encompassing the tool becomes, the more dramatic the fallback would be”). However, results of the post-simulation questionnaire showed that an acceptable level of situational awareness was achievable for all the reported levels of workload. Most entries (57.6%) indicated a very good SA level, with the TMA data feed scenario yielding the best results. Positive feedback from participants on seeing/hearing/understanding the information given by the tool for task completion (most of them agreed), as well as on mental model acquisition. There were no outstanding issues about potential distractions regarding the tool affecting SA, other than the potential for being distracted by corrupt data if the tool malfunctioned. No outstanding issues were identified in terms of scanning patterns.	OK
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Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0022	Assess the extent to which automating SID separation calculations enables controllers to make quicker decisions	CRT-37-W3-DEMOP-HUP1-0022	V3. Task allocation is found to be consistent with good deliverables of 16.5.1, "Guidance material for HP automation support", and/ or other automation guidelines. Please note: deliverable 16.5.1 is SESAR's Guidance Materials on HP Automation Support (Edit 00.01.00). This document provides guidance material on automation design and evaluation that HF specialists can apply to airborne and ground operational and technical projects involving automation.	The post-sim questionnaire data analysis and workshop discussion revealed that controllers not only felt that the extended OSD tool enabled them to achieve tasks in a timely manner, but also considered that by means of eliminating the mental calculations they would be supported in faster decision making. Moreover, the taskload decrease would even allow for additional mental resources to reallocate to other relevant activities.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0023	Assess the extent automating route spacing calculations improves human performance	CRT-37-W3-DEMOP-HUP1-0023	V3. The task allocation is consistent with deliverable of 16.5.2. Please note: deliverable 16.5.2 is SESAR's Final Report on the trade-off between planning and flexibility (Edit 00.00.02). The purpose of this document is to guide the SESAR primary projects in assessing the impact of any automated planning tools on the flexibility of the aviation system, with a focus on the flexibility to introduce changes after the planning cycle is complete.	ATCOs stated that they feel confident in the level of automation of the extended OSD tool and the task allocation between themselves and the tool. They feel like the tool represents a good “median” solution: considering that it cannot take into account all the external variables with high precision (e.g., the wind) such that a generic algorithm would be devised for accurate and optimised day-by-day operation, they are still required to make judgements on the length of the take-off roll depending on those variables (which avoids total deskilling and ensures they are not overly reliant on the tool for issuing take-off clearances, making ATCOs feel like they are still in the loop), but they are supported in their controlling tasks.	OK
OBJ-37-W3-DEMOP-HUP1-0024	Assess users' mode switching capability	CRT-37-W3-DEMOP-HUP1-0024	V3. There are no excessive cognitive demands or potential for error in transition tasks.	Consider currency training for manual mode operations (potentially during the yearly emergency training or other methods). The concept should be expanded to include the impact on the total training pipeline (i.e., TATCs & inexperienced controllers).	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0026	Assess the extent to which actors can acquire mental models	CRT-37-W3-DEMOP-HUP1-0026	V3. Understanding of the technical system's behaviour is consistent with the operator's task demands.	All participants agreed and strongly agreed with the fact that the tool supports them in creating an accurate mental model, which aids them in decision making and future state forecasting of separating aircraft. Still, during the expert workshop they stated that when using the tool, they were thinking less about the geometry and the situation, hinting at automation complacency and degraded SA. Although respondents claimed that the tool allowed for more time to plan, sequence and monitor, they felt like they could benefit from support from a departure manager (DMAN), which would help better separate aircraft based on predicted sequencing.	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0027	Assess the extent to which the accuracy of the system meets HP requirements	CRT-37-W3-DEMOP-HUP1-0027	V3. Information accuracy experienced as sufficient by the end user.	During the expert workshop, ATCOs emphasized that credibly corrupt data could be a critical issue, as both the experienced and inexperienced ATCOs would have difficulty in realizing that something is wrong, based on the type of traffic they have (the issue would be more prominent for inexperienced ATCOs: “If you don’t have the knowledge to know what the separations really should be, there are minimal chances you’ll even notice that”). Participants also felt like the corrupt data could create distractions if still displayed and expressed a preference for having the option to switch the tool off in such scenarios. Failure to address the credibly corrupt data scenario could have a serious negative impact on the safety of operations, as controllers could give a premature take-off clearance and/or be overwhelmed upon realizing the issue and should be further studied in future project stages	POK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0028	Assess the extent to which the timeliness of the system meets HP requirements	CRT-37-W3-DEMOP-HUP1-0028	V3. Timeliness of information is judged as being sufficient.	Positive feedback was gathered from the ATCOs in terms of task completion for efficiency, accuracy and timeliness (most respondents strongly agreed). The respondents felt confident about using the tool in all modes of operation but emphasized the need for differentiating between the different times provided in normal operations, the potential for workload spiking in failure modes and the difficulty of spotting credibly corrupt data in degraded modes. Information displayed too early or too late could cause confusion, but if it represents an indication of a degraded mode, ATCOs expressed the preference for having the option to switch the tool off in such scenarios. Overall, ATCOs felt that the tool is useful and the time of displaying the information is adequate for supporting their tasks. Still, the concept could be improved by introducing DMAN support. Activities and information exchange processes for technical problems were defined in PJ02-01 OSED-SPR-INTEROP, but their efficiency should be assessed	OK

OBJ-37-W3-DEMOP-HUP1-0029	Assess the credibility of the benefit and identify how to realise the benefit if appropriate	CRT-37-W3-DEMOP-HUP1-0029	V3. Information provided allows task achievement.	Overall, participants felt that the extended OSD tool is helpful in supporting decision making and task achievement: most entries (75%) suggested an agreement that the extended OSD tool aided decision making for aircraft separation. All participants agreed and strongly agreed with the fact that the tool supports them in creating an accurate mental model, supporting them in achieving their tasks in an accurate, timely and efficient manner. Additionally, a taskload decrease was quoted: this would allow for speedier decisions by eliminating the need for mental calculations. The ATCOs also felt like the tool would decrease WL, including when operating during the hours of darkness. The solution proposes that the HMI will ultimately display the most restrictive condition put forth by the wake separation timer and the route separation timer, with a TOGGLE possibility in case the controller wishes to see what the other condition is. If the displayed condition is the route separation but a wake separation also exists, the letter “w” will be displayed to clearly indicate that. As such, it was concluded that the HMI design offers an appropriate indication of wake vs non-wake pairs, which satisfies the information requirements of the human. Overall, participants claimed that this is a good useful concept, that would benefit from refinements of route pairings and/or HMI. Most questionnaire entries (50%) quote the existence of mildly unpleasant deficiencies, rendering the system	OK
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Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				acceptable with minimal compensation to meet the required performance	
OBJ-37-W3-DEMOP-HUP1-0030	Assess the credibility of the issue, the associated risk and identify mitigations if appropriate	CRT-37-W3-DEMOP-HUP1-0030	V3. Information provided allows task achievement.	The need for coordination between the Tower ATC Supervisor and the Approach Supervisor was identified, as was the need for the current operating mode (normal, degraded, failure) to be displayed on the CWP's of the Supervisors and Controllers. The supervisor should also be aware of the system failure to be able to turn the tool off, if such a procedure is implemented. If these needs are met, no outstanding issue was identified	OK
OBJ-37-W3-DEMOP-HUP1-0031	Assess the extent to which the user interface impacts human performance and service delivery	CRT-37-W3-DEMOP-HUP1-0031	V3. End user experiences integrated interface including any new system components as sufficiently usable.	Participants stated they could perform their tasks in a timely, efficient and accurate manner. However, they highlighted that being supported by a type of departure manager (DMAN) would be useful, as tasks could be achieved more efficiently by knowing departure information in advance: "having the knowledge about departure sequence would be helpful and less distracting".	OK

OBJ-37-W3-DEMOP-HUP1-0033	Assess the extent to which the concept solution complies with the relevant HP Principles	CRT-37-W3-DEMOP-HUP1-0033	V3. Number and/or severity of errors is within acceptable limits.	While several participants found the HMI design reasonable and usable on ADIS, suggestions were put forth for fitting the timer on the EFPS, the FDE or the RWY bay strip, with a main preference for EFPS (controllers ultimately felt like including the timer on this display or any other frequently checked display would ease the integration of use, by building it into their usual scan). Additionally, creating a visual representation for the system failure instead of not displaying a time was proposed, as not displaying the time may not be a clear enough indication that the system has failed. An indication to make it clear what the time on the route separation timer is against (i.e., whether it relates to a route separation or flow restriction) was suggested, as was for crossing aircraft on the runway and the SID pairing the separation applies to (e.g., 1 & 2, or 1 & 3). In terms of the displayed time indicating method, ATCOs felt like it would be useful to have the ability for the controller to swap/have a choice: either time displayed only in seconds, or in both minutes and seconds - participants considered that there is potential for confusion between times (e.g., 140 s vs 1 min 40 s). Other aspects that were highlighted during the expert workshop were the prominence of the timer (making it more specific) and its location (preferably centrally placed on the strip).	OK
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Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
				The solution proposes that the HMI will ultimately display the most restrictive condition put forth by the wake separation timer and the route separation timer, with a TOGGLE possibility in case the controller wishes to see what the other condition is. If the displayed condition is the route separation but a wake separation also exists, the letter “w” will be displayed to clearly indicate that. It was concluded that the HMI design thus offers an appropriate indication of wake vs non-wake pairs	



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0034	Assess the impact the user interface has on individual situation awareness levels	CRT-37-W3-DEMOP-HUP1-0034	V3. End user is able to perceive and interpret task relevant information and anticipate future events/actions	Positive feedback from participants on seeing/hearing/understanding the information given by the tool for task completion (most of them agreed). Most participants (75%) agreed that the extended OSD tool aided decision making for aircraft separation. However, the need for a visual representation (not an audio alert) of the system failure was highlighted, as opposed to not displaying a time, as the presented interface did not indicate the failure clearly enough and impaired SA. Moreover, an indication of what the time is against was quoted, as this feature was not present in the simulation and participants felt like their workload increased and SA decreased while understanding what the indication referred to. The benefits of providing information on separation between a/c 1 and 3 was also discussed, with a view to avoid confusion with residual time (it's credible on easterlies) – but this was not deemed as a significant issue. A similar discussion was carried out for indicating crossing aircraft on the runway. Further consideration should be given to these proposals in the future stages of the project, as means of improving individual SA. For more on individual SA results, see Arg. 1.3.5	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0035	Assess the impact the user interface has on team situation awareness levels	CRT-37-W3-DEMOP-HUP1-0035	V3. Team is able to perceive and interpret task relevant information and anticipate future events/actions.	It is assumed that the separation delivery tool deployment will not cause any change to team structure and team communication, with only a negligible difference in communication load and coordination. The current HMI design does not feature an indication for system failure or differentiation between times provided, which the ATCOs stated impaired their individual SA during the SIM run and should be reconsidered in the next stage of the project, as it could negatively impact team SA. According to PJ02-01 OSED-SPR-INTEROP, the current operating mode shall be displayed on the CWP of the Supervisors and Controllers, to ensure adequate team SA. The efficiency of the HMI design in maintaining team SA should be further studied in the next stage of the project.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0036	Assess the credibility of an interference risk	CRT-37-W3-DEMOP-HUP1-0036	V3. Interferences between existing and required new knowledge & skills are identified. The ITARO Departures Solution is shown to be operationally feasible for the Aerodrome when the IBP is tested in a realistic environment. The OSD and extended OSD Tool design and usability is considered appropriate by users.	The solution proposes that the HMI will ultimately display the most restrictive condition put forth by the wake separation timer and the route separation timer, with a TOGGLE possibility in case the controller wishes to see what the other condition is. If the displayed condition is the route separation but a wake separation also exists, the letter “w” will be displayed to clearly indicate that. It was concluded that the HMI design thus offers an appropriate indication of wake vs non-wake pairs, and the interference risk does not pose an outstanding issue.	OK
OBJ-37-W3-DEMOP-OPF1-0001	To provide evidence that the ITARO Departures Solution is operationally feasible for the Aerodrome when integrated in a realistic environment in segregated mode.	CRT-37-W3-DEMOP-OPF1-0001	The ITARO Departures Solution is shown to be operationally feasible for the Aerodrome when the IBP is tested in a realistic environment. The OSD and extended OSD Tool design and usability is considered appropriate by users.	The RTS and follow-on post-sim workshop gathered sufficient evidence from NATS ATCOs to suggest that the extended OSD tool is operationally feasible for the aerodrome and that the extended OSD tool design and usability is considered appropriate for end users. For a detailed description of the results see Appendix D.3.21.	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-CAP1-0004	To assess the improvement in airport capacity due to the ITARO Departures Solution versus the Reference Scenario.	CRT-37-W3-DEMOP-CAP1-0004	Evidence shows an increase in maximum hourly operational runway throughput for departures in the Solution Scenario versus the Reference Scenario.	SOL1 (extended OSD without TMA Data Feed) achieved a higher throughput than the REF in 9 out of 11 matches and an average increase of 1.3 movements an hour (2.4%) . SOL2 (extended OSD with TMA Data Feed) achieved a higher throughput than the REF in 7 out of 10 matches and an average increase of 1.7 movements (3.2%). Whilst the t-test for SOL1 versus Reference did not provide evidence of a significant difference between the two ($t = -1.52$, $p = 0.16$), the t-test for SOL2 versus Reference did provide evidence of a significant difference the two at 90% confidence ($t = -1.90$, $p = 0.09$). Although these quantitative results should be caveated with two main factors (learning effect from the ATCOs being exposed to the same traffic sample across matched runs and the algorithm requiring refinement in future iterations), expert feedback from the ATCOs reported that there will be a positive impact from the tool in terms of achieving an improvement in capacity in the region of 1-2 aircraft per hour.	OK





Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-PRD1-0002	To assess the improvement in predictability per flight for the Aerodrome due to the ITARO Departures Solution versus the Reference Scenario.	CRT-37-W3-DEMOP-PRD1-0002	Evidence shows a decrease in taxi out variability for departing aircraft in the Solution Scenario versus the Reference Scenario.	Average Taxi-out time: The average taxi-out time across all matches for SOL1 compared to REF shows a reduction of 0.4 minutes. A reduction is also seen between SOL2 and REF of 0.9 minutes. Taxi-out Variability: The results show a reduction in Standard Deviation for SOL1 runs compared to the matched Reference Scenario runs of -0.10 minutes. A similar result is found for SOL2 compared with the matched Reference Scenario runs with a reduction of standard deviation by -0.40 minutes. Runway Hold Area (RHA) Delay: The data analysis shows that there was a reduction in mean RHA delay of 0.3 minutes when comparing REF with SOL1 (extended OSD without TMA Data Feed) and REF with SOL2 (extended OSD with TMA Data Feed).	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-PRD1-0003	To assess the predictability per flight for the TMA due to the ITARO Departures Solution versus the Reference Scenario.	CRT-37-W3-DEMOP-PRD2-0003	Evidence shows a more consistent delivery of aircraft into the TMA in the Solution Scenario versus the Reference Scenario.	The SESAR measurement of Predictability KPI is defined as variances in differences of actual and the flight plan. As this simulation was a Tower focussed simulation with no measured TMA sector, the data is not available to measure this KPI. However, one way of looking at predictability into the TMA is by assessing the consistency (and therefore a reduction in variability) of delivery into the TMA. As described in the Operational Feasibility objective analysis section, it was agreed amongst the ATCOs that the extended OSD tool would help to provide a more consistent flow of traffic into the TMA.	Not Applicable



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-PUN1-0001	To assess the impact on ANSP-attributed holding delay at the Aerodrome as a result of the ITARO Departures Solution versus the Reference Scenario.	CRT-37-W3-DEMOP-PUN1-0001	There is evidence to show that the ANSP-attributable delay at the Aerodrome is reduced in the Solution scenario versus the reference scenario.	Punctuality as defined by SESAR is departure delay in minutes of flights departing within +/- 3 minutes of SOBT (Scheduled Off-blocks Time), which is measured by taking the difference between AOBT (Actual Off-blocks time) and the SOBT. The data from the RTS is not available to measure this objective quantitatively, as the aircraft in the traffic samples generated at holding points from the runway, rather than at the stand. However an argument can be made for an improvement in punctuality which links to the PRD001 and CAP results. If the solution reduces the variability in the taxi-out time, time spent waiting to depart at the RHA, and increases the runway throughput, it can therefore be argued that the queue of aircraft waiting to depart is reduced and the GMC may be more able to push aircraft back sooner. In addition in periods of disruption (i.e. adverse weather) the increase in runway throughput allows the runway throughput to recover faster than before.	Not Assessed



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-ENV1-0002	To assess the impact of the ITARO Departures Solution on the average fuel burn per flight versus the Reference Scenario.	CRT-37-W3-DEMOP-ENV1-0002	There is evidence to show there is a reduction in the average fuel burn per flight, and therefore average CO2 emissions per flight in the Solution Scenario versus the Reference Scenario.	Analysis on the RTS data has indicated that, when compared to the REF: SOL 1 (extended OSD without TMA data-feed) produced a fuel burn saving of 7kg and CO₂ emissions of 23 kg per flight. SOL 2 (extended OSD with TMA data-feed) produced a fuel burn saving of 18kg and CO₂ emissions of 57 kg per flight. SOL1 presented the most efficient departure separation times and lowest ground holding durations but resulted in smaller average environmental savings of 7kg fuel burn and 23 kg CO₂ emissions per flight respectively compared to REF. This was due to more aircraft types with higher taxi fuel burn rates holding for longer durations and also likely the small sample sizes likely to have an effect on the results.	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-CEF1-0001	To assess the increase to Aerodrome ATCO productivity in terms of flights handled per unit time in the ITARO Departures Solution versus the Reference Scenario.	CRT-37-W3-DEMOP-CEF1-0001	Evidence shows an increase in the number of flights handled by an Aerodrome ATCO per hour in the Solution Scenario versus the Reference Scenario.	Analysis of the runway throughput data, including all arriving and crossing aircraft produced the following results: The extended OSD Tool without TMA Data Feed (SOL1): 0.6 (1.1%) increase aircraft handled per hour The extended OSD Tool with TMA Data Feed (SOL2): 1.6 (2.9%) increase in aircraft handled per hour	OK



OBJ-37-W3-DEMOP-SAF1-0008	To assess the impact of the ITARO Departures Solution on operational safety in the Tower compared to the Reference Scenario.	CRT-37-W3-DEMOP-SAF1-0008 CRT-37-W3-DEMOP-SAF1-0008	There is evidence that the level of safety for the Tower controllers operations is maintained and not negatively impacted with the ITARO Departures Solution compared to the Reference Scenario. (CRT-37-W3-DEMOP-SAF1-0008) There is evidence that the ITARO Departures Solution does not increase the number of minor wake under-separations and decreases the number of large wake under-separations (i.e. those with potential for severe wake encounters and / or loss of separation) compared to the Reference Scenario.(CRT-37-W3-DEMOP-SAF1-0008) There is evidence that the ITARO Departures Solution does not increase the number of route under-spacing events relative to the target distance spacing and compared to the	The overall feedback from ATCOs was that safety was not compromised as a result of the concept and discussions with ATCOs revealed they were confident with the output of the tool with regards to wake separations and route spacings. To provide evidence for the success criterion 002a/b, data created in the validation simulations was collated and specific analysis was undertaken for wake-separations, route under-separations, route under-spacings and potential catch-ups in the TMA. This has provided evidence to support the success criterion; however, the analysis did highlight a number of issues and areas where improvements could be incorporated to progress the concept for future iterations. Recommendations for the following have been raised: - To ensure Reduced Separation is recorded correctly and accurately. - To ensure accuracy amongst all SID profile combinations. - To investigate the effects of simulated weather conditions on the algorithm - To ensure realistic departure speed profiles are inputted in the simulation environment - To reduce the probability of under-separations on certain route pairings.	OK
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Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
		CRT-37-W3-DEMOP-SAF1-0008	Reference Scenario.(CRT-37-W3-DEMOP-SAF1-0008)	To understand differing aircraft speed data and performance. To ensure that the target distance separations used in the extended OSD tool are sufficiently accommodating of all traffic operating in the wider TMA environment. To understand whether other parameters need to be included in the solution to increase accuracy. To understand what impact the Solution has on traffic above the Controlled Traffic Region. To ensure wake separations are clearly displayed to the ATCO. To understand the impact of the extended OSD tool on catch-ups in the TMA To understand the impact of the extended OSD tool on catch-ups in the TMA. To assess the target distance spacings for SID pair combinations To assess the differences in aircraft performance, particularly the planned distances to particularly the planned distances to be flown and associated differing Take-Off Weights for different aircraft.	



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-SAF1-0009	To assess the impact on safety by the associated procedures	CRT-37-W3-DEMOP-SAF1-0009	Evidence is gathered regarding the impact on safety and associated procedures that the ITARO Departures Solution has.	Overall, once the ATCOs became familiar with the extended OSD tool during the validation simulations there was little impact on safety and associated procedures. From questionnaire and post-simulation expert workshop, the main issues to be investigated further are: • placement & design of the timers • MDI and TMA data information (HMI design) • the potential failure of the tool and the subsequent procedures.	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-SAF1-0010	Understand the equipment requirements, e.g. software levels required, corrupt data, hardware failures.	CRT-37-W3-DEMOP-SAF1-0010	Evidence is gathered regarding equipment requirements and the ITARO Departures Solution	Following ATCOs comments raised in the questionnaires and subsequently discussed in detail in the workshop the main area of concern was the failure of the extended OSD tool and associated hardware but also the delivery of corrupt but believable data to the controller which would be difficult for the ATCO to notice. The conversations allowed a greater understanding of the safety implications of tool failure / corrupt data. Recommendations for future investigations into possible system interactions, use of existing back up servers and assigning the correct software assurance levels and compliance to ED153 are required once the full design of the system is known have been made. Furthermore, recommendations on future HMI design regarding the status of system have been included.	OK

4.4 Detailed analysis of Departure Demonstration Results per Demonstration objective

Human Performance Demonstration Objective Detailed analyses of the HP Objectives are provided in section 4.4.1, Appendix A (HP Log) and Appendix D (Real Time Simulation Data Set) of the Human Performance Assessment Report (DEMOR Part III – Track PJ.37-W3-01B) [19].

4.4.1 Operational Feasibility Demonstration Objective

4.4.1.1 OBJ-37-W3-DEMOP-OPF1-0001

Identifier	OBJ-37-W3-DEMOP-OPF1-0001	KPA Category	OPF
Title	Operational Feasibility		
Objective	To provide evidence that the ITARO Departures Solution is operationally feasible for the Aerodrome when integrated in a realistic environment in segregated mode.		
Success Criterion	CRT-37-W3-DEMOP-OPF1-0001	The ITARO Departures Solution is shown to be operationally feasible for the Aerodrome when the IBP is tested in a realistic environment. The extended OSD Tool design and usability is considered appropriate by users.	
Results	The RTS and follow-on post-simulation workshop gathered sufficient evidence from NATS ATCOs to suggest that the extended OSD tool is operationally feasible for the aerodrome and that the extended OSD tool design and usability is considered appropriate for end users. Refer to text below for a summary of results and for a detailed analysis of results refer to Appendix D.3.21		OK
Reference	End of Day Questionnaire questions (for those questions that provided a scale or options to answer also asked the participant to elaborate following the response): • The extended OSD tool with the TMA data feed is operationally feasible – check one option from Strongly Agree to Strongly Disagree • The extended OSD tool without the TMA data feed is operationally feasible – check one option from Strongly Agree to Strongly Disagree • Did the extended OSD tool non-wake countdown timer enable you to apply more efficient route separations than without tool support? - check one option: Yes; No; Unsure. • Did you consider the extended OSD tool non-wake countdown timer to accurately deliver 3.5NM for early diverging SID pairs and 5NM for same/similar SID pairs? – check one option: Yes; No; Unsure. • Did you consider the extended OSD tool countdown timer to consistently deliver 3.5NM for early diverging SID pairs and 5NM for same/similar SID pairs? – check one option: Yes; No; Unsure.		

- Did you consider the non-wake separations delivered by the extended OSD tool to be appropriate? – check one option from Strongly Agree to Strongly Disagree.
- Which route pairings was the non-wake countdown timer extended OSD tool support most useful for? (Please consider in terms of same/similar/diverging SIDs)? – free text response.
- Did the extended OSD tool non-wake countdown timer provide more benefit in non-RSVA conditions? (Please consider in terms of same/similar/diverging SIDs)? – check one option: Yes; No; Unsure.
- Did you consider the use of separate wake and non-wake countdown timers to be acceptable? – check one option from Strongly Agree to Strongly Disagree.
- Did you consider the timing of the display of the wake/non-wake separation time for the next follower aircraft to be acceptable? – check one option from Strongly Agree to Strongly Disagree.
- Did you consider the inclusion of the route flow restrictions into the non-wake countdown timer to be acceptable? – check one option from Strongly Agree to Strongly Disagree.
- Did you consider the flow rate of traffic into the TMA sectors using the extended OSD tool without the TMA data-feed flow restrictions to be acceptable? – check one option from Strongly Agree to Strongly Disagree.
- Did you consider the flow rate of traffic into the TMA sectors using the extended OSD tool with the TMA data-feed flow restrictions to be acceptable? – check one option from Strongly Agree to Strongly Disagree.
- Can you suggest any improvements to the extended OSD tool (including the TMA data-feed component)? - free text response.

Feedback gathered from post-simulation Expert workshop.

In addition, also refer to Data Analysis in Appendix D.3.21.

4.4.2 Capacity Demonstration Objective

4.4.2.1 OBJ-37-W3-DEMOP-CAP1-0004

Identifier	OBJ-37-W3-DEMOP-CAP1-0004		KPA Category	CAP
Title	Capacity			
Objective	To assess the improvement in airport capacity due to the ITARO Departures Solution versus the Reference Scenario.			
Success Criterion	CRT-37-W3-DEMOP-CAP1-0004	Evidence shows an increase in maximum hourly operational runway throughput for departures in the Solution Scenario versus the Reference Scenario.		
Results	SOL1 (extended OSD Tool without TMA Data Feed) achieved a higher throughput than the REF in 9 out of 11 matches. SOL2 achieved a higher throughput than the REF in 7 out of 10 matches. SOL2 (extended OSD with TMA Data Feed) achieved an equal or higher throughput in SOL1 in 4 out of 8 matches, with no clear trend observed of an incremental increase in throughput from REF – SOL1 – SOL 2. For 2 matches, the REF achieved higher than the solution runs and the ATCO reported that this was due a learning effect of being exposed to the same traffic sample consecutively during the day, and the REF run was conducted at the end of the day. However, from ATCO feedback an estimate for increase in capacity was estimated to be between 1-2 aircraft per hour. When comparing REF with SOL1 an average increase of 1.3 movements an hour is seen (2.4%). When comparing REF with SOL2 an average increase of 1.7 movements can be seen (3.2%). Paired t-tests have been carried out on the runway throughput data samples. Whilst he t-test for Solution 1 versus Reference did not provide evidence of a significant difference between the two (t= -1.52, p=0.16), the t-test for Solution 2 versus Reference did provide evidence of a significant difference the two at 90% confidence (t= -1.90, p=0.09) The detailed Capacity Analysis section D.3.2.3 also includes a breakdown of the results of the split between those runs using Pairwise and those using RECAT for completeness, although the results above are based on RECAT and Pairwise combined.			OK
Reference	Capacity Data Analysis – see Appendix D.3.23.			

4.4.3 Predictability Demonstration Objective

4.4.3.1 OBJ-37-W3-DEMOP-PRD1-0002

Identifier	OBJ-37-W3-DEMOP-PRD1-0002	KPA Category	PRD1
Title	Predictability 0002		
Objective	To assess the improvement in predictability per flight for the Aerodrome due to the ITARO Departures Solution versus the Reference Scenario.		
Success Criterion	CRT-37-W3-DEMOP-PRD1-002	Evidence shows a decrease in taxi out variability for departing aircraft in the Solution Scenario versus the Reference Scenario.	
Results	Different metrics were used to assess Predictability: Taxi-out variability and Runway Hold Area (RHA) Delay. Average Taxi-out time: The average taxi-out time across all matches for SOL1 compared to REF shows a reduction of 0.4 minutes. A reduction is also seen between SOL2 and REF of 0.9 minutes. Taxi-out Variability: The results show a reduction in Standard Deviation for SOL1 runs compared to the matched Reference Scenario runs of -0.10 minutes. A similar result is found for SOL2 compared with the matched Reference Scenario runs with a reduction of standard deviation by -0.40 minutes. RHA Delay: The data analysis shows that there was a reduction in mean RHA delay of 0.3 minutes when comparing REF with SOL1 (extended OSD without TMA Data Feed) and REF with SOL2 (extended OSD with TMA Data Feed). The average taxi-out time across all matches for SOL1 compared to REF shows a reduction by 0.4 minutes. A reduction is also seen between SOL2 and REF of 0.9 minutes. The detailed Predictability analysis section D.3.24 also includes a breakdown of the results of the split between those runs using Pairwise and those using RECAT for completeness, although the results above are based on RECAT and Pairwise combined.		Not Assessed
Reference	Predictability Analysis – see Appendix D.3.24		

4.4.3.2 OBJ-37-W3-DEMOP-PRD1-0003

Identifier	OBJ-37-W3-DEMOP-PRD1-0003	KPA Category	PRD2
Title	Predictability 003		
Objective	To assess the predictability per flight for the TMA due to the ITARO Departures Solution versus the Reference Scenario.		
Success Criterion	CRT-37-W3-DEMOP-PRD1-003	Evidence shows a more consistent delivery of aircraft into the TMA in the Solution Scenario versus the Reference Scenario.	
Results	The SESAR measurement of Predictability KPI is defined as variances in differences of actual and the flight plan. As this simulation was a Tower focussed simulation with no measured TMA sector, the data is not available to measure this KPI. However, one way of looking at predictability into the TMA is by assessing the consistency of delivery into the TMA. As described in the Operational Feasibility objective analysis section, it was agreed amongst the ATCOs that the extended OSD tool would help to provide a more consistent flow of traffic into the TMA.		Not Assessed
Reference	Predictability Analysis – see Appendix D.3.24		

4.4.4 Punctuality Demonstration Objective

4.4.4.1 OBJ-37-W3-DEMOP-PUN1-0001

Identifier	OBJ-37-W3-DEMOP-PUN1-0001	KPA Category	PUN1
Title	Punctuality		
Objective	To assess the impact on ANSP-attributed holding delay at the Aerodrome as a result of the ITARO Departures Solution versus the Reference Scenario.		
Success Criterion	CRT-37-W3-DEMOP-PUN1-0001	There is evidence to show that the ANSP-attributable delay at the Aerodrome is reduced in the Solution scenario versus the reference scenario.	
Results	Punctuality as defined by SESAR is departure delay in minutes of flights departing within +/- 3 minutes of SOBT (Scheduled Off-blocks Time), which is measured by taking the difference between AOBT (Actual Off-blocks time) and the SOBT. The data from the RTS is not available to measure this objective, as the aircraft in the traffic samples generated at holding points from the runway, rather than at the stand. However an argument can be made for an improvement in punctuality which links to the PRD001 and CAP results. If the solution reduces the variability in the taxi-out time, time spent waiting to depart at the RHA, and increases the runway throughput, it can therefore be argued that the queue of aircraft waiting to depart is reduced and the GMC may be more able to push aircraft back sooner. In addition in periods of disruption (i.e. adverse weather) the increase in runway throughput allows the runway throughput to recover faster than before.		Not Assessed
Reference	N/A		

4.4.5 Environment Demonstration Objective

4.4.5.1 OBJ-37-W3-DEMOP-ENV1-0002

Identifier	OBJ-37-W3-DEMOP-ENV1-0002	KPA Category	ENV1
Title	Fuel Efficiency and CO ₂ Emissions		
Objective	To assess the impact of the ITARO Departures Solution on the average fuel burn per flight versus the Reference Scenario.		
Success Criterion	CRT-37-W3-DEMOP-ENV1-0002	There is evidence to show there is a reduction in the average fuel burn per flight, and therefore average CO ₂ emissions per flight in the Solution Scenario versus the Reference Scenario.	
Results	Analysis on the RTS data has indicated that, when compared to the REF: SOL 1 (extended OSD without TMA data-feed) produced a fuel burn saving of 7kg and CO₂ emissions of 23 kg per flight. SOL 2 (extended OSD with TMA data-feed) produced a fuel burn saving of 18kg and CO₂ emissions of 57 kg per flight. SOL1 presented the most efficient departure separation times and lowest ground holding durations but resulted in smaller average environmental savings of 7kg fuel burn and 23 kg CO₂ emissions per flight respectively compared to REF. This was due to more aircraft types with higher taxi fuel burn rates holding for longer durations and also likely the small sample sizes likely to have an effect on the results.		OK
Reference	SESAR Solution PJ37-W3-ITARO, DEMOR - Part IV - Environment Assessment Report, Track PJ.37-W3-01B. [20]		

4.4.6 Aerodrome Cost Efficiency Demonstration Objective

4.4.6.1 OBJ-37-W3-DEMOP-CEF1-0001

Identifier	OBJ-37-W3-DEMOP-CEF1-0001	KPA Category	CEF2
Title	Aerodrome Cost Efficiency		
Objective	To assess the increase to Aerodrome ATCO productivity in terms of flights handled per unit time in the ITARO Departures Solution versus the Reference Scenario.		
Success Criterion	CRT-37-W3-DEMOP-CEF1-0001	Evidence shows an increase in the number of flights handled by an Aerodrome ATCO per hour in the Solution Scenario versus the Reference Scenario.	
Results	As Analysis of the runway throughput data, including all arriving and crossing aircraft produced the following results: The extended OSD Tool without TMA Data Feed (SOL1): 0.6 (1.1%) increase aircraft handled per hour The extended OSD Tool with TMA Data Feed (SOL2): 1.6 (2.9%) increase in aircraft handled per hour The detailed Aerodrome Cost Efficiency Analysis section D.3.27 also includes a breakdown of the results of the split between those runs using Pairwise and those using RECAT for completeness, although the results above are based on RECAT and Pairwise combined.		OK
Reference	For Aerodrome Cost Efficiency analysis - see Appendix D.3.27.		

4.4.7 Safety Demonstration Objective

4.4.7.1 OBJ-37-W3-DEMOP-SAF1-0008

Identifier	OBJ-37-W3-DEMOP-SAF1-0008	KPA Category	Safety
Title	Safety 0008		
Objective	To assess the impact of the ITARO Departures Solution on operational safety in the Tower compared to the Reference Scenario		
Success Criterion	CRT-37-W3-DEMOP-SAF1-0008	There is evidence that the level of safety for the Tower controllers' operations is maintained and not negatively impacted with the ITARO Departures Solution compared to the Reference Scenario.	
	CRT-37-W3-DEMOP-SAF1-0008	There is evidence that the ITARO Departures Solution does not increase the number of minor wake under-separations and decreases the number of large wake under-separations (i.e., those with potential for severe wake encounters and / or loss of separation) compared to the Reference Scenario.	
	CRT-37-W3-DEMOP-SAF1-0008	There is evidence that the ITARO Departures Solution does not increase the number of route under-spacing events relative to the target distance spacing and compared to the Reference Scenario.	

Results

The overall feedback from ATCOs was that safety was not compromised as a result of the concept and discussions with ATCOs revealed they were confident with the output of the tool with regards to wake separations and route spacings. To provide evidence for the success criterion, data created in the validation simulations was collated and specific analysis was undertaken for wake-separations, route under-separations, route under-spacings and potential catch-ups in the TMA. This has provided evidence to support the success criterion; however, the analysis did highlight a number of issues and areas where improvements could be incorporated to progress the concept for future iterations. The following summarises the issues and recommendations:

OK

Safety Issue	Recommendation
To ensure Reduced Separation is recorded correctly and accurately.	REC-37-W3-SAF-R8.1: During future testing of this solution in future projects, more robust procedures should be created to ensure all forms of Reduced Separation that ATCOs apply are recorded accurately and correctly in the simulation environment.
To ensure accuracy amongst all SID profile combinations.	REC-37-W3-SAF-R8.2: For future iterations of the extended OSD algorithm, refinements are required to ensure accuracy of the input values to the extended OSD tool describing the SID profiles flown by aircraft.
Effects of simulated weather conditions on the algorithm	REC-37-W3-SAF-R8.3: Further investigation should be undertaken regarding the MET conditions used in simulations and its interaction with the algorithm in order to refine the calculation of the route time spacing required.
To ensure realistic departure speed profiles are inputted in the simulation environment.	REC-37-W3-SAF-R8.4: Further investigation should be undertaken in future projects to ensure realistic departure speed profiles are used as an input in the simulation environment (Note this aligns with Operational Feasibility REC-37-W3-OPF-R1 in Appendix D.3.2 paragraph 1.
Reduce the probability of under-separations on certain route pairings.	REC-37-W3-SAF-R8.5: Further investigations should be undertaken in future projects to examine the use of 'safety buffers' on certain route pairings.
To understand differing aircraft speed data and performance.	REC-37-W3-SAF-R8.6: A larger sample size of differing aircraft types should be utilised in future projects to deduce whether improved departure speed

	profiles are required and if there are any issues with specific aircraft speed data.
To ensure that the target distance separations used in the extended OSD tool are sufficiently accommodating of all traffic operating in the wider TMA environment.	REC-37-W3-SAF-R8.7: Additional simulations should be undertaken to explore the interactions of Heathrow departures with all traffic movements both through the TMA and into and out of the major airports in the London TMA, with a consideration to include unfavourable wind profiles at all levels.
To understand whether other parameters need to be included in the solution to increase accuracy.	REC-37-W3-SAF-R8.8: Further investigation should be undertaken in future projects to ascertain whether other significant parameters need to be included in the Solution (e.g., Airline, destination, and air pressure.)
To understand of what impact the Solution has on traffic above the Controlled Traffic Region.	REC-37-W3-SAF-R8.9: Further investigations should be undertaken in future projects regarding same SID pair departures, catch-ups and potential wake encounters above the Controlled Traffic Region.
To ensure wake separations are clearly displayed to the ATCO	REC-37-W3-SAF-R8.10: The HMI needs to clearly display when there is wake separation.
To understand the impact of the extended OSD tool on catch-ups in the TMA.	REC-37-W3-SAF-R8.11: Further investigations should be undertaken to assess the impact of the extended OSD tool on catch-up occurring in the TMA and if the defined spacing delivery points for the leader and follower aircraft are appropriate on a SID pair basis.
To assess the target distance spacings for SID pair combinations.	REC-37-W3-SAF-R8.12: Further investigations should be undertaken to assess whether the target distance spacings assigned to SID pair combinations are sufficient.
To assess the differences in aircraft performance, particularly the planned distances to be flown and associated differing Take-Off Weights for different aircraft.	REC-37-W3-SAF-R8.13: An investigation into whether a destination reference table should be an input to the extended OSD tool should be carried out.

Reference	The following references can be found in PJ37-W3-ITARO DEMO Report Part II, Track PJ.37-W3-01B [18]. Appendix A.1.4 - End of Day Question <i>‘What the level of impact will the concept have on Operational Safety?’</i> Out of 14 ATCOs, 7 highlighted ‘same as current operations’, 7 highlighted ‘positive impact’. This provides evidence (although of a subjective nature) to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.1.1 – Analysis of Wake Encounter Risk provides partial evidence to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.1.2 – Analysis of total number of Wake Under Separations (Solution vs Reference Runs) provides evidence to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.1.2 – Controller Delivery performance using the Wake Countdown timer provides partial evidence to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.1.3 - End of Day Question <i>‘When using their own experience and judgement, what would the probability of a wake separation infringement occurring using this concept in comparison to current operations?’</i> Out of 15 ATCOs, 6 highlighted ‘same as current operations’, 8 highlighted ‘less likely to occur’. This provides partial evidence (although of a subjective nature) to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.2.1 – Analysis of Total Number of Route Under-Separations / Under-Spacings (Solution vs. Reference Runs) provides evidence to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.2.1 - Analysis of Rate of Route Under-Separations / Under-Spacings per 100 000 Departures (Solution vs. Reference Runs) provides evidence to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.2.1 - Analysis of Under Separations / Under- Spacings per SID Pair (Solution vs Reference Runs) provides partial evidence to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.2.1 - Analysis of Under Separation / Under- Spacings per MET Condition (Solution vs Reference Runs) provides partial evidence to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.2.2 - End of Day Question asked when using their own experience and judgement, what would the probability of an under separations (SID/Route) occurring using this concept in comparison to current operations? <i>Out of 15 ATCOs, 10 highlighted ‘same as current operations’, 4 highlighted ‘less likely to occur’ and 1 highlighted ‘more likely to occur’.</i> This provides evidence (although of a subjective nature) to support CRT-37-W3-DEMOP-SAF1-0008. Appendix A.1.3.2 - Analysis of Extended OSD tool Impact on Departure Catch-Ups in the TMA provides evidence to support CRT-37-W3-DEMOP-SAF1-0008.
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4.4.7.2 OBJ-37-W3-DEMOP-SAF1-0009

Identifier	OBJ-37-W3-DEMOP-SAF1-0009	KPA Category	SAF
Title	Safety 0009		
Objective	To assess the impact of the ITARO Departures Solution on associated procedures.		
Success Criterion	CRT-37-W3-DEMOP-SAF1-0009	Evidence is gathered regarding the impact on safety and associated procedures that the ITARO Departures Solution has.	

Results	Overall, once the ATCOs became familiar with the extended OSD tool during the validation simulations there was little impact on safety and associated procedures. After collating information from the questionnaires and discussing the pertinent points in the workshop, the main issues which were raised surround the placement & design of the timers, MDI and TMA data information (HMI design) and the potential failure of the tool and the subsequent procedures associated with these issues. The following summarises the issues and recommendations: <table><tr><th>Safety Issue</th><th>Recommendation</th></tr><tr><td>Timer display</td><td>REC-37-W3-SAF-R9.1: A toggle switch should be provided to enable ATCO personalisation of the timer. (See also REQ-37-W3-HP-6)</td></tr><tr><td>Placement of wake and route countdown timer</td><td>REC-37-W3-SAF-R9.2: An HMI workshop should be held to discuss suitable placement of the extended OSD tool output. (See also REQ-37-W3-HP-7)</td></tr><tr><td>Placement of MDI and TMA data feed information</td><td>REC-37-W3-SAF-R9.3: An HMI workshop should be held to discuss the suitable placement of the MDI and TMA data feed information.</td></tr><tr><td>Ability for ATCO to undertake other safety critical tasks</td><td>REC-37-W3-SAF-R9.4: During the next wave of this solution, more scenarios and tasks that ATCOs experience daily should be incorporated into the simulated exercises.</td></tr><tr><td>Procedures when extended OSD tool fails</td><td>REC-37-W3-SAF-R9.5: A simple to follow separations matrix and immediate action procedures should be produced to enable safe operations to continue.</td></tr><tr><td>Procedures to deal with skill fade</td><td>REC-37-W3-SAF-R9.6: HF, Safety and ATCOs should fully investigate the required procedures, tasks and possible ATCO training requirements in the event of tool failure.</td></tr><tr><td>Future deployment and effect on current procedures</td><td>REC-37-W3-SAF-R9.7: All ATC procedures which will be affected by the deployment of the tool should be highlighted early in future projects to assess for any major safety issues.</td></tr></table>	Safety Issue	Recommendation	Timer display	REC-37-W3-SAF-R9.1: A toggle switch should be provided to enable ATCO personalisation of the timer. (See also REQ-37-W3-HP-6)	Placement of wake and route countdown timer	REC-37-W3-SAF-R9.2: An HMI workshop should be held to discuss suitable placement of the extended OSD tool output. (See also REQ-37-W3-HP-7)	Placement of MDI and TMA data feed information	REC-37-W3-SAF-R9.3: An HMI workshop should be held to discuss the suitable placement of the MDI and TMA data feed information.	Ability for ATCO to undertake other safety critical tasks	REC-37-W3-SAF-R9.4: During the next wave of this solution, more scenarios and tasks that ATCOs experience daily should be incorporated into the simulated exercises.	Procedures when extended OSD tool fails	REC-37-W3-SAF-R9.5: A simple to follow separations matrix and immediate action procedures should be produced to enable safe operations to continue.	Procedures to deal with skill fade	REC-37-W3-SAF-R9.6: HF, Safety and ATCOs should fully investigate the required procedures, tasks and possible ATCO training requirements in the event of tool failure.	Future deployment and effect on current procedures	REC-37-W3-SAF-R9.7: All ATC procedures which will be affected by the deployment of the tool should be highlighted early in future projects to assess for any major safety issues.	OK
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Reference	The following references can be found in PJ37-W3-ITARO DEMO Report Part II, Track PJ.37-W3-01B [18].																	

End of Day Question 12 - *'Are there any circumstances that you think using this concept will have a SAFETY impact on associated procedures and or other tasks that are performed by you?'*

ATCO 6 – 'As long as the timer HMI is good then no'.

ATCO 10 – 'not if it works correctly'

ATCO 17 – 'Potentially if an ATCO becomes over reliant on timer and it fails, your workload could increase significantly to compensate and calculate separations'

ATCO18 – 'Need to ensure all separations wake/route/MDI can be understood by the ATCO'

End of Day Question 14 – *'Are there any scenarios you can envisage where the failure of the tool could have a SAFETY impact?'*

ATCO 12 – 'If the ATCO could not revert to manual application successfully due skill fade etc'

ATCO 11 – 'Feel you could become reliant on the tool and if failed, increase in mental workload would be significant during high traffic volumes and MDIs'.



4.4.7.3 OBJ-37-W3-DEMOP-SAF1-0010



Identifier	OBJ-37-W3-DEMOP-SAF1-0010	KPA Category	SAF
Title	Safety 0010		
Objective	Understand the equipment requirements, e.g. software levels required, corrupt data, hardware failures.		
Success Criterion	CRT-37-W3-DEMOP-SAF1-0010	Evidence is gathered regarding equipment requirements and the ITARO Departures Solution.	

Results	Following ATCOs comments raised in the questionnaires and subsequently discussed in detail in the workshop the main area of concern was the failure of the extended OSD tool and associated hardware but also the delivery of corrupt but believable data to the controller which would be difficult for the ATCO to notice. The conversations allowed a greater understanding of the safety implications of tool failure / corrupt data. The following summarises the issues and recommendations: <table><tr><th>Safety Issue</th><th>Recommendation</th></tr><tr><td>Tool error / failure messages</td><td>REC-37-W3-SAF-R10.1: A visual-only alert (not audible) of the status of the equipment is required to allow maximum time for controllers to identify the failure and then to quickly revert to the alternate procedures.</td></tr><tr><td>Interaction between existing ATC equipment (including back-up servers).</td><td>REC-37-W3-SAF-R10.2: Further investigations are undertaken regarding possible interaction between other ATC systems and the extended OSD tool system and the utilisation of any back up servers already in use in the Air Traffic Control tower.</td></tr><tr><td>Tool Failure – Corrupt but believable data.</td><td>REC-37-W3-SAF-R10.3: A function should be introduced to allow the Supervisor only to switch off the system (either in certain elements or the whole extended OSD tool) in situations where there was any doubt about the integrity of the information being presented to the controller. (See REQ-37-W3-HP-3) REC-37-W3-SAF-R10.4: Further investigation into the issue of corrupt but believable data and its impact to the system should be undertaken in future projects. REC-37-W3-SAF-R10.5: Further examination should be made into the assigning of the correct software assurance level to the system in association with compliance of ED153.</td></tr></table>	Safety Issue	Recommendation	Tool error / failure messages	REC-37-W3-SAF-R10.1: A visual-only alert (not audible) of the status of the equipment is required to allow maximum time for controllers to identify the failure and then to quickly revert to the alternate procedures.	Interaction between existing ATC equipment (including back-up servers).	REC-37-W3-SAF-R10.2: Further investigations are undertaken regarding possible interaction between other ATC systems and the extended OSD tool system and the utilisation of any back up servers already in use in the Air Traffic Control tower.	Tool Failure – Corrupt but believable data.	REC-37-W3-SAF-R10.3: A function should be introduced to allow the Supervisor only to switch off the system (either in certain elements or the whole extended OSD tool) in situations where there was any doubt about the integrity of the information being presented to the controller. (See REQ-37-W3-HP-3) REC-37-W3-SAF-R10.4: Further investigation into the issue of corrupt but believable data and its impact to the system should be undertaken in future projects. REC-37-W3-SAF-R10.5: Further examination should be made into the assigning of the correct software assurance level to the system in association with compliance of ED153.	OK
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Reference	End of Day Question 14 – ‘Are there any scenarios you can envisage where the failure of the tool could have a SAFETY impact?’ ATCO 1 – ‘Only if the failure was not known about, i.e. issuing corrupt info’. End of Day Questions 15 – ‘Are there any changes or suggestions you would like see to the functions or presentations of the tool that would improve SAFETY?’									

ATCO 14 – ‘A clear status of the system’.

Appendix A.3 of the DEMO Report Part II (Safety Assessment Report), Track PJ.37-W3-01B [18] details how likely a controller would be to identify an error if the indication was early by 10/20/30 seconds.

4.5 Confidence in Results of Demonstration Exercises

4.5.1 Limitations and impact on the level of Significance

The quality and significance of the results of each demonstration exercise is presented for each individual demonstration in their according appendix. For EXE-PJ.37-W3-001 refer to Appendix A.3.4, for EXE-PJ.37-W3-002 refer to Appendix B.3.4, for EXE-PJ.37-W3-003 refer to Appendix C.3.4 and for EXE-PJ.37-W3-004 refer to Appendix D.3.4.

5 Conclusions and recommendations

5.1 Conclusions for Arrival Solutions

For Safety, the real time simulations have not shown that the new combination of tools increases the number of controller-instructed go-arounds or the number of losses of separation. However, there are a few issues regarding interoperability of the different tools in the combination, and the controllers involved had some issues with the perceived controllability of the traffic situation. Another conclusion is that the nature of the real time simulations did not allow a complete safety assessment, and recommendations for further work have been formulated in Section 5.2.

From a Human Performance perspective, the real time simulations revealed that the concept is acceptable to the controllers (OBJ-37-W3-HUP1-0003) only when the accuracy of delivery into the TMA is sufficiently accurate (within plus or minus 30 seconds), the pilots are timely following up instructions and equipage levels are substantial (e.g., 80%). An important finding was that the controllers had the feeling not to have sufficient time for monitoring the traffic that is turning in for final and being able to instruct interventions when necessary. Furthermore, the ATCOs were successful in achieving the tasks (OBJ-37-W3-HUP1-0008).

It was demonstrated that combining the SESAR solutions under investigation does not have a negative impact, that is no gaps were identified, on airspace capacity, runway throughput, predictability, CO2 emissions and noise profiles.

The general findings are considered the most important outcome of the real time simulations as they represent the aspects related to the integration of the SESAR solutions. The integration did not reveal major issues, but a few topics could benefit from further refinements:

- The target distance indicator (TDI) display and calculations have to be along the published fixed approach route instead of along the extended runway centreline. It has to consider turns, winds and speed profiles along the route. This finding was validated in RTS2.
- The transition from the Minimum Radar Separation (MRS) of 3 NM as applicable in the TMA to an MRS of 2.5 NM (or 2.0 NM) on the final approach track needs further attention. Several methods can be envisioned to design this transition.
 - The presentation of the TDI would gradually reduce the separation to the applicable separation distance, while also taking into account the compression effect on final.
 - Though when the 3 NM is the most stringent, the TDI on short final may still indicate a value slightly above 2.5NM (or 2.0NM).
 - However one could also think of a more abrupt change in TDI presentation once both aircraft are established on the extended centreline.
- The Interval Management Achieve-by Point, that is the ATCO assigned point at which the spacing goal needs to be achieved, not only needs to support the ATCO task to space aircraft very precisely on the final approach track to retain/increase runway capacity, but also needs to support the ATCO merge task earlier on. The Achieve-by Point therefore needs to be located not later than the merge point of the fixed approach routes. This finding was validated in RTS2.
- IM spacing goal determination, based on integration with AMAN and ORD tools, could be further improved. The spacing goal was based on the minimum separation between aircraft

pairs (from ORD tool) as well as arrival planning information (from AMAN) to not only increase runway capacity by setting the spacing goals to the minimum separation, but also considering operations in accordance with the planning. However, this resulted in front-loading behaviour, the airspeeds beyond the merge point (the IM Achieve-by Point) and in particular on the final approach track were found to be too high.

- The combination of the fixed route presentation with the distance-based merge tool and IM operations has been positively received by the ATCOs. However, it was suggested to explore whether the IM Clearance could be given by Area Control (ACC) as the arrival sequence is already known before entering the terminal airspace. This gives more time to correct errors and could further reduce the communication task load of the APP controllers. Furthermore it was questioned whether in real life the merge tool should already be presented so early. The ghost blip was already presented on the long approach transitions when the aircraft was still under control of ACC and also for a significant amount of time, hence potentially not stable on a route to the TMA entry point.
- The integrated solutions could handle high traffic loads very efficiently for nominal operations and single aircraft events/disturbance. However, the use of fixed routes with a very high traffic load and therefore high pressure on the ATM system, will need additional measures (e.g., tools or working methods) to create a gap in case of challenging (e.g., multi aircraft) disturbances/events. A level of flexibility is needed.

More details on the general findings can be found in Appendices A.4 and B.4.

The live trial has demonstrated that IM operations on fixed routes with fixed descent profiles work very well together (from a pilot perspective), IM spacing performance is very impressive, no changes to standards have been identified and no integration issues have been identified. Several recommendations on the ADS-B IN and the FIM system itself have been identified, see recommendations REC-37-W3-SAF-R7.1 to REC-37-W3-SAF-R7.6 in section 5.2.1 and some more generic recommendations in section 5.2.3.

5.2 Recommendations Arrival Solutions

5.2.1 Recommendations for industrialization and deployment

For Safety, the following recommendations have been formulated (for details, see Section 4.2.5):

REC-37-W3-SAF-R1.1: For a more accurate representation of the safety objectives being studied, incorporate a runway controller in future simulations to manage traffic on the final approach segment and collaborate with the arrival (ARR) controller in instances that may result in go-arounds

REC-37-W3-SAF-R1.2: In future simulations it is recommended to incorporate an ACC controller. If a go-around occurs, the ACC or the APP controller should delay the traffic that is still further away from the runway, in order to create some space in the sequence.

REC-37-W3-SAF-R3.1: For future simulations or demonstrations, implement a safety mechanism to alert ATCOs in case of any compatibility issues between the FIM system/algorithm and the E-AMAN system/algorithm, such as illogical aircraft pairings.

REC-37-W3-SAF-R3.2: Consider expanding the coverage of the FIM system to include the ACC airspace, in addition to the TMA airspace. This could provide more time and space for the system to maintain appropriate spacing between aircraft and to create gaps in case an aircraft needs to re-sequenced.

REC-37-W3-SAF-R3.3: Enhance the realism of future simulations or demonstrations by incorporating more realistic speed profiles of aircraft. Refining the FIM algorithms and ensuring seamless transitions between them may be necessary to achieve this.

REC-37-W3-SAF-R4.1: To include a runway controller in the simulations, who controls the traffic on the final approach segment, and who can coordinate with the arrival (ARR) controller regarding situations that may lead up to losses of separation due to WTS, MRS and ROT. This would provide a more realistic picture regarding the safety objectives studied.

REC-37-W3-SAF-R4.2: The previous recommendation would also create the opportunity to study a safety objective that was omitted from the analysis in this report (i.e. the variability in Clearance to Land margin decreases for ROT constrained pairs).

REC-37-W3-SAF-R4.3: The objectives studied looked at safety up to the level of potential for loss of separation, limited by the nature of real time simulations. In order to assess the risk of a mid-air collision and the risk of wake turbulence related accidents, as is required in SESAR safety reference material (SRM), in a follow on project it is recommended to use Dynamic Risk Modelling to assess the safety benefits of the combination of tools more accurately.

REC-37-W3-SAF-R5.1: Assess the similarity of simulation issues encountered during RTS2 to real-world operational scenarios. In future testing and simulations, include these types of events in scenarios to gauge the operational efficiency and durability of the tools used.

REC-37-W3-SAF-R5.2: Evaluate the ability of controllers to handle non-typical operational disruptions that occur frequently in real-world practice. Incorporate these events into scenarios for future testing and simulations to assess the efficiency and stability of the tools and overall operation during such situations.

REC-37-W3-SAF-R7.1: It is recommended to address the ADS-B IN system performance gap by setting up a test/exercise to demonstrate adequate ADS-B In range performance, with an improved antenna installation and possibly a decreased RF interference at the aircraft level. As part of this demonstration on an aircraft, the RF performance should be verified after installation and before starting the flight test.

REC-37-W3-SAF-R7.2: It is recommended to update the FIM software to comply with the new traffic alignment requirements of the FIM MOPS.

REC-37-W3-SAF-R7.3: It is recommended that the FIM software should be improved to be more robust regarding waypoint sequencing and should have an easier option for restoring waypoints that should not have been sequenced

REC-37-W3-SAF-R7.4: It is recommended to update the FIM software to ignore traffic reports after it sequences the PTP for time-based IM clearances. However, this is not a critical issue and it is therefore proposed to address/discuss it in the standards (FIM MOPS requirement IM.011) whenever the FIM MOPS will be revised for others reasons.

REC-37-W3-SAF-R7.5: It is recommended to update the FIM software to comply with the updated traffic path conformance requirements of the FIM MOPS.

REC-37-W3-SAF-R7.6: It is recommended to perform a live trial in Europe with a (limited) number of airliner's aircraft being equipped with a FIM system that is approved under TSO-C195c (and therefore complies with the system requirements of EUROCAE ED-236A Change 1 / RTCA DO-361A Change 1) and an ATC centre/sector actively supporting and using IM operations. This operational trial could seamlessly be continued (i.e. deployed) in that ATC environment. Prerequisite is the availability and usage of a PBN route structure in that part of the airspace.

For Human Performance, the following recommendations have been formulated (for details, see Section 4.2.1):

REC-37-W3-HUP-R4.1: Design arrival routes such that turns are 135 degree or larger and that routes to parallel runways are not exactly mirrored (avoid head-on base legs). **Validated in RTS2.**

REC-37-W3-HUP-R4.2: Standardised altitude at IAF or start the RNP approach at the merge point. **Standardised altitude was validated in RTS2.**

REC-37-W3-HUP-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. **This was validated in RTS 2.**

REC-37-W3-HUP-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.

REC-37-W3-HUP-R6.1: In case of changes in the inbound sequence it is recommended to update the inbound planning (AMAN/Supervisor) or cancel the IM for one (or several) flights, instead of changing IM targets.

REC-37-W3-HUP-R6.2: It is recommended to take a closer look at responsibilities such as monitoring the traffic at final, with high volumes of traffic. Can this reasonably be expected from the ATCO?

REC-37-W3-HUP-R7.1: Design the HMI, such that:

- It is clear which flights are IM capable and which are not; **Validated in RTS2**
- It is clear which flights are applying IM (**validated in RTS2**), and whether it is applied correctly (to the flight preceding on the route);
- It is clear which flights are established on RNP; **Validated in RTS2**
- That ATCO can change the sequence with a minimal number of actions

REC-37-W3-HUP-R7.2: When the actual sequence is different from the planned sequence, the planning is preferably updated (automatically ensuring the right IM target for each flight). If a mix up of IM targets is a possible occurrence, the controller could be made aware of such mix-ups.

REC-37-W3-HUP-R8.1: Consider automated adherence monitoring of the NTZ.

REC-37-W3-HUP-R8.2: The concept should ensure the gradual reduction of speeds of arriving traffic.

REC-37-W3-HUP-R9.1: Divide the work of the FDR between two ATCOs (TWEC/TOC). **Validated in RTS 2.**

REC-37-W3-HUP-R9.2: Expand Non Transition Zone (automated monitoring) for traffic established on RNP (18/18). **Validated in RTS 2**

REC-37-W3-HUP-R10.1: Trust should develop with more experience. Test the concept with, for example:

- Go-arounds: **Validated in RTS2**
- Provide a gap for runway inspection
- Change sequence (e.g. emergency). **Validated in RTS2**
- Runway closure
- Runway change

REC-37-W3-HUP-R11.1: Improve IM alert: **Validated in RTS2**

REC-37-W3-HUP-R11.2: Improve HMI to provide an indication when a flight is established on RNP: **Validated in RTS2**

REC-37-W3-HUP-R11.3: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: **Validated in RTS2**

REC-37-W3-HUP-R14.1: Provide ghost indicator only for flights almost in TMA. **Validated in RTS 2**

5.2.2 Recommendations on regulation and standardisation initiatives

No relevant recommendations from the Integrated Arrival concept.

5.2.3 Recommendations for updating ATM Master Plan Level 2

Update the ATM Master Plan Level 2 for SESAR Solutions PJ.02-01-01, PJ.02-01-04 and PJ.02-08-07 indicating the outcome of SESAR Project PJ37-W3-ITARO → achieved maturity is TRL7 ongoing.

Update the ATM Master Plan Level 2 for SESAR Solution PJ.01-05 'Airborne Spacing – Flight-deck Interval Management' indicating the outcome of SESAR Project PJ37-W3-ITARO → achieved maturity is V3 ongoing.

It is strongly recommended to rate SESAR Solution PJ.01-05 as Key R&D based on the outcomes of the PJ.37-W3-01A exercises and the significant benefits previously demonstrated for the solution [22].

5.3 Conclusions for Departure Solutions

The results show that the PJ.37-W3-01B Departures Solution is both operationally feasible and acceptable based on the following findings (for details, see Appendix D.3.5):

- The extended OSD tool enables the ATCOs to provide **more efficient and granular route spacings**, particularly in the case of same/similar SID pairs.

- In the case of diverging SIDs, the extended OSD tool allows the ATCOs to **provide more consistent route spacings**, particularly when reduced visual separations cannot be applied.
- The inclusion of the TMA data-feed is considered to be beneficial as it allows the ATCOs to apply **more efficient non-integer flow restrictions** and allows for **greater flexibility in departure spacing**.
- The extended OSD tool support **reduces the workload of the ATCO**, providing them with additional thinking time to perform other tasks, such as planning ahead with the departure sequence.
- The **target distance spacings used in the RTS were considered to be appropriate**, but further research is needed into whether they need refining on a SID pair basis.
- **Departure throughput benefits** were brought about from the optimised route spacings; however, some of the observed increase is likely to be a result of the learning effect of the traffic samples.
- Further work is needed to address the **potential for human error** from the risk of over-reliance on the extended OSD tool leading to de-skilling of the ATCOs.
- The extended OSD tool was found to be **technically feasible** for the application of the ITARO Departures Solution Scenario⁶, although further work is needed to improve the accuracy of the algorithm that converts the target distance spacing into a time spacing.
- **Improvements to the extended OSD tool HMI** are required for future versions of the tool.

5.4 Recommendations Departure Solutions

5.4.1 Recommendations for industrialization and deployment

The following recommendations have been formulated to improve the operational feasibility of the extended OSD tool (for details, see Appendix D.3.21):

REC-37-W3-OPF-R1: The extended OSD tool algorithm which calculates the time spacing required to achieve the target distance spacing should be improved by considering the accuracy and appropriateness of the:

- Source of wind information aloft used by the extended OSD tool.
- Departure tracks used by the extended OSD tool.
- Aircraft departure speed profiles used by the extended OSD tool.

⁶ Note that Technical Feasibility of the extended OSD tool was considered within the Operational Feasibility assessment as there was no dedicated Technical Feasibility demonstration objective for the PJ.37-W3-01B Departures Solution.

- Assumptions used by the extended OSD tool about how the time-to-fly of the aircraft is affected by wind.

REC-37-W3-OPF-R2: The feasibility of including the impact of individual airline behaviour on the time-to-fly calculation should be considered as part of future extended OSD tool development.

REC-37-W3-OPF-R3: The feasibility of considering the whole geometry of the SID pairs rather than single Delivery Points should be considered as part of future extended OSD tool development.

REC-37-W3-OPF-R4: Future demonstration exercises should use traffic samples which are conducive to same/similar SID pairs being created in the departure sequence, whilst remaining realistic.

REC-37-W3-OPF-R5: Future demonstration exercises should test integration of air traffic departing from the aerodrome using the extended OSD tool with wider TMA traffic.

REC-37-W3-OPF-R6: There should be flexibility to tailor the target distance spacings on a SID pair basis in future demonstration exercises.

REC-37-W3-OPF-R7: Future versions of the extended OSD tool should differentiate between route spacings and route flow restrictions on the controller's HMI.

REC-37-W3-OPF-R8: Future versions of the extended OSD tool should differentiate between whether the time on the route countdown timer applies to the current leader-follower pair or the follower and the aircraft ahead of the leader.

REC-37-W3-OPF-R9: Future versions of the extended OSD tool should locate the wake and route countdown timers on the electronic flight progress strips, as well as investigate the option to go on ADIS.

The following recommendations have been formulated to improve the safety of the extended OSD tool (for details, see Appendix A.1 of DEMO Report Part II [18]):

REC-37-W3-SAF-R1.1: During future testing of this solution in future projects, more robust procedures should be created to ensure all forms of Reduced Separation that ATCOs apply are recorded accurately and correctly in the simulation environment.

REC-37-W3-SAF-R1.2: For future iterations of the extended OSD algorithm, refinements are required to ensure accuracy of the input values to the extended OSD tool describing the SID profiles flown by aircraft.

REC-37-W3-SAF-R1.3: Further investigation should be undertaken regarding the MET conditions used in simulations and its interaction with the algorithm in order to refine the calculation of the route time spacing required.

REC-37-W3-SAF-R1.4: Further investigation should be undertaken in future projects to ensure realistic departure speed profiles are used as an input in the simulation environment (note this aligns with REC-37-W3-OPF-R1).

REC-37-W3-SAF-R1.5: Further investigations should be undertaken in future projects to examine the use of 'safety buffers' on certain route pairings.

REC-37-W3-SAF-R1.6: A larger sample size of differing aircraft types should be utilised in future projects to deduce whether improved departure speed profiles are required and if there are any issues with specific aircraft speed data.

REC-37-W3-SAF-R1.7: Additional simulations should be undertaken to explore the interactions of Heathrow departures with all traffic movements both through the TMA and into and out of the major airports in the London TMA, with a consideration to include unfavourable wind profiles at all levels.

REC-37-W3-SAF-R1.8: Further investigation should be undertaken in future projects to ascertain whether other significant parameters need to be included in the Solution (e.g., Airline, destination, and air pressure.)

REC-37-W3-SAF-R1.9: Further investigations should be undertaken in future projects regarding same SID pair departures, catch-ups and potential wake encounters above the Controlled Traffic Region.

REC-37-W3-SAF-R1.10: The HMI needs to clearly display when there is wake separation.

REC-37-W3-SAF-R1.11: Further investigations should be undertaken to assess the impact of the extended OSD tool on catch-up occurring in the TMA and if the defined spacing delivery points for the leader and follower aircraft are appropriate on a SID pair basis.

REC-37-W3-SAF-R1.12: Further investigations should be undertaken to assess whether the target distance spacings assigned to SID pair combinations are sufficient.

REC-37-W3-SAF-R1.13: An investigation into whether a destination reference table should be an input to the extended OSD tool should be carried out.

REC-37-W3-SAF-R2.1: A toggle switch should be provided to enable ATCO personalisation of the timer. (See also REQ-37-W3-HP-6).

REC-37-W3-SAF-R2.2: An HMI workshop should be held to discuss suitable placement of the extended OSD tool output. (See also REQ-37-W3-HP-7).

REC-37-W3-SAF-R2.3: An HMI workshop should be held to discuss the suitable placement of the MDI and TMA data feed information.

REC-37-W3-SAF-R2.4: During the next wave of this solution, more scenarios and tasks that ATCOs experience daily should be incorporated into the simulated exercises.

REC-37-W3-SAF-R2.5: A simple to follow separations matrix and immediate action procedures should be produced to enable safe operations to continue.

REC-37-W3-SAF-R2.6: HF, Safety and ATCOs should fully investigate the required procedures, tasks and possible ATCO training requirements in the event of tool failure.

REC-37-W3-SAF-R2.7: All ATC procedures which will be affected by the deployment of the tool should be highlighted early in future projects to assess for any major safety issues.

REC-37-W3-SAF-R2.8: Further investigations are required to fully understand the content and duration and frequency of training required for ATCOs to sufficiently maintain currency and skills to manually apply accurate and efficient separations.

REC-37-W3-SAF-R3.1: A visual only alert (not audible) of the status of the equipment is required to allow maximum time for controllers to identify the failure and then to quickly revert to the alternate procedures.

REC-37-W3-SAF-R3.2: Further investigations are undertaken regarding possible interaction between other ATC systems and the extended OSD tool system and the utilisation of any back up servers already in use in the Air Traffic Control tower.

REC-37-W3-SAF-R3.3: A function should be introduced to allow the Supervisor only to switch off the system (either in certain elements or the whole extended OSD tool) in situations where there was any doubt about the integrity of the information being presented to the controller. (See also REQ-37-W3-HP-3)

REC-37-W3-SAF-R3.4: Further investigation into the issue of corrupt but believable data and its impact to the system should be undertaken in future projects.

REC-37-W3-SAF-R3.5: Further examination should be made into the assigning of the correct software assurance level to the system in association with compliance of ED153.

The Human Performance recommendations can be found in Appendix D of the PJ.37-W3-01B DEMO Report Part III (HPAR) [19].

5.4.2 Recommendations on regulation and standardisation initiatives

No relevant recommendations from the Departure concept.

5.4.3 Recommendations for updating ATM Master Plan Level 2

Update the ATM Master Plan Level 2 for SESAR Solutions PJ.02-01-02 indicating the outcome of SESAR Project PJ37-W3-ITARO → achieved maturity is TRL7 ongoing.

6 Summary of Communications and Dissemination activities

6.1 Summary of communications and dissemination activities

Please refer to the Communication, Dissemination and Exploitation Plan of this project [7].

6.2 Target Audience Identification

Please refer to the Communication, Dissemination and Exploitation Plan of this project [7].

6.3 Project High Level Messages

Please refer to the Communication, Dissemination and Exploitation Plan of this project [7].

7 References

- [1] SESAR Concept of Operations (CONOPS 2019), D2.5, Edition 01.00.00, SESAR PJ19, May 2019.
- [2] SESAR 2020 Project PJ37-W3-ITARO, D1.4 Demonstration Plan – Part I, Edition 01.00.00, January 2023.
- [3] SESAR 2020 Project PJ37-W3-ITARO, D1.5 – PJ.37-W3-ITARO, DEMOR – Part II Safety Assessment Report, Track PJ.37-W3-01A, Edition 00.01.00, March 2023.
- [4] SESAR 2020 Project PJ37-W3-ITARO, D1.5 – PJ.37-W3-ITARO, DEMOR – Part III Human Performance Assessment Report, Track PJ.37-W3-01A, Edition 00.01.00, March 2023.
- [5] SESAR 2020 Project PJ37-W3-ITARO, D1.5 – PJ.37-W3-ITARO, DEMOR – Part IV, Environment Assessment Report, Track PJ.37-W3-01A, Edition 00.01.00, March 2023.
- [6] SESAR 2020 Project PJ37-W3-ITARO, D1.5 – PJ.37-W3-ITARO, DEMOR – Part V Performance Assessment Report, Track PJ.37-W3-01A, Edition 00.01.00, March 2023.
- [7] SESAR 2020 PJ37-W3-ITARO D1.2.05 Communication, Dissemination and Exploitation Plan, Edition 01.00.00, January 2023.
- [8] PJ19.04 SESAR Performance Framework Edition 01.00.01, 30 November 2019
- [9] PJ19.4.2 SESAR Environment Assessment Process Edition 04.00.00, 23 September 2019
- [10] Methodology for the Performance Planning and Master Plan Maintenance, Edition 0.13, Dec 2017
- [11] SESAR2020 PJ.20 WP2.2 Airport OE (Edition February 2019) & TMA and En-Route OE (Edition April 2019)
- [12] SESAR Solution PJ.02-01 VALR for V3, V00.01.01, D1.1.04, Validation Exercise RTS5 Report, 31st January 2020.
- [13] SESAR Solution PJ.02-01 SPR-INTEROP/OSED for V3 – Part I, D1.1.01, 31st January 2020.
- [14] SESAR Solution PJ.02-01-06 SPR-INTEROP/OSED for V3 Intermediate Version for V3 – Part I, D4.14.001, 31st March 2021.
- [15] P06.08.01, Wake Turbulence Re-Categorisation and Pair-Wise Separation on Approach and Departure (RECAT-PWS-EU) Safety Case, v1.2, D38, 4th February 2016.
- [16] SESAR Solution PJ.02-W2-14.8 OSED for V2 Intermediate Version - Part I, D4.8.001, 28th May 2021.
- [17] SESAR PJ.01-W2-08B for V2 SPR-INTEROP/OSED – Part I, D.3.1.100, Edition 00.01.03, 27th July 2022.
- [18] SESAR 2020 Project PJ37-W3-ITARO, D1.5 – PJ.37-W3-ITARO, DEMOR – Part II, Safety Assessment Report, Track PJ.37-W3-01B, Deliverable ID D1.5, Edition 00.02.00, May 2023.



- [19] SESAR 2020 Project PJ37-W3-ITARO, D1.5 – PJ.37-W3-ITARO, DEMOR – Part III, Human Performance Assessment Report, Track PJ.37-W3-01B, Edition 00.01.00, March 2023.
- [20] SESAR 2020 Project PJ37-W3-ITARO, D1.5 – PJ.37-W3-ITARO, DEMOR – Part IV Environment Assessment Report, Track PJ.37-W3-01B, Edition 00.01.00, March 2023.
- [21] SESAR 2020 Project PJ37-W3-ITARO, D1.5 – PJ.37-W3-ITARO, DEMOR – Part V Performance Assessment Report, Track PJ.37-W3-01B, Edition 00.01.00, March 2023.
- [22] SESAR 2020 Project PJ.01-W1-EAD, SESAR Solution PJ.01-05 Contextual Note, Airborne Spacing Flight-deck Interval Management, 2019.



Appendix AEXE-PJ.37-W3-001 Report

This appendix describes the results for the EXE-PJ.37-W3-001 and presents conclusions and recommendations of this exercise.

A.1 Summary of the Demonstration Exercise #01 Plan

The demonstration exercise is as elaborated in the DEMOP ed01.00.00 [2]. No major deviations have taken place. The minor deviations are described in Appendix A.2.

A.1.1 Exercise description and scope

Exercise description and scope are in accordance to the DEMOP ed01.00.00 [2].

A.1.2 Summary of Demonstration Exercise #01 Demonstration Objectives and success criteria

For a summary of the demonstration exercise objectives and success criteria, please refer to DEMOP ed01.00.00 [2].

A.1.3 Summary of Demonstration Exercise #01 Demonstration scenarios

The various reference and scenario demonstration runs are provided in Table 7-1.

Date	Run	Scenario Category	Runway [arr / dep]	Wind condition	Throughput per runway per hour
14-01-2022	1	Solution	06+36R / 36L+36C	calm	35
	2	Reference	06+36R / 36L+36C	calm	35
	4	Reference	18R+18C / 24+18L	Strong headwind on final	35
21-01-2022	5	Solution	18R+18C / 24+18L	Light headwind on final	35
	6	Solution	06+36R / 36L+36C	Calm	40
	7	Reference	06+36R / 36L+36C	Calm	40
	8	Reference	18R+18C / 24+18L	Light headwind on final	35
18-02-2022	9	Solution	18R+18C / 24+18L	Light headwind on final	40
	10	Reference	18R+18C / 24+18L	Light headwind on final	40
	3	Solution	18R+18C / 24+18L	Strong headwind on final	35
	11	Solution with MRS 2.0, IM speed bracket was $\pm 10\%$ instead of $\pm 15\%$	06+36R / 36L+36C	Calm	40

Table 7-1: EXE-PJ.37-W3-001 demonstration/simulation scenario overview

Chronological order displayed in figures

Run 3 was performed on the same day as run 11 due to planning rescheduling compared with the original numbering as provided in the DEMOP.

A.1.4 Summary of Demonstration Exercise #01 Demonstration Assumptions

For a summary of the demonstration assumptions, please refer to DEMOP ed01.00.00 [2].

A.2 Deviation from the planned activities

Several deviations to the planned activities have occurred, as elaborated in the paragraphs below.

Demonstration run numbers: The demonstration exercise run numbers as documented in the DEMOR are not identical to the run numbers as presented in the DEMOP Part I ed01.00.00. For the analysis in the DEMOR Table 7-1 presented in Section A.1.3 shall be used when referring to the executed simulation runs.

Demonstration run definition: During the execution of the reference run with ‘strong headwind on final’ with a throughput of 35 aircraft per runway per hour (Run 4), it was noticed that the distance-based merge support ghost blip was presented near the actual aircraft to which the merge had to be performed. This is an inherent behaviour of a distance-based merge support presentation, however the combination of wind speed and direction in addition to the presentation of the merge support ghost blip on the FAR for aircraft not yet entering the TMA resulted in the merge support ghost blip presentation to overtake or stay nearby the actual aircraft. Figure 7-1 presents an example of such behaviour. Based on the performance of Demonstration Run 4, it was decided to include two new demonstration runs with less wind (Run 5 and Run 8) in order to have the controllers more familiar and experienced with this presentation. In return, two originally planned solution runs with ‘non-nominals’ (bunches and missed approaches) were not performed. However, both bunching and missed approaches occurred throughout the performance of this demonstration exercise.

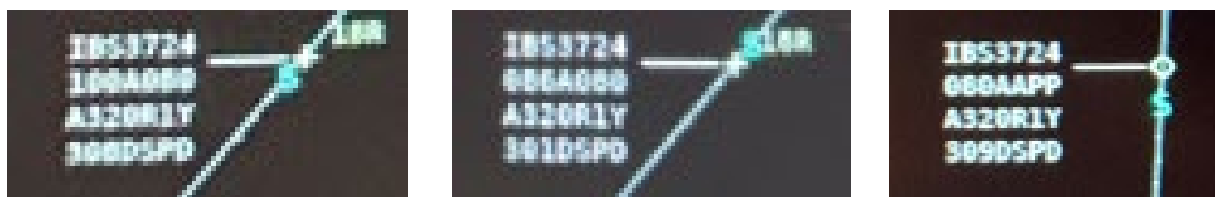


Figure 7-1: Demonstration Run 4 - merge support ghost blip presentation (captured at around 28, 29 and 33 minutes into the simulation).

Deviations between experiment day 1 and day 2: On day 1, it was observed that in the solution runs with Interval Management (IM) active, speed was high near the final track intercept. To correct this, a constraint has been introduced 2 NM before the final track intercept of a speed of 180 KIAS.

A.3 Demonstration Exercise #01 Results

A.3.1 Summary of Demonstration Exercise #01 Demonstration Results

Table 7-2 presents results of each demonstration objective of this exercise.

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0003	The arrival management process is found acceptable by the ATCOs present in the RTS.	CRT-37-W3-DEMOP-HUP1-0003	No acceptance issues are identified both during the RTS and debriefings by the ATCOs involved in the simulations.		Several acceptability issues were identified during the RTS.	POK
OBJ-37-W3-DEMOP-HUP1-0004	Assess completeness and acceptability of working procedures (regarding transition between IM/merge tool and PWS/ORD tool whilst operating RNAV/RNP transition procedures followed by instrument approach procedures).	CRT-37-W3-DEMOP-HUP1-0004	V3. Operating methods are found to cover identified normal operating conditions.		The acceptability of working procedures is at an acceptable level as it was rated on average 3.5 to 4 out of 7 in the post-experiment questionnaire, with a lot of variation between individual ratings. The completeness of the working procedures and the acceptability of the procedures were rated 4 (scale 1 to 5) in the post-experiment questionnaire.	OK
OBJ-37-W3-DEMOP-HUP1-0005	Assess working procedures for normal mode of operations are clear and consistent.	CRT-37-W3-DEMOP-HUP1-0005	V3. The content of the operating methods has been determined to be clear and consistent by end users and native		The controllers rated the clarity and consistency of the procedures at 3 or 4 (scale 1 to 5) in the post-experiment questionnaire. The average on clarity was 3.7 and on consistency 3.3, which indicates the	POK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			speakers/linguistic experts.		controllers rated it neutral to positive.	
OBJ-37-W3-DEMOP-HUP1-0006	Assess the ability of controller to follow working procedures.	CRT-37-W3-DEMOP-HUP1-0006	V3. [GND only] Number of errors in the solution not significantly higher than in reference scenario, taking into account error type & operational impact.		Based on RTS 1 no conclusion can be drawn on the registered number of errors (due to limited size of experiment and small error probability). The post experiment ratings show that the clearness and consistency are rated on average between 3 and 4 (scale 1 to 5).	POK
OBJ-37-W3-DEMOP-HUP1-0007	Assess the types, likelihood and effect of errors that occur, in particular due to the simultaneous presentation ORD and Merge tool indicators.	CRT-37-W3-DEMOP-HUP1-0007	V3. Recovery means for errors in the solution minimise operational impact.		No errors were observed in RTS1 as a result of the simultaneous presentation.	OK
OBJ-37-W3-DEMOP-HUP1-0008	Assess the extent to which task performance is reduced by the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0008	V3. Tasks are effectively achieved		Tasks were adequately and timely performed. Some potential improvements were identified in order to earlier detect when sequences are not as planned. ATCOs mentioned that it was difficult to re-accommodate a flight going around in the dense traffic. Merging and spacing tasks were effectively achieved. Nevertheless,	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
					ATCOs mentioned to lack the time to monitor the traffic on final.	
OBJ-37-W3-DEMOP-HUP1-0009	Assess the impact on ATCO workload by the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0009	V3. Level of workload within acceptable limits ('acceptable limits' to be defined with regard to the tool used for the assessment).		The experienced workload was within acceptable limits.	OK
OBJ-37-W3-DEMOP-HUP1-0010	Assess the impact on ATCOs level of trust in the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0010	V3. Potential issues related to trust and the preliminary mitigation identified are acceptable.		The main concern regarding the ATCOs' trust was the reliability and timeliness of the pilot responses.	POK
OBJ-37-W3-DEMOP-HUP1-0011	Assess the impact on individual ATCO situation awareness levels by the integrated arrival concept	CRT-37-W3-DEMOP-HUP1-1011	V3. [GND only] Level of situational awareness not lower in the solution than in the reference scenario.		On average the ATCO Situational Awareness seems sufficient. ATCOs mentioned that monitoring the flights turning in for final was difficult while merging and spacing on the route.	POK
		CRT-37-W3-DEMOP-HUP1-2011	V3. End user is able to perceive and interpret task relevant information and anticipate future events/actions.			

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0012	Assess the extent to which the integrated arrival concept complies with the relevant HP Principles.	CRT-37-W3-DEMOP-HUP1-0012	V3. Visual displays are consistent with design standards or regulations. Rationales are provided in case of deviations from standards.		The visual displays are consistent with design standards and with the design principles applicable to the working position.	OK
OBJ-37-W3-DEMOP-HUP1-0013	Assess the extent to which the user interface reduces human performance and service delivery.	CRT-37-W3-DEMOP-HUP1-0013	V3. [GND only] Usability rating for the integrated interface not lower in the solution than in the reference scenario.		No significant differences were found in performance between Reference and Solution.	OK
OBJ-37-W3-DEMOP-HUP1-0014	Assess the impact on team ATCO situation awareness levels by the integrated arrival concept	CRT-37-W3-DEMOP-HUP1-0014	V3. Team is able to perceive and interpret task relevant information and anticipate future events/actions.		The Team SA was sufficient and stable.	OK
OBJ-37-W3-DEMOP-HUP1-0015	The integrated tool does not deteriorate the arrival management process	CRT-37-W3-DEMOP-HUP1-0015	Under nominal conditions, there shall be no need to fall back on the use of vectoring operations while using the integrated tool.		The integrated tool does not deteriorate the arrival management process as the count of the vectored flights does not show significant differences between the reference and solution runs.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-CAP1-0001	The runway throughput level shall remain at the same level or increase against the reference scenario	CRT-37-W3-DEMOP-CAP1-0001	.There is no negative effect on the runway throughput by using the integrated tool in nominal operations against the reference scenario.		Traffic sample between runs were not identical to perform comparison. However analysis shows no reduction in runway throughput and a reduction in the average TMA flight time, highlighting potential increase of runway throughput.	POK
OBJ-37-W3-DEMOP-CAP1-0002	The airspace capacity shall remain at the same level or increase against the reference scenario	CRT-37-W3-DEMOP-CAP1-0002	There is no negative effect on the airspace capacity by using the integrated tool in nominal operations against the reference scenario.		Traffic sample between runs were not identical to perform comparison. In the post-experiment debrief, controllers did not mention an experience of deterioration of airspace capacity. An analysis of the number of aircraft under control by each controller throughout the run resulted in a similar number of aircraft under control.	POK
OBJ-37-W3-DEMOP-PRD1-0001	The predictability of arriving traffic shall remain at the same level or increase against the reference scenario.	CRT-37-W3-DEMOP-PRD1-0001	There is no negative effect on the predictability of the traffic in the TMA by using the integrated tool		The integrated tool does not have a negative effect on the predictability as the average difference between the actual and planned time in the TMA is smaller for the solution runs.	OK
OBJ-37-W3-DEMOP-NOI1-0001	The noise profile will not increase against the reference scenario	CRT-37-W3-DEMOP-NOI1-0001	The use of the integrated tool does not increase the noise profile in the nominal		Traffic sample between runs were not identical to perform comparison. However analysis shows that due to higher speeds flown in the TMA, the sound exposure time is reduced,	POK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			simulation against the reference scenario.		having a positive effect on the 55dB noise contour areas.	
OBJ-37-W3-DEMOP-ENV1-0001	The CO2 emissions will not increase against the reference scenario	CRT-37-W3-DEMOP-ENV1-0001	The use of the integrated tool does not increase the CO2 emission in the nominal simulation against the reference scenario.		Traffic sample between runs were not identical to perform comparison. However analysis shows that in general, a decrease in CO2 emission is obtained in the solution runs.	POK
OBJ-37-W3-DEMOP-SAF1-0001	The number of go-arounds due to insufficient spacing shall not be greater than in the reference scenario	CRT-37-W3-DEMOP-SAF1-0001	The use of the integrated tool shall not increase the number of controller-instructed go-arounds.		The fact that more go-arounds due to insufficient spacing occurred in solution runs than in reference runs could not be related to the new combination of tools.	OK
OBJ-37-W3-DEMOP-SAF1-0003	The interoperability of the different tools in the integrated tool shall not introduce safety issues.	CRT-37-W3-DEMOP-SAF1-0003	Ensure that the functionalities of all solutions complement one another without negative interference.		After RTS1, it is unclear what exact role is played by the interoperability, due to factors that are not part of the SESAR solutions to be validated in ITARO	-
OBJ-37-W3-DEMOP-SAF1-0004	There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts).	CRT-37-W3-DEMOP-SAF1-0004	The use of the integrated tool and the Airborne Spacing Flight Deck Interval Management does not lead to an increased number of separation losses in the nominal solution as compared		The solution runs did not have more cases of LOS than the reference runs. In the questionnaires the controllers did have a few concerns with Wake separation losses	OK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			against the reference scenario.			
OBJ-37-W3-DEMOP-SAF1-0005	The perceived controllability of the operation by ATCO shall not degrade due to the use of the integrated tool.	CRT-37-W3-DEMOP-SAF1-0005	The tool gives the ATCO the means to intervene. The use of the tool does not lead to a perceived loss of controllability of the operation by the ATCO in relation to the conventional operation. This is assessed through a qualitative analysis.		The perceived controllability of the operation by the controllers improved with time.	OK

Table 7-2: Exercise 1 Demonstration Results



1. Results per KPA

Note that the exercise is a 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 on Capacity, Operational Efficiency and Environment.

Human Performance

The main HP findings based on RTS 1 are:

- The acceptability of the concept (OBJ-37-W3-HUP1-0003) was rated Partially OK (POK);
- The ATCOs were successful in achieving the tasks (OBJ-37-W3-HUP1-0008);
- The workload (OBJ-37-W3-HUP1-0009) in the solution and the reference is not significantly different, but was expected to be slightly reduced in the solution compared to the reference, in the long run;
- The ATCOs situational awareness in the solution compared to the reference was not significantly different (OBJ-37-W3-HUP1-0011).

This led to the following recommendations:

- Improve route design, prevent 90 degree turns and merges;
- Standardise the altitude at IAF or start the RNP at the merge point;
- Achieve-by point at the merge point;
- Automated IM cancellation at FAP;
- Reduce speeds earlier;
- Set a minimum separation at the merge point;
- Consider a time-based merge tool instead of the distance-based merge tool, a time-based tool that includes estimated wind conditions;
- Simplify the R/T protocol;
- Improve HMI, IM notification, indication whether flights are established on RNP, error robustness;
- Divide the work amongst more ATCOs (Feeder East and West);
- Expand Non Transition Zone (automated monitoring) for traffic established on RNP.

Capacity

Due to the traffic sample between the reference and solution runs not being identical, the capacity objectives have been assessed as Partially OK (POK). Analysis of runway throughput show no reduction between the reference and solution runs. Based on the average TMA flight time, it is expected that the runway throughput can increase. For the airspace capacity, the controllers mentioned in the post-experiment debrief that they did not experience a deterioration of airspace capacity. An analysis of the number of aircraft under control by each controller throughout the run resulted in a similar number between the reference and solution run. This implies that in the airspace under control by a controller, the total count under control by a controller at a single time did not increase. This was expected as the traffic load was not increased.

For RTS-2, it is of importance to use identical traffic samples between the reference and solution runs, and to perform runs with a higher traffic load in order to close the objectives related to this KPA.

Operational Efficiency

The single predictability objective has been assessed as OK. The integrated tool does not have a negative effect on the predictability as the average difference between the actual and planned time in the TMA is smaller for the solution runs. A variation in longer or shorter flight time than the planned time is noticed, based on the FAR and wind conditions. However, this relates to the accuracy of the Trajectory Predictor of the AMAN and the IM system as well.

For RTS-2 it is of interest whether a mixed equipage rate has an influence on the predictability.

Environment

Due to the traffic sample between the reference and solution runs not being identical (e.g. slightly different wake category aircraft landing within the simulation time), the environmental objectives could not be compared directly. However, based on the simulation run with the most identical traffic sample, a reduction in CO₂ emission and a reduction in the 55 dB noise contour area is obtained. Thus the objectives have been assessed as Partially OK (POK).

For RTS-2, it is of importance to use identical traffic samples between the reference and solution runs to close the objectives related to this KPA.

Safety

The main Safety findings based on RTS1 are:

- The number of go-arounds due to insufficient spacing was not greater than in the reference simulation (OBJ-37-W3-DEMOP-SAF1-0001): OK (Full), but to be confirmed during RTS2;
- Objective OBJ-37-W3-DEMOP-SAF1-0003 (interoperability of the different tools in the integrated tool shall not introduce safety issues) had inconclusive results. Conclusion to be formulated after RTS2;
- There was no negative impact on the number of losses of separation (wake, minimum radar separation infringements and tactical conflicts) (OBJ-37-W3-DEMOP-SAF1-0004): OK (Full), but to be confirmed during RTS2;
- The perceived controllability of the operation by ATCO did not degrade due to the use of the integrated tool (OBJ--W3-DEMOP-SAF1-0005): OK (Full), but to be confirmed during RTS2.

2. Results impacting regulation and standardisation initiatives

The results of this demonstration exercise will be used to prepare the second demonstration experiment on the NARSIM (EXE-PJ.37-W3-002). Results impacting regulation and standardisation initiatives will be provided afterwards.

A.3.2 Analysis of Exercises Results per Demonstration objective

In the following sections, each demonstration objective is evaluated by a consolidated analysis of the demonstration result, including a rationale of the result, potential deviation with respect to the expected performance benefit (if any) and in case applicable, possible reasons and relationship between the results and the appropriate assumptions.

1. OBJ-37-W3-DEMOP-HUP1-0003

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0003 “The arrival management process is found acceptable by the ATCOs present in the RTS” has been assessed as Partially OK (POK).

The acceptability has been assessed by ATCO ratings in the post-run questionnaire (I rate the acceptability of the operational concept as performed in this run, under the presented wind conditions, as..) on a seven-point scale (Figure 7-2:).

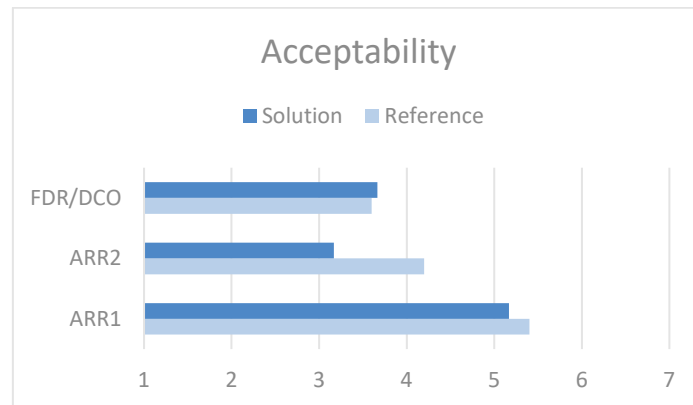


Figure 7-2: Average post-run acceptability ratings (n=5)

The air traffic controllers that participated in the demonstration exercise considered acceptability of the arrival management process as acceptable to be used in operation in its current form, including the human machine interface. The result of this objective is POK as ratings vary greatly between runs and comments and observations from this exercise reveal room for improvement in terms of route design and HMI. Besides that it was mentioned that the accuracy of delivery at TMA entry is crucial as well as accuracy at which pilots follow up the instructions. The Controller Acceptance Rating Scale in the end-of-day questionnaire confirmed that ‘improvement is mandatory’ on certain aspects (6 out of 9 ratings).

2. OBJ-37-W3-DEMOP-HUP1-0004

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0004 “Assess completeness and acceptability of working procedures (regarding transition between IM/merge tool and PWS/ORD tool whilst operating RNAV/RNP transition procedures followed by instrument approach procedures)” has been assessed as OK. The controllers rated the completeness and acceptability of the working procedures 4 (on a scale of 1 to 5) in the post-experiment questionnaire (Figure 7-3). It is concluded that both completeness and acceptability of working procedures are at an acceptable level. Nevertheless there is room for further improvement to be implemented in RTS 2.

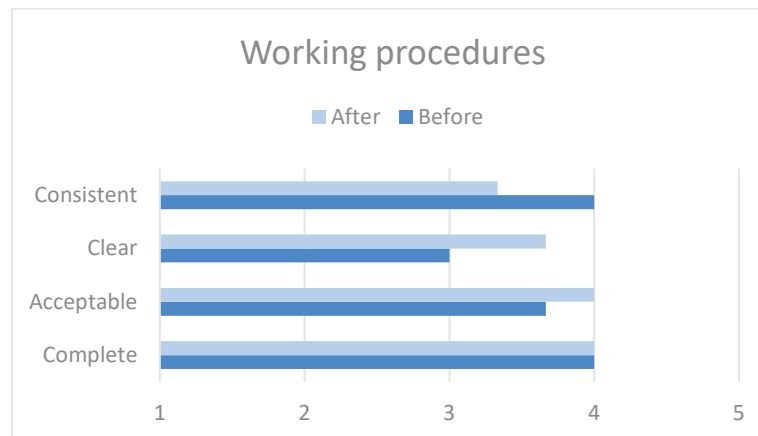


Figure 7-3: ATCO ratings, before and after the experiment, on the working procedures of the concept (n=3)

3. OBJ-37-W3-DEMOP-HUP1-0005

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0005 “Assess working procedures for normal mode of operations are clear and consistent” has been assessed as POK. The controllers rated the clarity and consistency of the procedures at 3 or 4 (scale 1 to 5) in the post-experiment questionnaire (Figure 7-3). The average on clarity was 3.67 and on consistency 3.3, which indicates the controllers found it neither consistent nor inconsistent.

4. OBJ-37-W3-DEMOP-HUP1-0006

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0006 “Assess the ability of controller to follow working procedures” has been assessed as Partially OK. The ATCOs mentioned that they had to intervene in several cases where the traffic seemed not to be safely planned, and as a result aircraft from two merging routes was moving with equal speeds towards the merge point (this issue was an error in the scenario and was solved in later phase of the experiment). In the end-of-day questionnaire the potential for Human Error of the solution was rated increased/negative in five of the nine observations.

5. OBJ-37-W3-DEMOP-HUP1-0007

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0007 “Assess the types, likelihood and effect of errors that occur, in particular due to the simultaneous presentation ORD and Merge tool indicators” has been assessed as Partially OK. ATCOs did not indicate to have experienced any confusion between the tools in the post-run ratings of the Solution concept (for the Reference this was indicated once (1 in 16 runs)). One of the three ATCOs rated the HMI's robustness against error negatively. In quite a few instances a loss of separation on final was recorded, but these were not increased in the solution compared to the reference and were thus not the result of the ORD and Merge tool indicators. This objective is to be further studied in RTS 2.

6. OBJ-37-W3-DEMOP-HUP1-0008

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0008 “Assess the extent to which task performance is reduced by the integrated arrival concept” has been assessed as OK. The ATCOs rated the influence of the solution concept (in comparison to the current way of working) neutral to positive regarding the HP aspects of workload, Situational Awareness, Team SA, Efficiency and Safety in the post-experiment questionnaire. The post-run ratings of 'the successfulness in achieving the task' was rated 5.9 (scale 1-7) for both conditions.

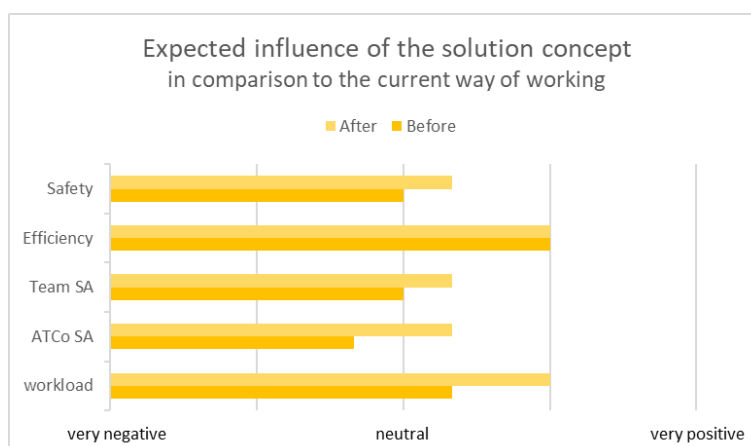


Figure 7-4: ATCo ratings before and after the experiment on the influence of the solution on HP aspects of Workload, ATCo Situational Awareness (SA), Team SA, Efficiency and Safety (n=3)

7. OBJ-37-W3-DEMOP-HUP1-0009

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0009 “Assess the extent to which workload is made worse by the integrated arrival concept” has been assessed as OK. The NASA-TLX ratings of controllers result in an average rating of 47 (on scale 0-100) and no significant differences between the solution and the reference (Figure 7-5). The post-experiment controller ratings showed that the controllers expected a positive influence of the solution concept on workload in comparison to the current way of working (Figure 7-4).

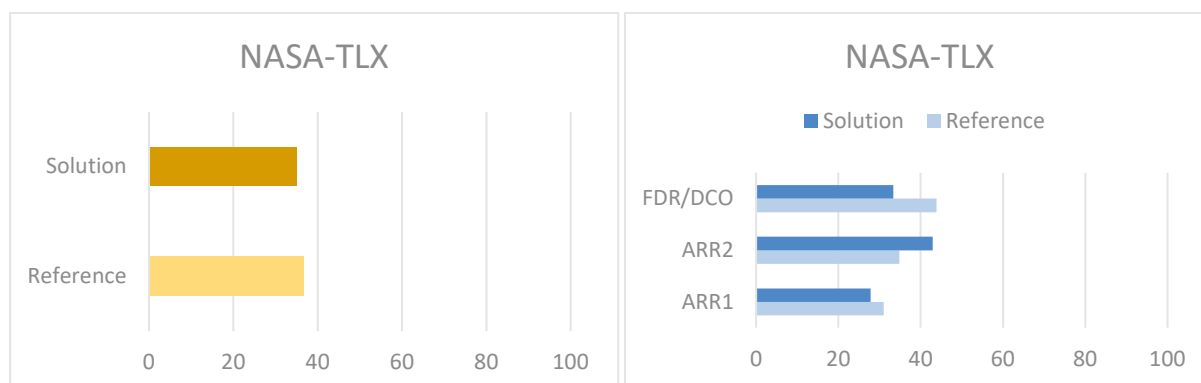


Figure 7-5: (n=15) and Figure 7-6: (n=5) Average post-run NASA-TLX ratings, in 7 per ATCO role

8. OBJ-37-W3-DEMOP-HUP1-0010

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0010 “Assess the impact on ATCOs level of trust in the integrated arrival concept” has been assessed as Partially OK. The average ATCO rating of confidence was around 6.2 (on scale 1-7) with no significant difference between the solution (6.1) and the reference (6.3). ATCO's mentioned that the confidence is strongly related to the confidence in the pilots to follow the routes, which will in reality be different.

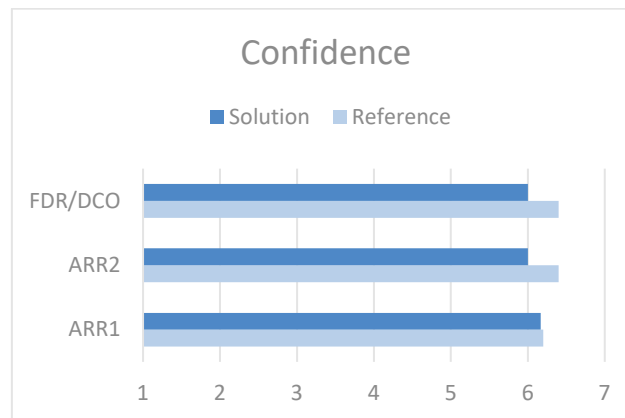


Figure 7-7: Average post-run ratings on level of confidence per ATCO role (n=5)

9. OBJ-37-W3-DEMOP-HUP1-0011

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0011 “Assess the impact on individual ATCO situation awareness levels by the integrated arrival concept” has been assessed as Partially OK. The post-run SASHA ratings show significant differences between the solution (4.6) and reference (5.1) (on the SASHA scale 0-6). Thus the SA was slightly reduced in the solution concept. Especially the statement 'there was a risk of forgetting something important' was rated differently for the two conditions in favour of the reference. The average SA ratings are quite acceptable, and post-experiment the ATCOs rated the impact of the concept on SA positively.

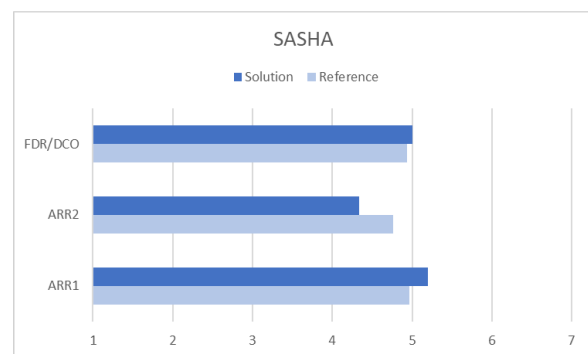
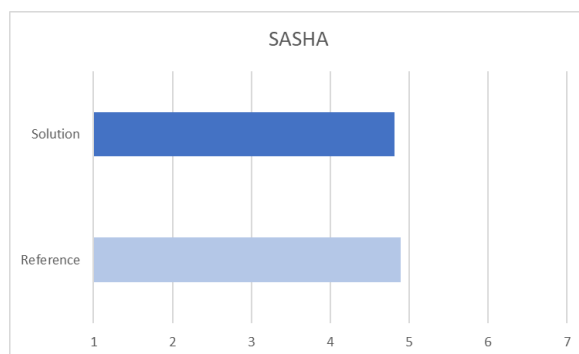


Figure 7-8: (n=15) and Figure 7-9: (n=5) Average post-run ratings of SASHA, in figure 10 per ATCO role

10. OBJ-37-W3-DEMOP-HUP1-0012

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0012 “Assess the extent to which the integrated arrival concept complies with the relevant HP Principles” has been assessed as POK. ATCOs did not indicate to have experienced any confusion between the tools in the post-run ratings of the Solution concept (for the Reference this was indicated once (1 in 16 runs)). Nevertheless, the consistency of the design of the tools was rated negative by two of the three controllers. The explanation by one of the ATCOs concerned the fact that when an alert was given for the IM, it was difficult to assess what was wrong (no input, wrong time or the sequence). In addition, the end-of-day questionnaires revealed that the potential for Human Error might increase with the Solution concept. These findings are used to improve the HMI and assess its usability in RTS 2.

11. OBJ-37-W3-DEMOP-HUP1-0013

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0013 “Assess the extent to which the user interface reduces human performance and service delivery” has been assessed as OK. The ATCOs rated the influence of the solution concept (in comparison to the current way of working) neutral to positive regarding HP aspects of workload, Situational Awareness, Team SA, Efficiency and Safety in the post-experiment questionnaire (see Figure 7-4). The post-run ratings of ‘the successfulness in achieving the task’ was rated 5.9 (scale 1-7) for both conditions. The post-experiment question regarding the consistency of the design of the different tools was answered negatively by two out of three controllers. The comment was that when an indication was given by IM it was difficult to find out what was wrong. Overall it was concluded that the HMI does not negatively impact the human performance. Nevertheless there is room for improvement.

12. OBJ-37-W3-DEMOP-HUP1-0014

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0014 “Assess the impact on team ATCO situation awareness levels by the integrated arrival concept” has been assessed as OK. The ATCO’s s post-run self-rating of team SA was not significantly different between the Reference and Solution runs. An exception is the Team SA of the FDR/DCO, which seems reduced for the solution (Figure 7-10).

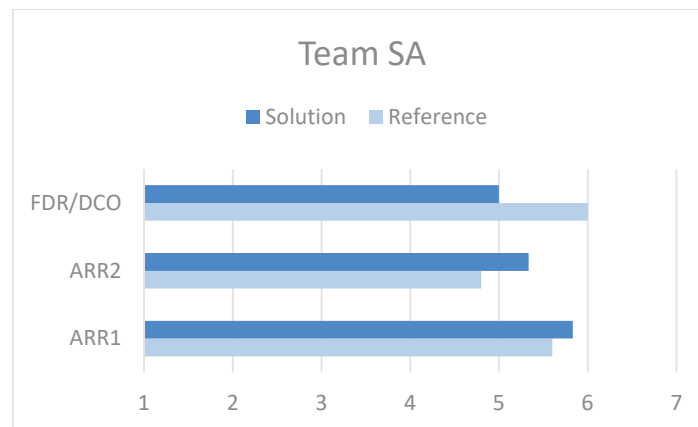


Figure 7-10: Average post-run ATCO ratings of team Situational Awareness (n=5)

13. OBJ-37-W3-DEMOP-HUP1-0015

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0015 “The integrated tool does not deteriorate the arrival management process” has been assessed as OK as the count of the vectored flights does not show significant differences between the reference and solution runs.

The deterioration of the arrival management process is defined for this objective as the need to revert to radar vectoring during nominal operations. Table 7-3 presents the number of vectored flights out of all arrivals of the simulation between the reference and solution run. As demonstration run 11 was only performed as solution run, it is not included in the table. The result for this run was that no flight was vectored.

It is noted that besides the reference run with strong wind (demonstration run 4), nearly all arriving aircraft did not deviate from their Fixed Approach Route (FAR). Demonstration run 4 was the first run for the controllers to experience wind during this demonstration exercise, as no test/practise run had been performed with the inclusion of wind. Combined with the observation that the distance-based merge support projected two aircraft near each other at an early stage after entering the TMA the controllers felt the need to increase separation. In later runs, the controllers got experienced with

simulations with the inclusion of wind and the presentation of the merge support. This resulted in fewer number of flights that were vectored.

Scenario	Reference run number	Nr of vectored flights	Solution run number	Nr of vectored flights
06+36R / 36L+36C, calm wind, 35 p/h	2	1	1	0
18R+18C / 24+18L, strong wind, 35 p/h	4	14	3	0
18R+18C / 24+18L, light wind, 35 p/h	8	1	5	1
06+36R / 36L+36C, calm wind, 40 p/h	7	2	6	2
18R+18C / 24+18L, light wind, 40 p/h	10	5	9	2

Table 7-3: OBJ-37-W3-DEMOP-HUP1-0015 Comparison of the number of vectored flights between the reference and solution run

14. OBJ-37-W3-DEMOP-CAP1-0001

Demonstration objective OBJ-37-W3-DEMOP-CAP1-0001 “The runway throughput level shall remain at the same level or increase against the reference scenario” has been assessed as Partially OK as the solution runs have often, but not always, an increased runway throughput compared to similar reference runs. However, the mean total TMA flight time for the solution runs decreased.

The method for calculating the runway throughput relies on dividing the number of “good landings” by the interval between the first and last good landing (in hours), per simulation run. A “good landing” has been defined as a flight which has;

- Horizontally passed the IAF within 2NM
- Horizontally passed the FAF within 0.1NM
- Vertically passed the RWY threshold

The filter protocol to select “good flights” should ensure that go-arounds and unfinished simulated flights are removed from the analysis, as these would corrupt the throughput calculation.

The results in Table 7-4 show the runway throughput per hour which are visualised in Figure 7-11. It is seen that the solution run only has a higher capacity for reference-solution pair 7-6. For the other pairs the solution run yields a lower throughput; 2-1, 4-3, 8-5, 10-9. Run 11 is considered a stand-alone special case as only the solution scenario was executed (with a MRS of 2.0 NM). However when comparing Run 11 with reference Run 7 it is seen that the throughput of Run 11 is higher, yet the value is lower than run 6. The latter is unusual as it would have been expected that run 11 (MRS of 2.0NM) would result a higher throughput than 6 (MRS of 2.5NM).

Run Nr	REF / SOL	Simulated entry throughput per hour per runway	Nr of good flights	WTC				Time interval [hr] between first and last landing	Throughput per hour
				H	M	L	J		
2	REF	35	51	8	43	0	0	0.82	62.24
1	SOL	35	45	6	38	0	1	0.73	61.77
4	REF	35	47	7	40	0	0	0.71	65.81
3	SOL	35	48	8	39	0	1	0.74	64.68
8	REF	35	50	7	43	0	0	0.73	68.14
5	SOL	35	50	8	41	0	1	0.76	66.12
7	REF	40	54	6	47	0	1	0.77	69.88
6	SOL	40	63	5	58	0	0	0.84	75.35
10	REF	40	53	5	48	0	0	0.71	74.67
9	SOL	40	54	5	49	0	0	0.74	72.97
11	SOL	40	56	7	48	0	1	0.79	70.74

Table 7-4: OBJ-37-W3-DEMOP-CAP1-0001 Total throughput per hour per run

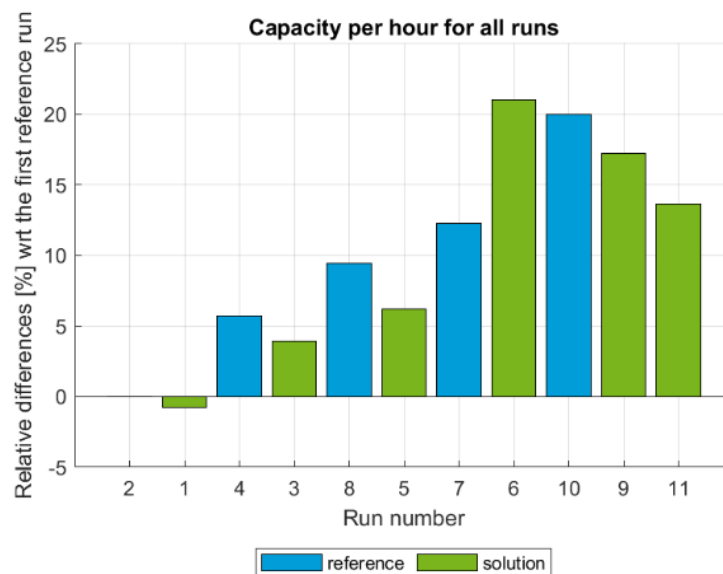


Figure 7-11: OBJ-37-W3-DEMOP-CAP1-0001 Relative differences in capacity per hour between the runs. Run-2 (reference) is taken as baseline for the capacity comparison. For each simulation, all landings were completed within one hour.

A reason why the solution runs sometimes have a lower throughput than the reference results could be related to the traffic mix. Table 7-4 shows that the relative contribution of the ICAO Wake Turbulence Category (WTC) H and J in the traffic mix varied between the runs. Part of this is caused by the simulation set up, where the order and spawn-time of aircraft was randomised per run using the

same traffic mix. This initial randomisation in combination with human factors related to local traffic separation could lead to situations where different aircraft have been filtered between the runs. As the H and J category aircraft have a significant impact on the wake separations, this could be a big contributor to the runway throughput calculation.

Because the runway throughput calculation only considers “good flights”, thus removing some aircraft out of the equation, and with a fixed number of aircraft (35 or 40 aircraft per hour per runway) in the simulation, it is understandable that the runway throughput would be below 70-80 aircraft per hour (as the simulation used 2 runways for inbound traffic). Furthermore, the simulation time per run between the first and last good landing was less than one hour. Therefore extrapolation was used to calculate the throughput per hour. Finally, the first and last timestamps of the “good flights” have a significant impact on the time interval used in the capacity calculation. Table 7-4 shows that the used interval varies between 0.71hr and 0.84hr, which is a 7min difference across the runs.

In Table 7-5 to Table 7-8, the results per runway are presented. Although the tables do not provide new findings to the initial analysis, it however better reflects the actual throughput and the difference per runway is clear.

Run Nr	Simulated entry throughput per hour per runway	Nr of good flights	WTC				Time interval [hr] between first and last landing	Throughput per hour
			H	M	L	J		
2	35	28	2	26	0	0	0.81	34.53
1	35	25	2	23	0	0	0.73	34.32
7	40	25	4	21	0	0	0.72	34.93
6	40	33	1	32	0	0	0.84	39.51
11	40	26	5	21	0	0	0.76	34.34

Table 7-5: OBJ-37-W3-DEMOP-CAP1-0001 Total throughput per hour per run, runway 06

Run Nr	Simulated entry throughput per hour per runway	Nr of good flights	WTC				Time interval [hr] between first and last landing	Throughput per hour
			H	M	L	J		
2	35	23	6	17	0	0	0.70	32.82
1	35	20	4	15	0	1	0.63	31.93
7	40	29	2	26	0	1	0.77	37.61
6	40	30	4	26	0	0	0.78	38.34
11	40	30	2	27	0	1	0.79	38.15

Table 7-6: OBJ-37-W3-DEMOP-CAP1-0001 Total throughput per hour per run, runway 36R

Run Nr	Simulated entry throughput per hour per runway	Nr of good flights	WTC				Time interval [hr] between first and last landing	Throughput per hour
			H	M	L	J		
4	35	25	1	24	0	0	0.70	35.85
3	35	25	2	23	0	0	0.73	34.21
8	35	26	1	25	0	0	0.73	35.43
5	35	26	2	24	0	0	0.76	34.38
10	40	27	1	26	0	0	0.67	40.11
9	40	27	1	26	0	0	0.66	40.80

Table 7-7: OBJ-37-W3-DEMOP-CAP1-0001 Total throughput per hour per run, runway 18R

Run Nr	Simulated entry throughput per hour per runway	Nr of good flights	WTC				Time interval [hr] between first and last landing	Throughput per hour
			H	M	L	J		
4	35	22	6	16	0	0	0.70	31.53
3	35	23	6	16	0	1	0.73	31.51
8	35	24	6	18	0	0	0.72	33.56
5	35	24	6	17	0	1	0.75	31.88
10	40	26	4	22	0	0	0.71	36.74
9	40	27	4	23	0	0	0.74	36.48

Table 7-8: OBJ-37-W3-DEMOP-CAP1-0001 Total throughput per hour per run, runway 18C

With the limited duration of the simulation runs and removal of some flights, it is difficult to use the “runway throughput” as an effective method to assess the capacity differences between the reference and solution runs. As such, it is recommended to assess the capacity from a “TMA flight time” point of view, which is in line with “CAP3 - Peak Runway Throughput (Mixed mode)” of the SESAR performance Framework [8][9]. The results of the TMA flight time are visualised in Figure 7-12. Since the 4th Schiphol IAF is not published, for the sake of this research it has been indicatively named as [XXXXX].

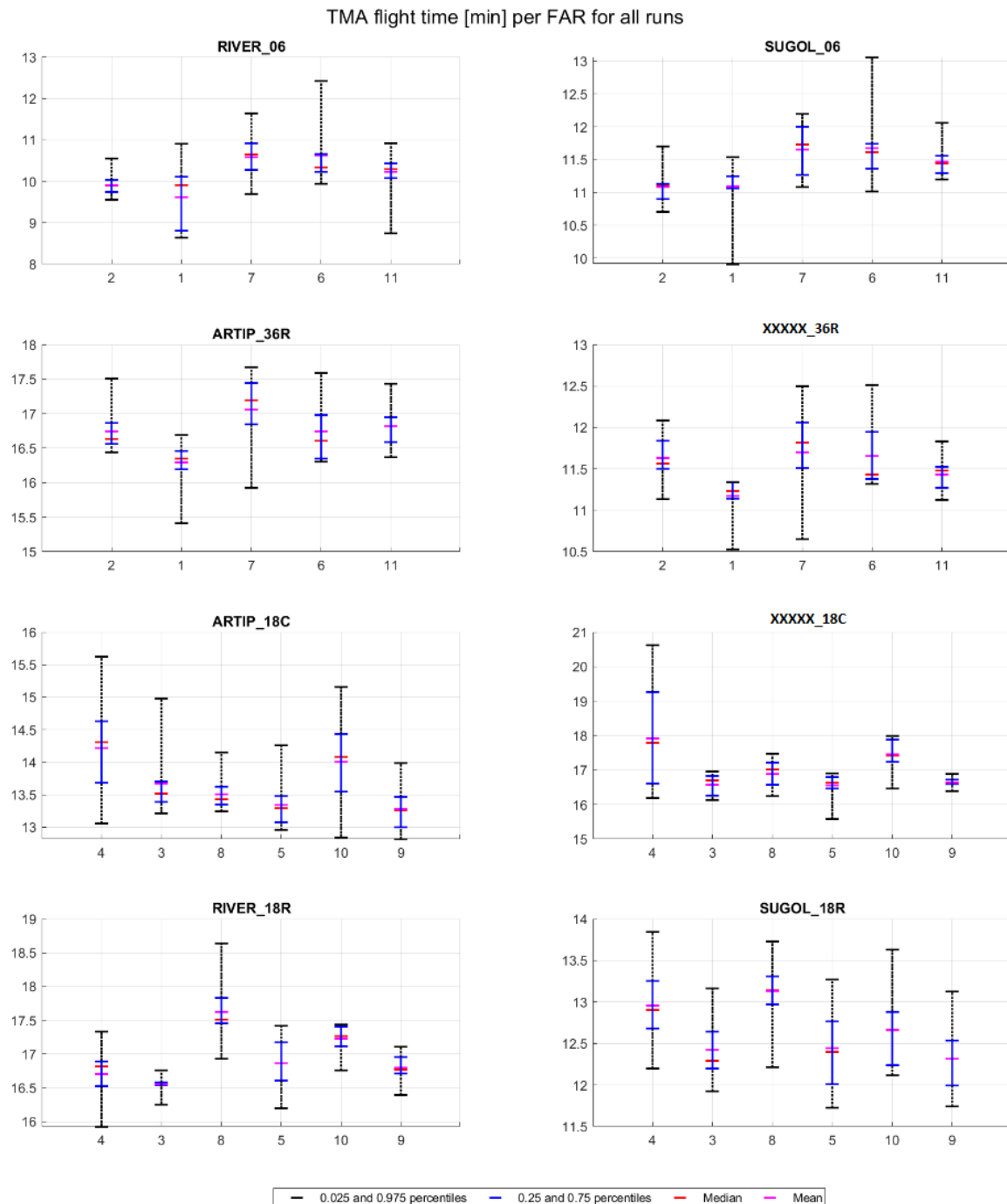


Figure 7-12: OBJ-37-W3-DEMOP-CAP1-0001 Flight time in TMA.

Figure 7-12 shows that overall the average flight time in the TMA is less for the solution runs compared to similar reference runs; 2-1 mainly on 36R and marginally on 06, 4-3 on all FARs, 8-5 on all FARs, 7-6 mainly on 36R and RIVER-06 but marginally on SUGOL-06, 10-9 on all FARs.

To conclude, Figure 7-12 shows reduction in flight time in the TMA, which demonstrates the higher-capacity potential of the solution scenario runs compared to the reference runs. As the TMA flight time provides more robust and more refined measurements, it is deemed that this provides a better view on the capacity potential than the throughput calculations.

15. OBJ-37-W3-DEMOP-CAP1-0002

Demonstration objective OBJ-37-W3-DEMOP-CAP1-0002 “The airspace capacity shall remain at the same level or increase against the reference scenario” has been assessed as Partially OK. As the assessment of the KPI airspace capacity in a simulation with the use of FARs and a fixed number of aircraft per hour per runway did not result in a quantified outcome that could meaningfully assess the success criteria. Qualitatively, based on the comments made by the controllers, the airspace capacity was not deteriorated as the controllers did not encounter issues with the airspace capacity throughout the simulations.

For this exercise, airspace capacity and runway throughput have been divided into two different objectives. The success criteria of this objective is defined as “There is no negative effect on the airspace capacity by using the integrated tool in nominal operations against the reference scenario”. As no ACC controller was involved with the simulation, the simulation platform would deliver aircraft at the TMA entry point according to the arrival planning. Thus even if necessary, the APP controller could not coordinate with the ACC controller to shift or delay the next inbound aircraft into the TMA. The runway throughput objective (OBJ-37-W3-DEMOP-CAP1-0001) may provide an indicative result to the airspace capacity evaluation. The focus is on arriving traffic only.

For the quantitative assessment, the airspace capacity for this objective is defined as a volume of TMA airspace under control of a controller. Due to the use of Fixed Approach Routes (FARs), aircraft under control (UCO) of a controller will also pass a predefined volume of the TMA airspace. In this exercise, three controllers participated:

- APP position, also called the Arrival Feeder position. Controls departing traffic and the two longest FARs starting at the IAF RIVER and XXXXX (1 each for the ARR controllers). Since the 4th Schiphol IAF is not published, for the sake of this research it has been indicatively named as [XXXXX].
- ARR1 and ARR2 position. With 2 runways in operation, each controller manages two eastern or two western FARs, which merge towards one runway.

Table 7-9 to Table 7-11 present the total number of movements per volume of the TMA airspace for each controller for all the simulations. As demonstration run 11 was only performed for the solution run, the results are presented separately in Table 7-12.

Scenario	Ref. run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	Sol. Run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	% Δ between Ref. and Sol. run
06+36R / 36L+36C, calm wind, 35 p/h	2	34	0.99	34.2	1	31	0.86	36.1	5.5%
18R+18C / 24+18L, strong wind, 35 p/h	4	34	0.94	36.3	3	31	0.95	32.5	-10.5%
18R+18C / 24+18L, light wind, 35 p/h	8	35	0.97	36.2	5	32	0.97	33.0	-8.9%

Scenario	Ref. run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	Sol. Run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	% Δ between Ref. and Sol. run
06+36R / 36L+36C, calm wind, 40 p/h	7	33	0.89	36.9	6	42	0.97	43.1	16.7%
18R+18C / 24+18L, light wind, 40 p/h	10	35	0.90	39.0	9	35	0.91	38.3	-1.8%

Table 7-9: OBJ-37-W3-DEMOP-CAP1-0002 Traffic volume in the TMA airspace under control of the ARR1 controller, as determined by the total number of aircraft under control and time interval based on the first aircraft under control until end of the simulation.

Scenario	Ref. run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	Sol. Run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	% Δ between Ref. and Sol. run
06+36R / 36L+36C, calm wind, 35 p/h	2	30	0.91	33.0	1	26	0.82	31.9	-3.4%
18R+18C / 24+18L, strong wind, 35 p/h	4	31	0.95	32.8	3	29	0.96	30.3	-7.4%
18R+18C / 24+18L, light wind, 35 p/h	8	30	0.98	30.8	5	29	0.98	29.6	-3.7%
06+36R / 36L+36C, calm wind, 40 p/h	7	36	0.97	36.9	6	40	0.97	41.4	12.0%
18R+18C / 24+18L, light wind, 40 p/h	10	33	0.93	35.4	9	34	0.96	35.4	-0.2%

Table 7-10: OBJ-37-W3-DEMOP-CAP1-0002 Traffic volume in the TMA airspace under control of the ARR2 controller, as determined by the total number of aircraft under control and time interval based on the first aircraft under control until end of the simulation.

Scenario	Ref. run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	Sol. Run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	% Δ between Ref. and Sol. run
06+36R / 36L+36C,	2	61	1.00	61.2	1	56	0.90	62.3	1.8%

Scenario	Ref. run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	Sol. Run #	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour	% Δ between Ref. and Sol. run
calm wind, 35 p/h									
18R+18C / 24+18L, strong wind, 35 p/h	4	58	0.99	58.6	3	54	1.00	53.8	-8.2%
18R+18C / 24+18L, light wind, 35 p/h	8	59	1.00	58.7	5	57	0.99	57.8	-1.5%
06+36R / 36L+36C, calm wind, 40 p/h	7	60	1.01	59.1	6	69	1.00	68.9	16.5%
18R+18C / 24+18L, light wind, 40 p/h	10	64	1.06	60.5	9	65	1.03	63.1	4.3%

Table 7-11: OBJ-37-W3-DEMOP-CAP1-0002 Traffic volume in the TMA airspace under control of the APP controller, as determined by the total number of aircraft under control and time interval based on the first aircraft under control until end of the simulation.

Run 11	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour
ARR1	33	0.91	36.2
ARR2	37	0.99	37.3
APP	61	1.03	59.5

Table 7-12: OBJ-37-W3-DEMOP-CAP1-0002 Traffic volume in the TMA airspace under control of the controller for demonstration run 11, as determined by the total number of aircraft under control and time interval based on the first aircraft under control until end of the simulation.

The calculations have been performed, where possible, in accordance with the KPI CAP1 “TMA throughput, in challenging airspace, per unit time” introduced in the SESAR Performance Framework [8]. The aircraft under control count considered in this analysis is based on the logging made by the platform when the controllers push the “UCO” button on their Touch Input Device (TID) when the flights calls to the controller for the first time. The data has been filtered for multiple incorrect TID inputs, but does account for flights that had been handed over initially, but have been take under control for a second time.

As the traffic sample was not completely identical, the comparison between the reference and solution run, as presented in the tables, cannot be accurately made. This has resulted in quite some variation in the % difference in hourly traffic volume between the reference and solution runs. Furthermore, use is made of the total number of aircraft landed. Thus as with the throughput per hour presented in Table 7-4, this is a difficult metric to quantify in a simulation.

When plotting the number of aircraft under control throughout the simulations, comparing the reference and solution runs, Figure 7-13 to Figure 7-15 are obtained.

For the ARR1 controller, in the solution run number 1, it had sustained a higher capacity for a longer period of time as compared to the reference run number 2. On the other hand, a higher capacity for a longer period of time was sustained by the ARR2 controller in the reference run number 2 and reference run number 4 as compared to their respective solution runs. For the APP controller, in solution run number 6, a higher capacity was sustained for a longer period of time as compared to reference run number 7. However, in general, the reference and solution runs have a similar maximum number of aircraft under control, which was as predicted due to the use of FARs and a fixed hourly capacity.

ARR1 position

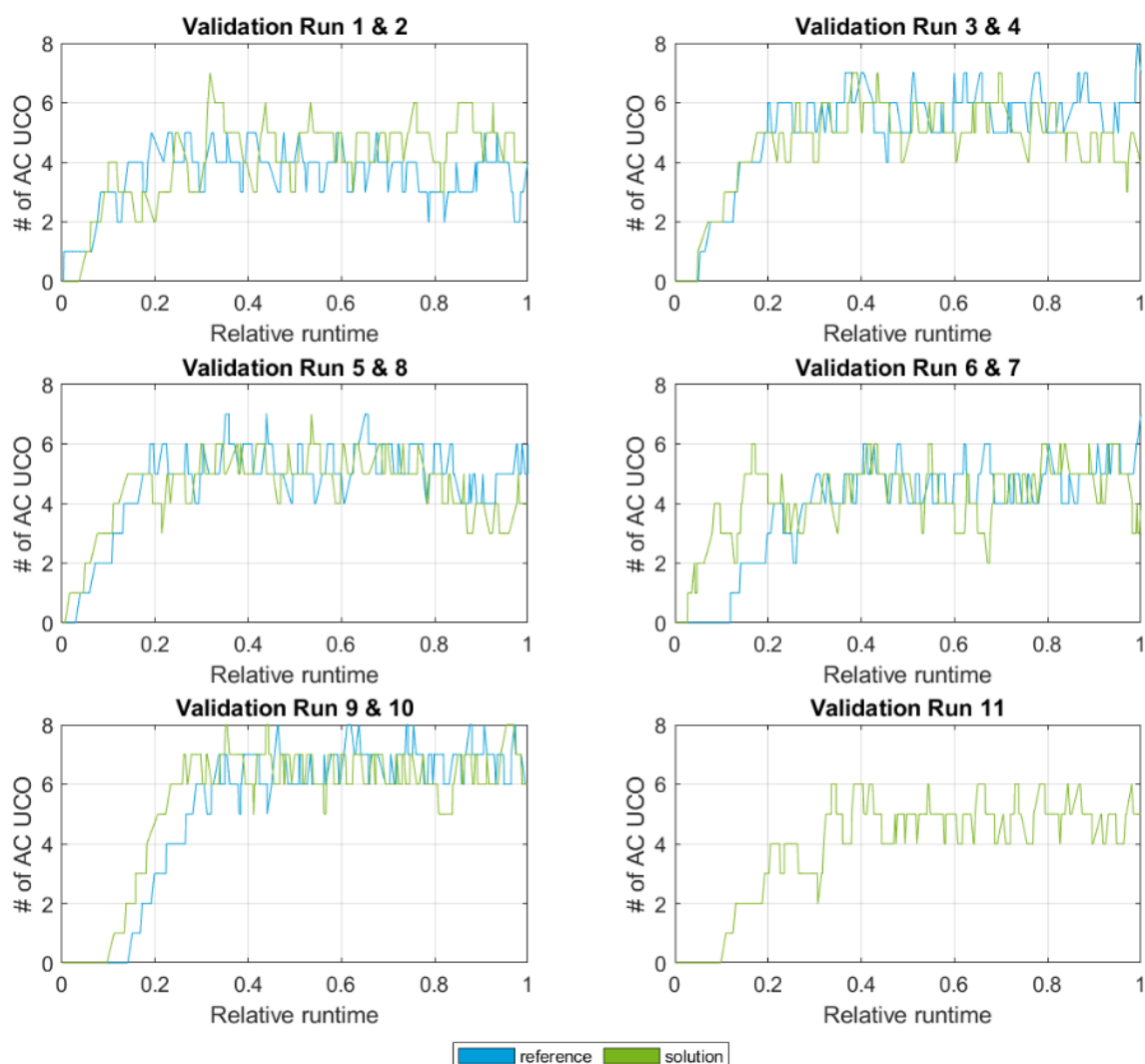


Figure 7-13: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft under control within the airspace under control by the ARR1 controller.

ARR2 position

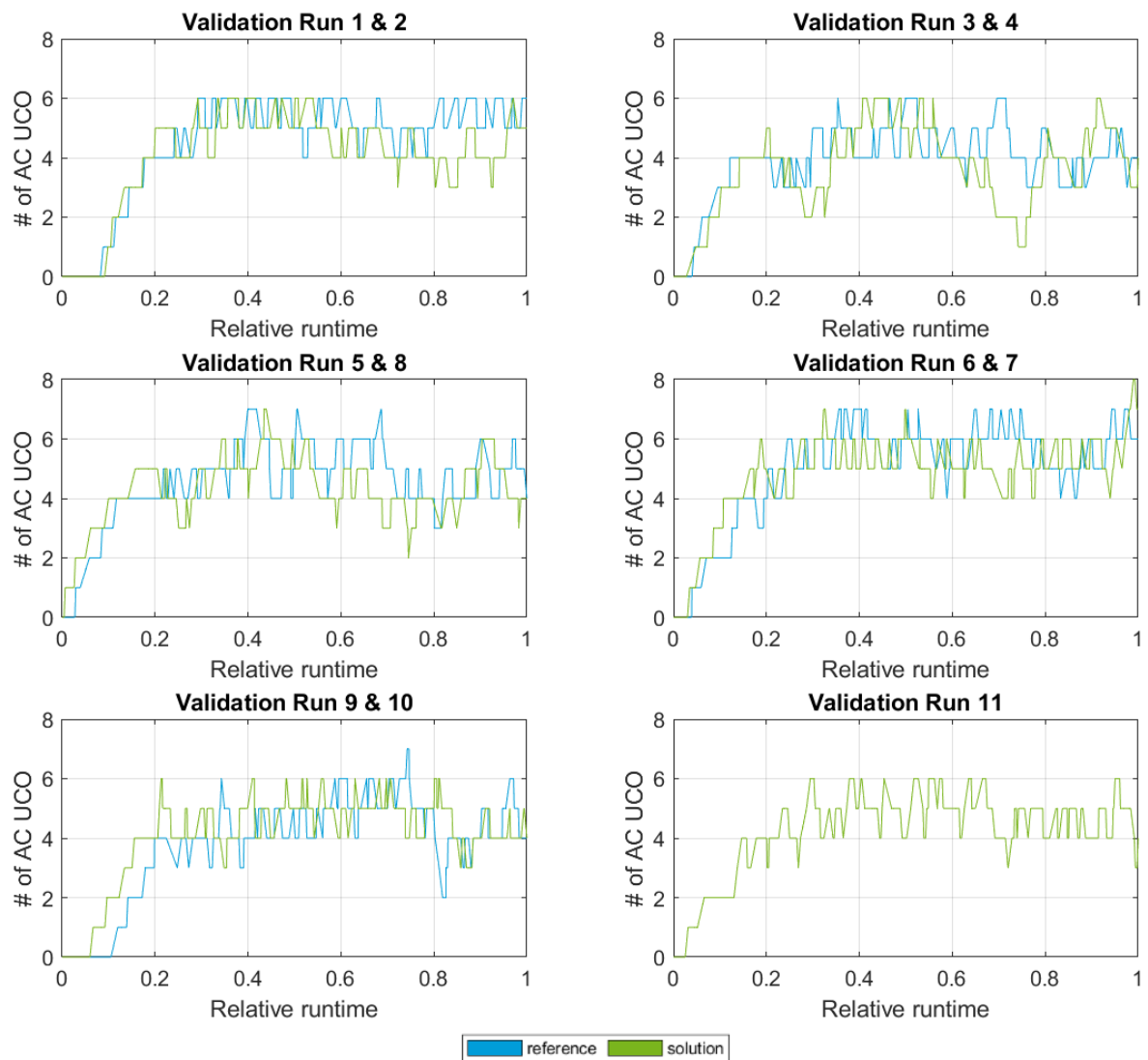


Figure 7-14: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft under control within the airspace under control by the ARR2 controller.

APP position

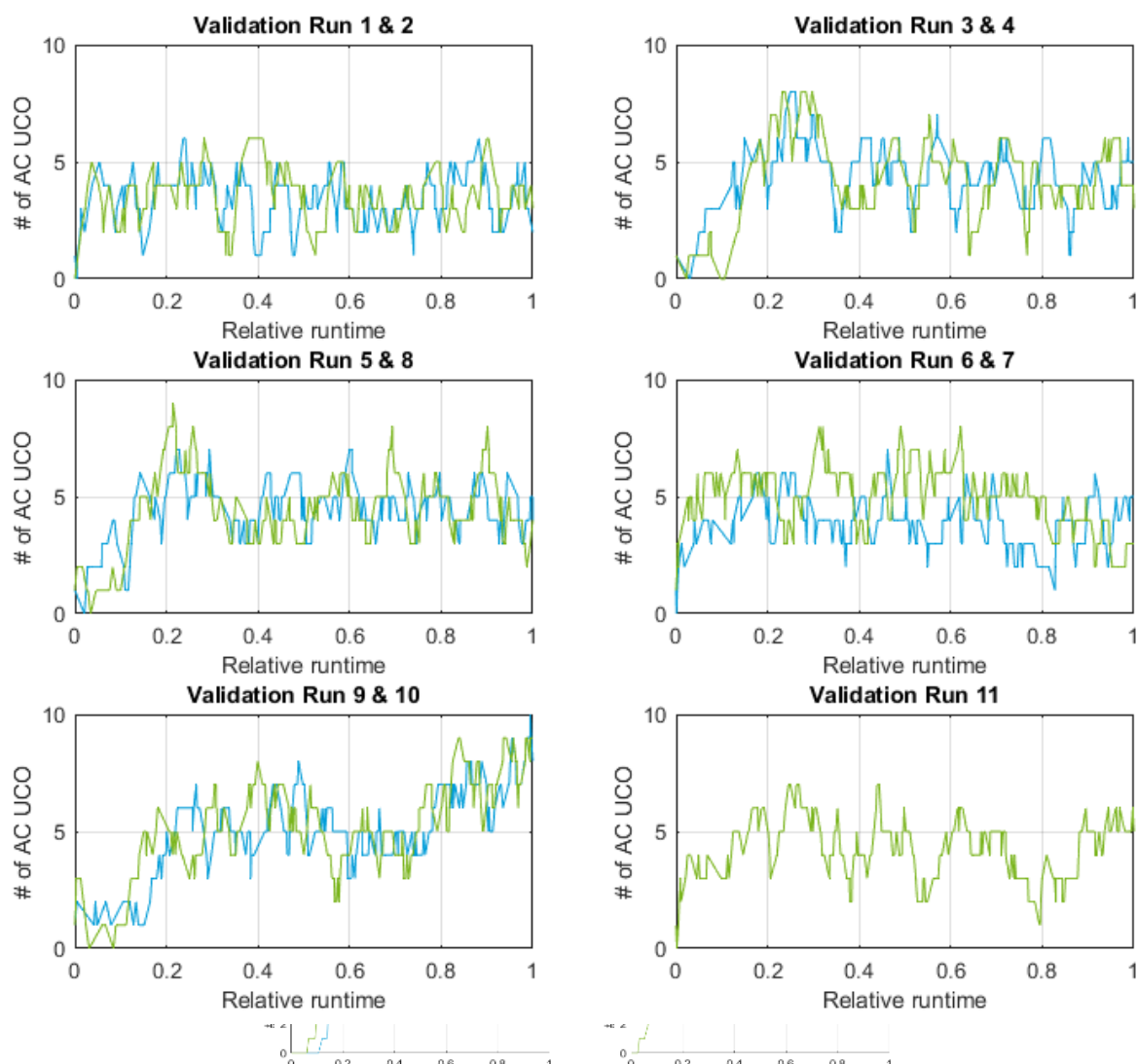


Figure 7-15: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft under control within the airspace under control by the APP controller.

16. OBJ-37-W3-DEMOP-PRD1-0001

Demonstration objective OBJ-37-W3-DEMOP-PRD1-0001 “The predictability of arriving traffic shall remain at the same level or increase against the reference scenario” has been assessed as OK as the average difference between actual and planned time in the TMA is smaller for the solution runs.

The success criteria of this objective is defined as “There is no negative effect on the predictability of the traffic in the TMA by using the integrated tool”. Table 7-13 presents the difference in time between the actual and planned time in the TMA. The planned time in the TMA is determined by the Arrival Manager. *The number of flights in the table equals the number of flights that have landed.* As demonstration run 11 was only performed as solution run, it is not included in the table. The result for this run was that the average difference between actual and planned time in the TMA was 4 seconds.

Scenario	Ref. run #	Total Δ in time [sec]	Nr of flights	Avg. Δ [sec]	Sol. Run #	Total Δ in time [sec]	Nr of flights	Avg. Δ [sec]
06+36R / 36L+36C, calm wind, 35 p/h	2	-179	51	-4	1	-813	45	-18
18R+18C / 24+18L, strong wind, 35 p/h	4	4,649	47	99	3	2,398	48	50
18R+18C / 24+18L, light wind, 35 p/h	8	3,580	50	72	5	1,781	50	36
06+36R / 36L+36C, calm wind, 40 p/h	7	1,095	54	20	6	903	63	14
18R+18C / 24+18L, light wind, 40 p/h	10	3,662	53	69	9	1,906	54	35

Table 7-13: OBJ-37-W3-DEMOP-PRD1-0001 Average difference (delta, Δ) between actual and planned time in the TMA (positive if actual time is larger than planned time)

It is noted that the total difference in time in the TMA is in general positive, thus actual time in the TMA is larger than planned time in the TMA. Furthermore when comparing the reference and solution run, the solution run is (on average) operating closer to the planning except the scenario with 35 aircraft per hour per runway in calm wind condition (Run 1). In this scenario the solution is increasingly ahead of time.

When the scenarios with the different hourly throughputs are compared (Run 2-7, 1-6), it is noted that in calm wind conditions, both average difference for the reference and solution increase, with a slightly larger increase for the solution run. In light wind conditions (Run 8-10, 5-9), both in the reference and solution runs with light wind conditions, the average difference did not change much.

Furthermore it is noticed that in demonstration runs 1 and 2, the average difference is negative while in the other runs, the average difference is positive. This may be an indirect influence of the adjustments made to the speed profile on the FAR between experiment day 1 and day 2, as discussed in Appendix A.2, and the request to the pilots to fly their own speed in case they did not receive speed instructions.

The results in Table 7-13 presents the KPI PRD7 “Average of difference in actual & Flight Plan TMA arrival durations” introduced in the SESAR Performance Framework [8]. To evaluate the mean of the distribution of the difference between the actual and planned time in the TMA, a modified boxplot is evaluated for each FAR (IAF-runway combination specific) in Figure 7-16. Since the 4th Schiphol IAF is not published, for the sake of this research it has been indicatively named as [XXXXX].

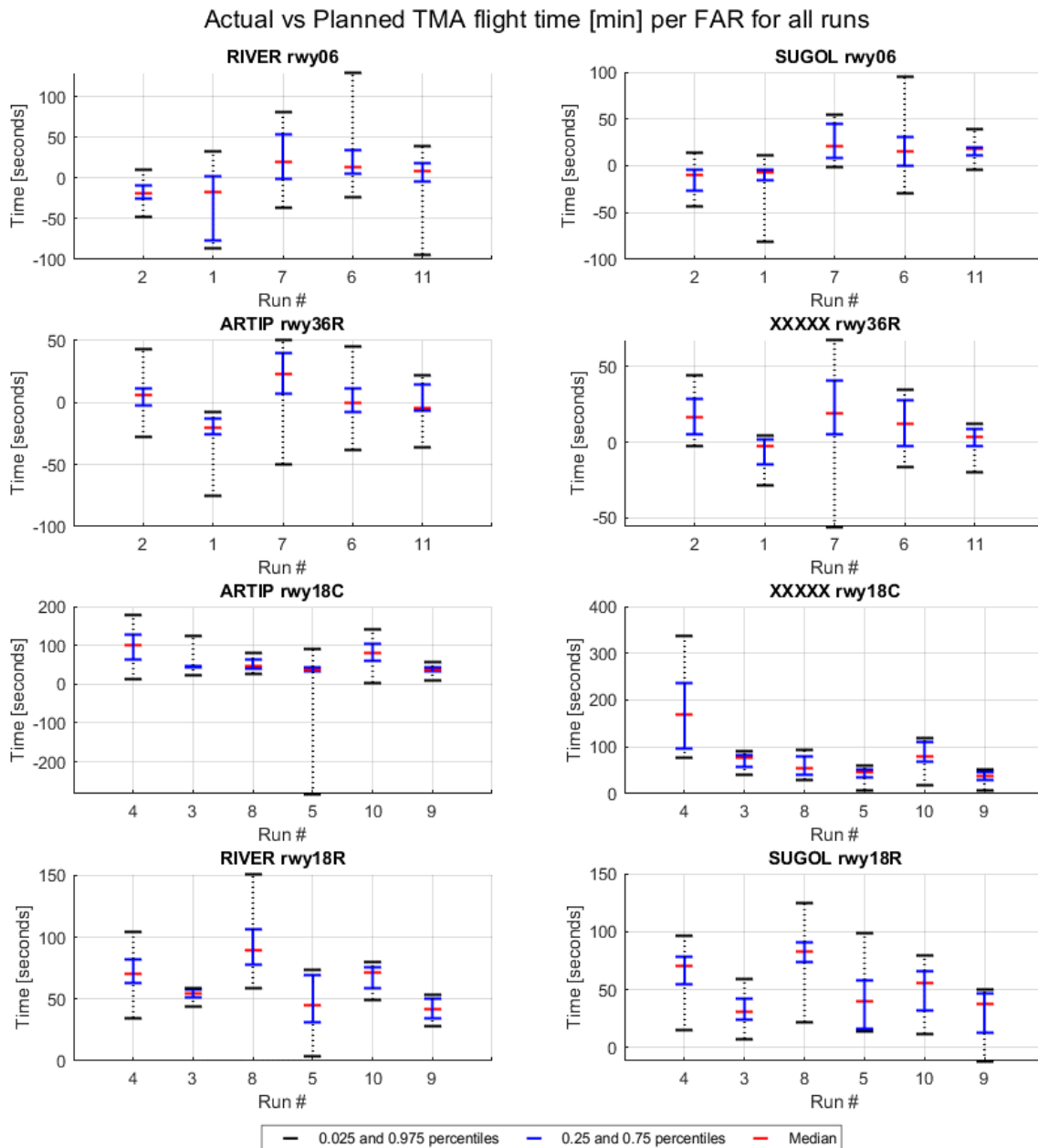


Figure 7-16: OBJ-37-W3-DEMOP-PRD1-0001 Average difference between actual and planned time in the TMA (positive if actual time is larger than planned time)

It is noticed that in general the median for the solution runs are smaller than for the respective reference run, thus the difference between the actual and planned time in the TMA are more similar. It is noticed that in several runs, the planned time in the TMA for a FAR deviates quite a lot compared to the median. To assess the impact of these flights, Table 7-14 presents the results with the removal of flights on a particular FAR which deviates more than 2σ (or 95%) of the mean time in the TMA on the specific FAR.

Run #	Total Δ in time [sec] after filtering	Nr of flights after filtering	Δ flights	Avg. Δ [sec] before filtering	Avg. Δ [sec] after filtering
2 – REF	-174	50	-1	-4	-3
1 – SOL	-790	44	-1	-18	-18
4 – REF	4,362	42	-5	99	104
3 – SOL	2,223	45	-2	50	49
8 – REF	3,580	50	-	72	72
5 – SOL	2,063	49	-1	36	42
7 – REF	929	51	-3	20	18
6 – SOL	775	56	-7	14	14
10 – REF	3582	52	-1	69	69
9 – SOL	1,857	53	-1	35	35
11	201	53	-3	4	4

Table 7-14: OBJ-37-W3-DEMOP-PRD1-0001 Average difference between actual and planned time in the TMA (positive if actual time is larger than planned time) filtered (95%/2 σ) of the mean of the planned time in the TMA for each FAR for all flights on the specific FAR.

The average difference for a demonstration run did not change much due to limited number of filtered flights with respect to the total number of flights considered, except for the ARTIP-runway 18C FAR.

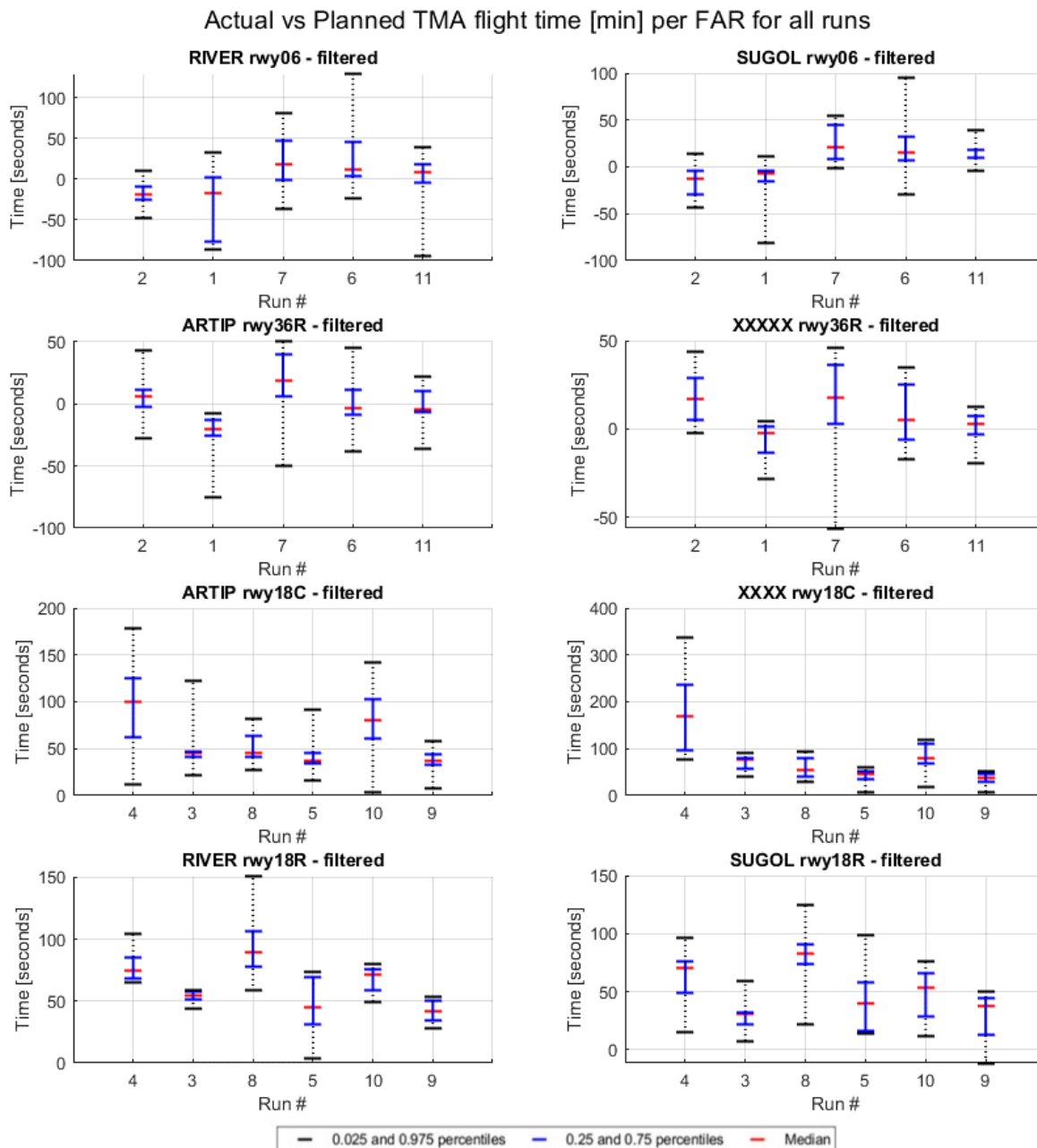


Figure 7-17: EXE-PJ.37-W3-001 PER-002 Average difference between actual and planned time in the TMA (positive if actual time is larger than planned time) filtered (95%/2 σ) of the mean of the planned time in the TMA for each FAR for all flights on the specific FAR.

17. OBJ-37-W3-DEMOP-NOI1-0001

Demonstration objective OBJ-37-W3-DEMOP-NOI1-0001 “The noise profile will not increase against the reference scenario” has been assessed as Partially OK 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 7-4, 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. The behaviour was identified to be related to the simulation rather than the integrated solution. Mitigating this effect in EXE-PJ.37-W3-002, it is expected that the integrated solution would yield an even better results with regards to noise emission.

If based on EXE-PJ.37-W3-001 a conclusion should be provided, it is concluded that the solution run had a reduction of the 55 dB noise contour between 3 to 7%. The detailed analysis is provided in DEMOR Part IV – Environment Assessment Report [5].

18. OBJ-37-W3-DEMOP-ENV1-0001

Demonstration objective OBJ-37-W3-DEMOP-ENV1-0001 “The CO₂ emissions will not increase against the reference scenario” has been assessed as Partially OK as the CO₂ emission was lower for most of the solution runs. However, the traffic sample, as presented in Table 7-4, was not completely identical between the reference and solution run, requiring further analysis to quantify the effect of the solution on the total CO₂ emission EXE-PJ.37-W3-002.

If based on EXE-PJ.37-W3-001 a 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 emission near to 10%. The detailed analysis is provided in DEMOR Part IV – Environment Assessment Report [5].

19. OBJ-37-W3-DEMOP-SAF1-0001

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0001 “The number of go-arounds due to insufficient spacing shall not be greater than in the reference scenario” has been assessed as OK (Full), but to be confirmed after RTS2.

During the 11 simulation runs in RTS1, there were 7 go-arounds (A-G). Five of these go-arounds (B, C, D, E, G) occurred in SOL runs, two (A, F) occurred in a REF run.

- In 2 of the cases (A, G) the pilot forgot to arm the ILS or to enter an altitude and did not even attempt a landing or a Go-Around (GA).
- In 1 of the cases (B), the GA was initiated by the pilot.
- In 2 of the cases (D, F), the GA was instructed by the ATCo, but because the aircraft was too high on approach, not because there was insufficient spacing.
- Only in 2 cases (C, E), the controller instructed a GA because the aircraft was flying too fast, which may have led to insufficient spacing if the controller had not intervened. Both cases occurred in SOL runs; however, the first GA (C = #6 (SOL)) was due to a simulation issue, and the second (E = #9 (SOL)) was because the pilot forgot to arm FIM. Neither was caused by the combination of tools.

Based on the data, the fact that more go-arounds occurred in SOL runs than in REF runs can be shown to be unrelated to the new combination of tools.

The questionnaires did not reveal any concern regarding this objective either. Therefore, we conclude at this moment that the number of go-arounds due to insufficient spacing is not increased by the combination of tools. It is recommended to confirm this statement during RTS2.

20. OBJ-37-W3-DEMOP-SAF1-0003

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0003 “The interoperability of the different tools in the integrated tool shall not introduce safety issues” has been assessed as Inconclusive; to be formulated after RTS2.

One issue has been identified in which the interoperability of the different tools might be a factor.

During RTS1, traffic on two RNP routes (‘transitions’) that merged further along the route often arrived at the IAF unseparated: the ‘merge support ghost blip’ of one aircraft was projected on or near the plot of the actual aircraft to which the merge had to be performed. This was an undesirable situation from the perspective of the ATCO, because in normal operations, the ATCO would expect ACC to deliver the aircraft without conflict.

A combination of multiple factors contributed to the discomfort of the ATCO. The following SESAR solutions are involved:

- E-AMAN (SESAR 1 Solution #5)
- Airborne Spacing Flight Deck Interval Management (SESAR 2020 W1 PJ.01-05)
- Enhanced Terminal Airspace Routing using RNP-based Operations (SESAR 1 Solution #62, #09, #51)

In addition, the merge tool and associated ghost blip plays a significant role. However this is not a SESAR solution to be validated in ITARO.

After RTS1, it is unclear what exact role is played by the interoperability of the different tools due to the many contributing factors. Some of these are due to simulation design and some are due to functionalities and tools that are not part of the SESAR solutions to be validated in ITARO.

In RTS2, some changes are made to the design of the simulation (route, algorithms) and functionality of the merge tool. This aims to reduce the contribution of the factors that are not related to the interoperability of the SESAR solutions. In RTS2, this issue can then be further investigated.

21. OBJ-37-W3-DEMOP-SAF1-0004

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0004 “There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)” has been assessed as OK (Full), but to confirmed after RTS2.

This objective aims to show that the use of the integrated tool and the Airborne Spacing Flight Deck Interval Management (FIM) does not lead to an increased number of separation losses (LOS) in the solution scenario (SOL) as compared with the reference scenario (REF).

A more detailed analysis considers each case of LOS in the runs of RTS1 and analyses the severity of the LOS (MRS and ROT; there were no WTS LOS). The LOS due to ROT are also Runway Incursions, since the follower aircraft is landing before the leader aircraft has vacated the runway.

The results can be summarised by comparison of the numbers of LOSs in the REF runs with the numbers of LOSs in the corresponding SOL runs. Here, A indicates the most serious LOSs (remaining separation is less than 50% of the minimum required separation), B indicates moderate LOS (between 50% and 66%), C indicates minor LOS (between 66% and 99%) and D indicates LOSs that are negligible (99% of the minimum required separation):

Run	A	B	C	D	Comparison (MRS)
#2 (REF)	0	0	1	0	#1 (SOL) has one additional LOS due to MRS of category A/B (50%). However, this may be due to unrealistic speeds being flown by the pilots in this first run. Both runs have one category C LOS (95%) right before leader is landing
#1 (SOL)	1	0	1	0	
#4 (REF)	0	2	2	0	#4 (REF) has multiple category B (62% and 65%) and C LOS (97% and 86%) while #3 (SOL) has none. #4 was the one with strong headwind on final and many plots on top of ghosts
#3 (SOL)	0	0	0	0	
#8 (REF)	0	0	2	7	Ignoring the 7 LOS of category D, #8 (REF) has two category C LOS (93% and 87%) compared to #5 (SOL) having one (93%)
#5 (SOL)	0	0	1	0	
#7 (REF)	0	0	2	1	Ignoring the LOS of category D, #7 (REF) has two category C LOS (93% and 90%), while #6 (SOL) has one (75%)
#6 (SOL)	0	0	1	1	
#10 (REF)	1	0	9	10	Ignoring the 10 LOS of category D, #10 has 9 category C LOS (mostly 90-93%, one 75%, one 85%), and one category A LOS (43%), while #9 (SOL) has one category C LOS (84%)
#9 (SOL)	0	0	1	0	
#11 (SOL*)	0	0	0	0	n.a.

Table 7-15: OBJ-37-W3-DEMOP-SAF1-0004 number of Loss of Separation due to MRS observed in the runs, specified per severity of the LOS.

Run	A	B	C	D	Comparison (ROT)
#2 (REF)	0	0	0	0	#1 (SOL) has one LOS of category A (42%) due to ROT and one of category C (89%) while #2 (REF) has none
#1 (SOL)	1	0	1	0	
#4 (REF)	0	0	2	0	#4 (REF) has two category C LOS (86%, 83%) due to ROT while #3 (SOL) has none
#3 (SOL)	0	0	0	0	
#8 (REF)	0	0	0	0	#5 (SOL) has one category C LOS (93%) due to ROT while #8 (REF) has none
#5 (SOL)	0	0	1	0	
#7 (REF)	0	0	0	0	Neither run had a LOS due to ROT
#6 (SOL)	0	0	0	0	
#10 (REF)	0	1	0	0	#10 (REF) has one category B (55%) LOS due to ROT while #9 (SOL) has none
#9 (SOL)	0	0	0	0	
#11 (SOL*)	0	0	0	0	n.a.

Table 7-16: OBJ-37-W3-DEMOP-SAF1-0004 number of Loss of Separation due to ROT observed in the runs, specified per severity of the LOS.

Based on the data, overall, the SOL runs did not seem to have more cases of LOS due to MRS than the REF runs, and even have much fewer. For LOS due to ROT, the REF runs and SOL runs have similar numbers on average. No LOS due to Wake was identified.

In the questionnaire, the controllers were asked whether they thought that the combination of tools will improve (i.e. decrease or not increase) the number of losses of separation. Overall, the controllers noted more concerns with Wake Turbulence separation (WTS), rather than MRS or ROT, which is notable since no Wake losses were identified in the data.

Concluding, overall, the data showed that for both MRS and ROT, the SOL runs did not seem to have more cases of LOS than the REF runs, and even showed much fewer. In the questionnaires and the debriefing the controllers did have a few concerns with WTS separation losses, however. Therefore it is advised to study this matter more closely during RTS2.

22. OBJ-37-W3-DEMOP-SAF1-0005

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0005 “The perceived controllability of the operation by ATCO shall not degrade due to the use of the integrated tool” has been assessed as OK (Full), but to be confirmed during RTS2.

In the beginning of RTS1, the controllers did feel less in control during the solution runs, compared to the reference runs. However, this was mainly due to the use of a single tool rather than the combination of tools. Moreover, post-experiment they indicated to be more positive regarding the solution runs. It is concluded that perceived controllability of the operation by ATCO did not degrade due to the use of the integrated tool.

A.3.3 Unexpected Behaviours/Results

No unexpected behaviours or results have occurred during the preparations and performance of demonstration exercise EXE-PJ.37-W3-001.

A.3.4 Confidence in the Demonstration Results

1. Level of significance/limitations of Demonstration Exercise Results

Findings are based on 11 measured runs and the feedback from 3 experienced ATCOs for specific use cases within the TMA operational environment of Amsterdam Airport Schiphol. This sample size is too little to provide definitive statements on the performance of the KPAs. However the exercise results provide a valuable initial feedback on the interaction between different SESAR solutions when integrated in an operational environment from a technical perspective (software connecting the different solutions and HMI to present the information the ATCOs).

2. Quality of Demonstration Exercise Results

Measures are taken to secure quality demonstration results. Exercise results are evaluated based on recorded data, widely accepted questionnaires formats and debriefings by very experienced ATCOs who are used to work in the simulated environment. The SESAR solutions are developed and integrated in the simulation environment in accordance with the latest available specifications. The developers and engineers are in contact with industry to implement best practises as observed in operation.

3. Significance of Demonstration Exercises Results

General integration and very specific integration findings of the SESAR solution combined have been obtained. The results have brought the TRL-level of the findings a step closer towards deployment.

A.4 General findings of the integrated solution

The following observations have been made on the integrated solutions whilst performing the simulation:

Route design

- Parallel runway operation
- Route structure at merge point
- IAF location
- Inbound outbound conflicts

Interval management

- Combine achieve-by-point with merge point
- Frontloading of aircraft
- Inputs to change IM target aircraft

Optimised runway delivery tool

- Time-based separation presentation along fixed routes

Merge tool

- Ghost blip presentation
- Ghost blip presentation of aircraft outside TMA
- Distance-based or time-based merge tool

Extended Arrival Manager

- Expected Approach Time (EAT) adherence at TMA entry

ATCO HMI

- IM information on radar screen aircraft label
- Established on RNP indicator
- NTZ presentation

Other

- ATCO positions during simulations
- Runway orientation impact on departures
- Non-nominal simulations to further test robustness of the integrated solution

Route design

The set of fixed arrival routes used in EXE-PJ.37-001 were preliminary designs, which contained certain design features which would not be used in actual operations. For example, the merging of two arrival routes with an angle of 90 degrees, parallel runway operations with the base legs of the fixed arrival routes located head-on followed by a 90 degree turn to final or the lack of a visual check that an aircraft is actually established on the RNP approach.

The design of fixed approach routes is a complex and iterative process, which is not the aim of PJ.37-W3-01A. However, in the exercise it was observed that the route design had impact on the assessment of the integrated concept. At the merge point, there could be some variability in performing the 90

degrees turn between aircraft, which could have an influence on the separation between aircraft on the base leg. The controllers desire a 30-45 degrees merge. If an aircraft is not established on the RNP in combination with independent parallel approaches, this would result in a separation loss. This is not desired when two aircraft are flying head on. Both instances required additional attention of the ARR controller which could be limited by route design.

All aircraft entered the TMA at the same altitude, but would pass the IAF at an altitude dependent on the transition. Having multiple IAF altitudes resulted in slightly different phraseology of the ATCO to the pilots. A single IAF altitude for all transitions would reduce R/T time and would create a uniform operation.

The SIDs and the fixed arrival routes cross. Tactical level-offs with 'at or above' constraints for arrivals in combination with 'at or below' constraints for departures ensured strategic deconfliction. In addition, it could be of interest to have all outbounds climb to the same flight level when using the 'climb via ...' procedure to limit variation in tactical level-off altitudes. However, the controllers indicated that they would not rely on compliance with these constraints to separate aircraft. They would provide altitude clearance to the constrained altitude, in case of a potential conflict, and only clear the aircraft further up and down when both aircraft are separated. As a consequence, the 'at or below' altitude constraints could be removed from the departure procedures.

Interval management

The starting point for the implementation of interval management is the work performed by Wave 1 PJ.01-05. During the performance of EXE-PJ.37-W3-001 new observations have been made with regards to the simulation environment set-up.

In the simulation, the Achieve-by Point (ABP) was located after the merge point at the start of final approach. This however required the controller to more actively monitor the separation between aircraft at the merge point to ensure that aircraft would not be in front of their spacing goal at the merge point. Re-locating the ABP to the merge point would solve this additional required attention. To have IM active until final approach, a second point, the so-called Planned Termination Point (PTP), could be introduced on final. IM will maintain its spacing goal until this point after passing the ABP.

The effect of frontloading was observed when a sequence of aircraft had a gap in planned arrival time considerably larger than the spacing goal, which was based solely on the ORD tool (minimum separation) plus a buffer of 12 seconds. The follower aircraft would try to close the gap and meet the spacing goal as good as possible. This results in undesired high speeds. To limit the effect of frontloading, perhaps the planned arrival time of the AMAN could be considered to increase the spacing goal such that the planned arrival time would be met at the ABP.

In the simulation runs, the controllers did not make use of the functionality to change IM target aircraft as the nominal simulation runs did not require such input. To test the functionality to change target aircraft, more appropriate situations have to be simulated and the controllers have to be actively informed to use the functionality.

Optimised runway delivery tool

The Optimised Runway Delivery (ORD) tool which determines the minimum separation criteria and time-based separation distance and presents this on the radar display along the extended centreline. The markers on the radar display have been well received, but the controllers commented that if the markers could be presented on the fixed arrival routes, it would be of more value. Especially as after the merge point, the controller has to ensure the separation.

Merge tool

For this simulation, a distance-based ghost tool was used as merge tool. The ghost tool would mirror the position of the aircraft on the other approach transition towards the same runway. Due to different lengths of the approach transition, aircraft on a short transition would have their ghost presented on the longer transition before it had entered the TMA. This caused some ghost blips to be on or near an aircraft on the other transition. In addition, this ghosting representation is based on aircraft on a 'direct' towards the TMA entry point, which is a fair assumption in a simulation. It is of discussion whether the ghost should be presented to the controller before TMA entry. However as the other aircraft had not entered the TMA, the FDR could not control this aircraft. Adding the groundspeed in the label of the ghost blip assisted the controller and improved situational awareness of the merge.

It could be argued whether a distance- or time-based tool is preferred. A time-based tool would predict the influences of the wind and more accurately estimate where the aircraft would be relative to the other aircraft at the merge point. However, if wind conditions are different than expected or speed instructions are given to the aircraft, the presentation of the ghost might 'jump' backward (or forward) which may not be a desired effect to the controller.

Extended Arrival Manager

The controllers mentioned that the integrated solution was workable mainly/likely due to the delivery of aircraft at the TMA entry point in accordance to the planning. Further investigation is required to assess the influence of several aircraft in the traffic mix with an increased EAT adherence time (e.g. worse delivery time at the TMA) on the integrated solution.

ATCO HMI

Based on the simulations, the controllers had suggestions for improvements to the HMI of the ATCO radar display.

Information of the IM status was presented in the aircraft track label. If IM target aircraft was not yet in the TMA due to it being on a shorter transition than the follower aircraft and IM instructions had been given, a nuisance warning was present until the target aircraft entered the TMA. Controllers indicated that the nuisance warning should be removed and could be perhaps replaced with an IM pending and IM active status.

The controllers need confirmation from the pilots that they are 'Established on RNP' (EOR) for Independent Parallel Approaches (IPA). This is done through the R/T. Although the route structure has been designed with a turn such that the controllers can monitor whether aircraft are following the fixed RNP route, suggestions have been made to include the possibility to make an EOR input in the aircraft label. This could especially be of use in case an aircraft is taken off the fixed route e.g. a missed approach. A potential increased workload in such situation, and the need to re-EOR once the aircraft is back on the fixed route, an additional reminder might assist the controllers. For independent parallel approaches, the No Transgression Zone (NTZ) presentation on the radar display is used to monitor the separation between aircraft on parallel runways is maintained. The presentation of the NTZ on the radar display was used by the controllers in the scenarios with parallel runway use. The fixed route design may influence the size of the NTZ as displayed on the radar screen.

Other

In the simulation, an eastern and western traffic stream with each two IAFs were simulated which merged towards a single runway. With 3 controllers --one feeder (FDR) controller and two arrival (ARR) controllers-- participating in the simulation, the FDR controller handled both eastern and western traffic streams on the two long approach transitions. The ARR controller handled the eastern (or

western) traffic stream in the merge and final approach areas, but also handled traffic arriving at the TMA entry fix on the eastern (or western) short approach transition. The ARR controllers argued that the monitoring of the airspace under control required a lot of shifting of attention within the airspace under control. It is suggested to add a fourth controller in order to have a dedicated FDR on the eastern (and western) traffic stream, who handles traffic on both one long and one short approach transition. The ARR controller would then only have to handle the eastern (or western) traffic stream in the merge and final approach areas.

With decreasing separation minima between aircraft, the number of departures may be impacted depending on the orientation of the departure runway in use and the missed approach procedure for the arrival runway. However, this is very airport specific and need to be evaluated on a case by case scenario per airport.

In this exercise, EXE-PJ.37-W3-001, valuable feedback is received to compare the reference and solution simulation runs. In order to identify additional integration aspects of the integrated tool, more non-nominal simulations have to be performed to test the robustness of the tool.

A.5 Conclusions

The demonstration exercise EXE-PJ.37-W3-001 has been successfully performed. There are no objectives that did not meet the expectations and 11 objectives have been assessed as Partially OK and 10 as OK. 1 objective was inconclusive.

8 of the 13 Human Performance objectives have been assessed as OK and 5 have been assessed as Partially OK. Several acceptability issues were identified during the exercise. Based on this exercise, no conclusion can be drawn on the registered number of errors (due to limited size of experiment and small error probability). Where possible, the above points will be addressed in EXE-PJ.37-W3-002.

Both Capacity objectives have been assessed as Partially OK. This is mainly caused by the traffic sample not being identical between runs in order to perform a comparison between the reference and solution runs. The single Predictability objective is assessed as OK. The Noise and Environmental objectives have been assessed as POK with similar reasons as the Capacity objectives.

3 Safety objectives have been assessed as OK with a single objective without conclusion. The impact on safety by the interoperability of the different tools within the integrated solution is unclear as factors that are not part of the SESAR solutions to be validated in this project had an influence. The interoperability will be further investigated in EXE-PJ.37-W3-002.

The objectives evaluated as Partially OK will be further analysed in demonstration exercise EXE-PJ.37-W3-002. Based on comments and observations made during this demonstration exercise, updates will be incorporated to the demonstration platform before performing EXE-PJ.37-W3-002. In addition, the objectives identified as OK will be re-evaluated in the next demonstration exercise to confirm that the changes made to the demonstration platform does not negatively influence the result of these objectives.

A.6 Recommendations

A.6.1 Recommendations for industrialization and deployment

The results of this demonstration exercise will be used to prepare the second demonstration exercise on the NARSIM (EXE-PJ.37-W3-002). Recommendations for industrialization and deployment will be provided afterwards.

A.6.2 Recommendations on regulation and standardization initiatives

The results of this demonstration exercise will be used to prepare the second demonstration exercise on the NARSIM (EXE-PJ.37-W3-002). Recommendations on regulation and standardization initiatives will be provided afterwards.

Appendix B EXE-PJ.37-W3-002 Report

This appendix describes the results for the EXE-PJ.37-W3-002 and presents conclusions and recommendations of this exercise.

B.1 Summary of the Demonstration Exercise #02 Plan

The demonstration exercise is as elaborated in the DEMOP ed01.00.00 [2]. No major deviations have taken place. The minor deviations are described in Appendix B.2.

B.1.1 Exercise description and scope

Exercise description and scope are in accordance to the DEMOP ed01.00.00 [2].

B.1.2 Summary of Demonstration Exercise #01 Demonstration Objectives and success criteria

For a summary of the demonstration exercise objectives and success criteria, please refer to the DEMOP ed01.00.00 [2].

B.1.3 Summary of Demonstration Exercise #02 Demonstration scenarios

The various reference and scenario demonstration runs are provided in Table 7-17. RunID #2 and #4 have been repeated.

Date	RunID DEMOP	Scenario Category	IM Equipage	Wind condition	Comment
05-10-2022	4	Solution	80%	Calm	Western traffic stream only
	9	Solution	100%	Strong wind conditions, incl. strong headwind on final	Western traffic stream only
	8	Reference	0%	Strong wind conditions, incl. strong headwind on final	Western traffic stream only
	5	Solution	100%	Calm	Western traffic stream only, forced landing sequence change (planned go-arounds). And an event where an aircraft reported 'unable RNP' & 'unable spacing' during RNP & IM execution.
09-11-2022	2	Solution	100%	Calm	
	1	Reference	0%	Calm	
	3	Solution	20%	Calm	

Date	RunID DEMOP	Scenario Category	IM Equipage	Wind condition	Comment
	7	Solution	100%	Calm	±60 seconds EAT adherence for several aircraft in both traffic streams
21-12-2022	4	Solution	80%	Calm	
	2	Solution	100%	Calm	
	10	Solution	First 40 mins 100%, last 20 minutes 0%	Calm	Demonstration run with MRS 2.0, increased hourly traffic.
	NA (7)	Solution	100%	Calm	±60 (Eastern) and ±90 (Western) seconds EAT adherence for several aircraft

Table 7-17: EXE-PJ.37-W3-002 demonstration /simulation scenario overview

B.1.4 Summary of Demonstration Exercise #02 Demonstration Assumptions

For a summary of the demonstration assumptions, please refer to the DEMOP ed01.00.00 [2].

B.2 Deviation from the planned activities

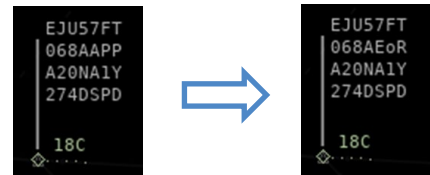
Several deviations to the planned activities have occurred, as elaborated in the bullets below.

- On the first simulation day, multiple pseudo pilots had to cancel their participation last-minute due to illness and calls to fly for their companies (mainly due to illness of colleagues). Last minute effort to source participants resulted in enough pseudo pilot participants in order to simulate 1 traffic flow (on the Western side) using 1 runway. The Eastern traffic flow was fully automated. For simulation day 2 and 3, additional pseudo pilots were trained and kept in reserve in case a similar event would happen.
- Run 2 had to be performed twice. The first simulation was stopped after 45 minutes for two reasons: (1) a pseudo pilot made an erroneous input, which had a big knock-on effect on the traffic stream behind this aircraft and (2) later on an actual arrival sequence occurred that differed from the planned arrival sequence without any notification due to simulation issues. The latter had a large disruptive effect on the IM operation to the extent that controller stated that it was of no use to continue with the run. In the second time, the run was stopped after 47 minutes as an aircraft had an incorrect IM target aircraft which went unnoticed by the ATCOs (again the actual arrival sequence differed from the planned sequence without any notification due to simulation issues).
- Run 4 had to be performed twice. In the first run, only the Western traffic stream was controlled by the ATCOs instead of an Eastern and a Western stream as is normally the case. In the second run, both traffic streams were controlled by the controllers and the simulation proceeded with no issue.
- Run 7 had simulation issues, where the TBS markers were not presented correctly. This resulted in this tool being not trustworthy for the ATCOs, meaning that they had to work without relying on the ORD tool. Run 7 will be disregarded in the analysis. A similar run has

been performed with a slightly adjusted variation in EAT adherence. This run did not have any deviation. For the sake of understanding, this run will be referred to as Run 7 in the analysis.

- Run 6 and 11 were not performed. Run 6 was incorporated in Run 5 in order to force a landing sequence change. For Run 11, as valuable feedback was received on increased traffic load and MRS 2.0 in Run 10, there was no need to perform this run anymore.

Deviations between simulation day 1 and day 2:

- A feature in the aircraft track label has been added making it possible to include an indication of an aircraft being Established on RNP (EOR).
- 
- Figure 7-18: Aircraft label with the addition of “EOR”**
- When an aircraft with a known Interval Management (IM) target aircraft is selected, the track label presentation of the target aircraft on the radar display is highlighted. Depending on the status (IM active, IM pending, IM warning, IM advisory), a different colour is presented. The track label returns to its original colour after 2 radar screen updates. Changes have been made to identify the target aircraft.
 - TBS indicators have been adjusted such that MRS 3.0 is applicable along the entire fixed arrival routes. When both aircraft are established on the final approach track, only then the MRS is reduced to 2.5 or 2.0NM depending on the simulation run.
 - AMAN Trajectory Predictor and IM Trajectory Predictor are based on different models. This resulted in slight variation in nominal speeds along the fixed descent profiles, resulting in a difference in the expected Target Time Over the merge point and the final approach fix. The AMAN Trajectory Predictor has been adapted to be more in-line with the IM Trajectory Predictor and in particular with the nominal altitude and speed profiles expected to be flown in accordance with the approach procedures, including the approach transitions.

Deviations between simulation day 2 and day 3:

- The highlighting of the track label of the IM target aircraft when an aircraft is selected was extended such that a target aircraft which has been handed over to the ARR controller was still highlighted to the APP controller.
- The duration of the highlighting of the track label of the IM target aircraft was changed such that the highlighting remained on the radar screen until a different aircraft was selected.
- Adjustments to AMAN reserved slots in the planning to avoid differences between the actual and planned arrival sequence and consequently wrong IM target aircraft selection.
- The merge support ghost blip presentation on fixed routes would disappear if an aircraft was vectored away from the fixed route. The distance when the presentation would disappear was extended from 2 to 3NM.

B.3 Demonstration Exercise #02 Results

B.3.1 Summary of Demonstration Exercise #02 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0003	The arrival management process is found acceptable by the ATCOs present in the RTS.	CRT-37-W3-DEMOP-HUP1-0003	No acceptance issues are identified both during the RTS and debriefings by the ATCOs involved in the simulations.		The acceptability of the concept was partially OK. ATCOs mentioned that they felt confident provided that speeds of flights reduce gradually towards final, and that traffic is delivered accurately (plus or minus 30 seconds from the Expected Approach Time at the TMA boundary, but preferably more accurate).	POK
OBJ-37-W3-DEMOP-HUP1-0004	Assess completeness and acceptability of working procedures (regarding transition between IM/merge tool and PWS/ORD tool whilst operating RNAV/RNP transition procedures followed by instrument approach procedures).	CRT-37-W3-DEMOP-HUP1-0004	V3. Operating methods are found to cover identified normal operating conditions.		The ATCOs rated the completeness 2.7 and acceptability 3 (scale 1-5). The completeness and acceptability apparently reduced in comparison to the first RTS. In RTS 2 the concept was evaluated against more challenging situations that required more controller actions. For example, merging a go-around, which was rather challenging in the high volume of traffic. Also, some unexpected simulation and technology behaviours may have had an effect.	POK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0005	Assess working procedures for normal mode of operations are clear and consistent.	CRT-37-W3-DEMOP-HUP1-0005	V3. The content of the operating methods has been determined to be clear and consistent by end users and native speakers/linguistic experts.		In RTS2, the ATCO rating regarding clarity and consistency of the procedures did not increase compared to RTS 1. In contrary, the consistency was reduced to 2.8. It is believed that the inconsistency due to technology aspects, that resulted in some flights increasing speeds at final approach, led to this decreased rating.	POK
OBJ-37-W3-DEMOP-HUP1-0006	Assess the ability of controller to follow working procedures.	CRT-37-W3-DEMOP-HUP1-0006	V3. [GND only] Number of errors in the solution not significantly higher than in reference scenario, taking into account error type & operational impact.		The RTS1 finding also applies but to a lesser extent as speeds were in general lower and the routes towards the parallel runways were no longer head-on.	POK
OBJ-37-W3-DEMOP-HUP1-0007	Assess the types, likelihood and effect of errors that occur, in particular due to the simultaneous presentation of ORD and Merge tool indicators.	CRT-37-W3-DEMOP-HUP1-0007	V3. Recovery means for errors in the solution minimise operational impact.		The combined presentation did not lead to confusion. ATCOs did not mention this as a problem. Increased confusion was reported in runs where simulation/automation generated illogical sequences and IM settings. The effect of the concept on task performance and potential for human error was rated neutrally to slightly	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
					negative in comparison to the current concept of operations (vectoring).	
OBJ-37-W3-DEMOP-HUP1-0008	Assess the extent to which task performance is reduced by the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0008	V3. Tasks are effectively achieved		Merging and spacing was performed in a timely manner. The post-run ratings of the successfulness was acceptable. Tasks are not unclear, but it is not possible to devote the same amount of attention to monitoring traffic in the way it is done today, and adequate or timely intervention when it is necessary is difficult. In addition, ATCOs mentioned it to be cumbersome to change all IM targets when a sequence change was required. It is not intended that ATCOs have to use this function frequently.	OK
OBJ-37-W3-DEMOP-HUP1-0009	Assess the impact on ATCO workload by the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0009	V3. Level of workload within acceptable limits ('acceptable limits' to be defined with regard to the tool used for the assessment).		The NASA-TLX ratings were between 30 and 40. The ratings of the runs with 100% equipage were increased compared to all other runs, contrary to what was expected. This is most likely due to simulation problems. For runs with more variation and with a go-around the workload rating was increased, as expected, but only slightly. For MRS 2.0 no increase was measured. For equipages of 20% and 80%, no increases	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
					in average ratings were found. The strong wind did not lead to increased workload, neither in the reference nor in the 100% equipage run, while the number of aircraft per hour remained at the level of 40/40.	
OBJ-37-W3-DEMOP-HUP1-0010	Assess the impact on ATCOs level of trust in the integrated arrival concept.	CRT-37-W3-DEMOP-HUP1-0010	V3. Potential issues related to trust and the preliminary mitigation identified are acceptable.		The average confidence in the concept was 4.8 (scale 1-9), in the end-of-day questionnaire, but was also rated value 1 and 2 (in day 2) and mentioned it was caused by the unexpected behaviour due to simulator issues. The results are not conclusive.	NOK (not conclusive)
OBJ-37-W3-DEMOP-HUP1-0011	Assess the impact on individual ATCO situation awareness levels by the integrated arrival concept	CRT-37-W3-DEMOP-HUP1-1011	V3. [GND only] Level of situational awareness not lower in the solution than in the reference scenario.		The average SASHA ratings varied between 4.4 and 5.5 (scale 0 – 6), which is acceptable. For the 20% equipage the rating was highest and lowest for 100% equipage with increased variation at TMA entry. Differences between conditions exist but several disruptive factors make it difficult to compare reference and solution. Nevertheless, as stated previously, ATCOs mentioned there was little time also monitor the traffic on final. This	OK
		CRT-37-W3-DEMOP-HUP1-2011	V3. End user is able to perceive and interpret task relevant information and			

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			anticipate future events/actions.		suggests that perception of information and anticipating may be compromised.	
OBJ-37-W3-DEMOP-HUP1-0012	Assess the extent to which the integrated arrival concept complies with the relevant HP Principles.	CRT-37-W3-DEMOP-HUP1-0012	V3. Visual displays are consistent with design standards or regulations. Rationales are provided in case of deviations from standards.		The HMI usability of 4.7 to 6.0 on average (scale 1-7). Overall it is concluded that the HMI was adequately improved for RTS 2. Lower SA ratings are explained by the more challenging scenarios in RTS 2 with more variation in the accuracy of delivered flight.	OK
OBJ-37-W3-DEMOP-HUP1-0013	Assess the extent to which the user interface reduces human performance and service delivery.	CRT-37-W3-DEMOP-HUP1-0013	V3. [GND only] Usability rating for the integrated interface not lower in the solution than in the reference scenario.		The HMI usability of 4.7 to 6.0 on average (scale 1-7), with no significant differences between the solution and reference.	OK
OBJ-37-W3-DEMOP-HUP1-0014	Assess the impact on team ATCO situation awareness levels by the integrated arrival concept	CRT-37-W3-DEMOP-HUP1-0014	V3. Team is able to perceive and interpret task relevant information and anticipate future events/actions.		The team SA was rated on average 5.7 (scale 1-7), post-run questionnaire. Nevertheless, the expected effect of the concept on Team SA was on average rated slightly negative (2.6 on scale 1-5, end-of-day questionnaire). It was concluded that Team SA may reduce slightly in comparison to current day operations but will remain at sufficient levels.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0015	The integrated tool does not deteriorate the arrival management process	CRT-37-W3-DEMOP-HUP1-0015	Under nominal conditions, there shall be no need to fall back on the use of vectoring operations while using the integrated tool.		Under normal conditions, with high accuracy of TMA entry and pilots following instruction timely there is no need to fall back on vectoring. This evidence is based on run results. Abnormal system behaviour was deteriorating the arrival management process in a few runs. This abnormal behaviour was in itself an integration issue but is believed to be solvable in next iterations. Overall, it is concluded that the integration is complex. Small changes meant to improve the integration proved to have unexpected results. Nevertheless, it is expected that if flights are delivered accurately into the TMA the concept could work, allowing continuous descents at high throughput.	POK
OBJ-37-W3-DEMOP-CAP1-0001	The runway throughput level shall remain at the same level or increase against the reference scenario	CRT-37-W3-DEMOP-CAP1-0001	There is no negative effect on the runway throughput by using the integrated tool in		There is no negative effect on the runway throughput by using the integrated tool in nominal operations against the reference scenario. The runway throughput for each runway does not vary much when increasing the	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			nominal operations against the reference scenario.		IM equipage rate. When increasing the traffic load, the throughput increases as expected as long as the traffic is operating nominally.	
OBJ-37-W3-DEMOP-CAP1-0002	The airspace capacity shall remain at the same level or increase against the reference scenario	CRT-37-W3-DEMOP-CAP1-0002	There is no negative effect on the airspace capacity by using the integrated tool in nominal operations against the reference scenario.		There is no negative effect on the airspace capacity by using the integrated tool in nominal operations against the reference scenario. Airspace capacity on fixed routes is evaluated using runway throughput and number of aircraft under control by a controller. Increasing traffic load resulted in more aircraft under control (UCO), however peak number of aircraft UCO is similar to lower traffic load.	OK
OBJ-37-W3-DEMOP-PRD1-0001	The predictability of arriving traffic shall remain at the same level or increase against the reference scenario.	CRT-37-W3-DEMOP-PRD1-0001	There is no negative effect on the predictability of the traffic in the TMA by using the integrated tool		The integrated tool does not have a negative effect on the predictability as the average difference between the actual and planned time in the TMA for the solution runs is within seconds compared to the reference run. With increasing IM equipage rate the spread in the difference between the actual and planned time in the TMA decreased.	OK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-NOI1-0001	The noise profile will not increase against the reference scenario	CRT-37-W3-DEMOP-NOI1-0001	The use of the integrated tool does not increase the noise profile in the nominal simulation against the reference scenario.		In the nominal simulation, the 55 dB noise contour area in the solution run has decreased with less than 1%. Differences are too small to conclude that the 55 dB noise contour area has improved.	OK
OBJ-37-W3-DEMOP-ENV1-0001	The CO2 emissions will not increase against the reference scenario	CRT-37-W3-DEMOP-ENV1-0001	The use of the integrated tool does not increase the CO2 emission in the nominal simulation against the reference scenario.		In the nominal simulation, the solution run with the integrated tool emits 6.7% less CO2 than the reference run.	OK
OBJ-PJ.37-W3-DEMOP-SAF1-0001	The number of go-arounds due to insufficient spacing shall not be greater than in the reference scenario	CRT-37-W3-DEMOP-SAF1-0001	The use of the integrated tool shall not increase the number of controller-instructed go-arounds.		The RTS1 conclusion was confirmed during RTS2, which did not include any go-arounds due to insufficient spacing.	OK
OBJ-PJ.37-W3-DEMOP-SAF1-0003	The interoperability of the different tools in the integrated tool shall not introduce safety issues.	CRT-37-W3-DEMOP-SAF1-0003	Ensure that the functionalities of all solutions complement one another without		The efficiency of FIM depends on the accuracy of the EAT provided by E-AMAN. During RTS2, illogical pairings and an unpredictable operation occurred, of which the ATCOs were not	POK

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			negative interference.		informed. Therefore, the safety objective is not fully met.	
OBJ-PJ.37-W3-DEMOP-SAF1-0004	There shall not be a negative impact on the number of losses of separation (wake, minimum radar separation infringements and tactical conflicts).	CRT-37-W3-DEMOP-SAF1-0004	The use of the integrated tool and the Airborne Spacing Flight Deck Interval Management does not lead to an increased number of separation losses in the nominal solution as compared against the reference scenario.		During RTS2, the number of LOSs during solution runs and reference runs was similar. The controllers did have concerns, but these seemed to due to aspects other than the combination of tools. Therefore, the results of RTS2 appeared to confirm the RTS1 conclusion.	OK
OBJ-PJ.37-W3-DEMOP-SAF1-0005	The perceived controllability of the operation by ATCO shall not degrade due to the use of the integrated tool.	CRT-37-W3-DEMOP-SAF1-0005	The tool gives the ATCO the means to intervene. The use of the tool does not lead to a perceived loss of controllability of the operation by the ATCO in relation to the conventional operation. This is		With time, the controllers became more familiar with the integrated tool, resulting in increased trust and increased perceived controllability. However, during RTS2, some abnormal disturbances led to a rapid loss of control and the need to halt the simulation. The controllability concerns warrant further attention in future testing and simulations.	POK



Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
			assessed through a qualitative analysis.			

Table 7-18: Exercise 2 Demonstration Results



1. Results per KPA

Note that the exercise is a Real-Time Simulation (RTS) with a focus on the safety and human performance aspects of the integrated solution. Thus, a limited number of simulations have been performed with a relatively strong focus on non-nominal conditions. 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 on Capacity, Operational Efficiency and Environment.

Human Performance

Of the 13 Human Performance objectives, 8 were assessed to be OK, 4 were Partially OK, and the results on one objective were not conclusive. In general the implementation seems OK: the usability is sufficient, the Situational Awareness and Workload are within acceptable limits. Nevertheless, ATCOs mentioned not to be able to devote the necessary attention to monitoring the traffic on final and turning towards final, and being able to timely intervene when necessary. The results on the level of trust were not conclusive as the outcomes were varying a lot. The ATCOs mentioned that the level of trust is much related to the expected reliability and timeliness of the pilots in following up instructions. The ATCOs mentioned the concept is acceptable when the delivery into the TMA is sufficiently accurate and, when pilots can reliability and timely follow up instructions.

Capacity

The capacity objectives have been assessed as OK. There is no negative effect on the runway throughput by using the integrated tool in nominal operations against the reference scenario. The runway throughput for each runway does not vary much when increasing the IM equipage rate. When increasing the traffic load, the throughput increases as expected as long as the traffic is operating nominally. There is no negative effect on the airspace capacity by using the integrated tool in nominal operations against the reference scenario. Airspace capacity on fixed routes is evaluated using runway throughput and number of aircraft under control by a controller. Increasing traffic load resulted in more aircraft under control (UCO), however peak number of aircraft UCO is similar to lower traffic load. To perform this analysis, an identical traffic sample has been used in the reference and solution runs.

Operational Efficiency

The single predictability objective has been assessed as OK. The integrated tool does not have a negative effect on the predictability as the average difference between the actual and planned time in the TMA (delta TMA time) for the solution runs is within seconds compared to the reference run. With increasing percentage of IM equipped aircraft in the traffic sample, the 95% spread in the delta TMA time decreases on most of the fixed routes, improving predictability.

Environment

The environmental objectives have been assessed as OK. In the nominal simulation, the solution run with the integrated tool emits 6.7% less CO₂ than the reference run for an identical traffic sample. There is a slightly negative influence on the CO₂ emission when there is a low percentage of aircraft equipped with IM (20%). With increasing IM equipage rate, the benefits are observed. The 55 dB noise contour area reduced by less than 1% in the solution run. Differences are too small to conclude that the 55 dB noise contour area has improved.

The environmental benefits are mainly obtained through efficient CDO operation without level flight. Other differences are caused through speed differences, where IM adjusts the speed profile to meet separation goals. This could result in later reduction of speed, meaning less airtime and thus less fuel burn (in combination with an optimal CDO). 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.

Safety

The objectives regarding the number of go-arounds and losses of separation have been assessed as OK. The RTS did not show more go-arounds or separation losses in the solution runs compared to the reference runs.

Regarding interoperability, the main issue was that the actual arrival sequence was sometimes different from the planned sequence, resulting in illogical pairings and an unpredictable operation. This highlights the need for reliable EAT on the TMA boundary for the IM operation to work properly. Even though the likelihood of the E-AMAN system providing unreliable EAT in real-life operations is small and the consequences are likely to be low, ATCOs are not informed if the pairing is illogical, resulting in the safety objective not being fully met.

Regarding controllability, the main issue was that some disturbances in the simulation led to a rapid loss of control and the need to halt the run. Some of these disturbances were related to the integration of AMAN and FIM. The concerns warrant further attention in future testing and simulations.

2. Results impacting regulation and standardisation initiatives

There are no relevant results impacting regulation and standardisation initiatives.

B.3.2 Analysis of Exercises Results per Demonstration objective

In the following sections, each demonstration objective is evaluated by a consolidated analysis of the demonstration result, including a rationale of the result, potential deviation with respect to the expected performance benefit (if any) and in case applicable, possible reasons and relationship between the results and the appropriate assumptions.

1. OBJ-37-W3-DEMOP-HUP1-0003

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0003 “The arrival management process is found acceptable by the ATCOs present in the RTS” has been assessed as Partially OK.

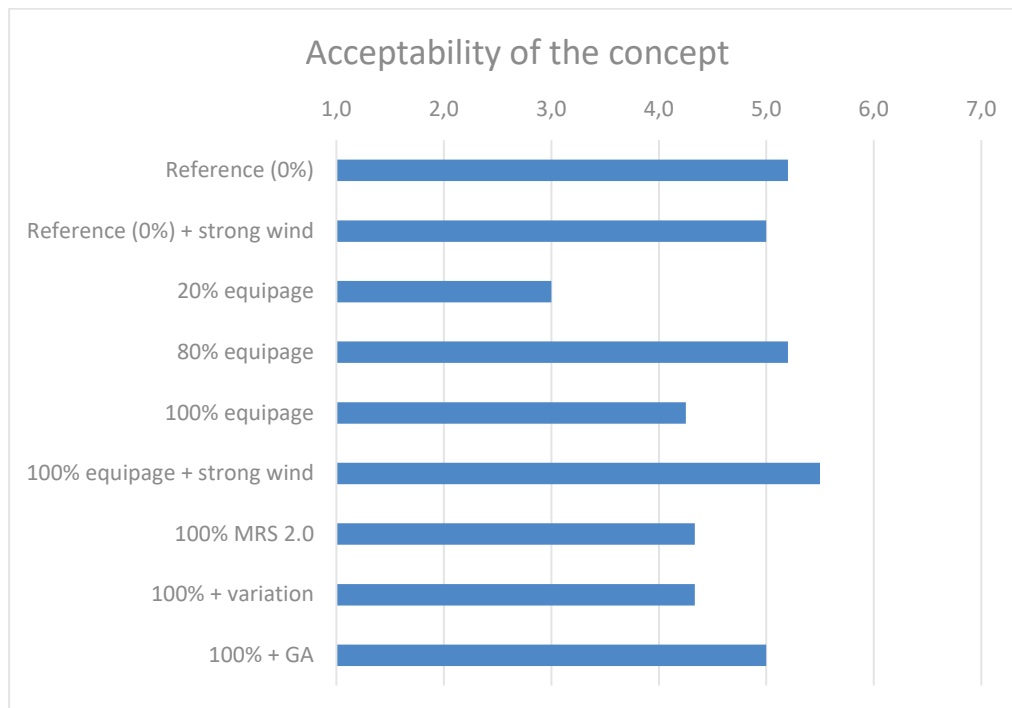


Figure 7-19: ATCO ratings of acceptability of the concept (post-run ratings, n varies between 2 and 6)

2. OBJ-37-W3-DEMOP-HUP1-0004

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0004 “Assess completeness and acceptability of working procedures (regarding transition between IM/merge tool and PWS/ORD tool whilst operating RNAV/RNP transition procedures followed by instrument approach procedures)” has been assessed as Partially OK. The ATCOs rated the completeness 2.7 and acceptability 3 (scale 1-5). The completeness and acceptability apparently reduced in comparison to the first RTS. In RTS 2 the concept was evaluated against more challenging situations that required more controller actions. For example, merging a go-around, which was rather challenging in the high volume of traffic. Also, some unexpected simulation and technology behaviours may have had an effect. The ATCOs answered in the post-run questionnaire quite a few times to be confused on what to do. The explanations concerned sequence failures (simulator issue). The HMI usability was rated positively.

Overall, working procedures seem not fully acceptable and complete. Certain aspects require further attention, e.g., how to deal with (inevitable) unexpected traffic behaviour, but still fall under normal operations

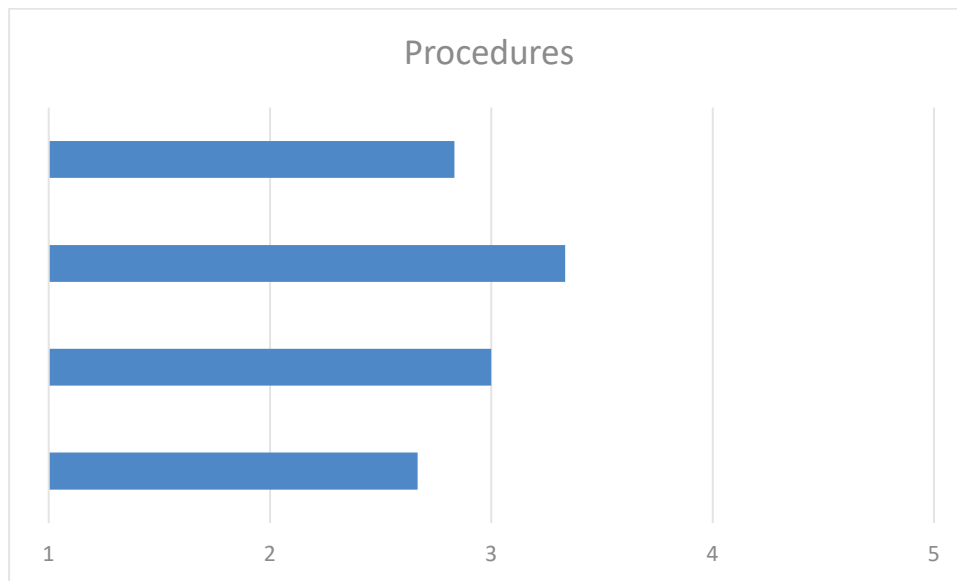


Figure 7-20: ATCO ratings on the procedures (post-experiment questionnaire, n=3)

3. OBJ-37-W3-DEMOP-HUP1-0005

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0005 “Assess working procedures for normal mode of operations are clear and consistent” has been assessed as Partially OK. The ATCO rating regarding clarity and consistency of the procedures did not increase compared to RTS 1. In contrary, the consistency was reduced to 2.8. It is believed that the inconsistency due to technology aspects, that resulted in some flights increasing speeds at final approach, led to this decreased rating.

Overall, working procedures clarity and consistency were neutrally rated in RTS 2. It seems that this requires further attention.

4. OBJ-37-W3-DEMOP-HUP1-0006

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0006 “Assess the ability of controller to follow working procedures” has been assessed as Partially OK. ATCOs were able to follow the working procedures but meanwhile mentioned that high volumes of traffic and high speeds make it difficult to monitor the traffic at all route segments in the same way it is done in current operations. Also, the task of changing IM targets should be avoided.

5. OBJ-37-W3-DEMOP-HUP1-0007

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0007 “Assess the types, likelihood and effect of errors that occur, in particular due to the simultaneous presentation ORD and Merge tool indicators” has been assessed as OK. The combined presentation did not lead to confusion. ATCOs did not mention this as a problem. Increased confusion was reported in runs where simulation/automation generated illogical sequences and IM settings.

It was concluded that the combined presentation of ITD, FTD and merge tool indications do not lead to confusion and the probability of human error is not increased.

6. OBJ-37-W3-DEMOP-HUP1-0008

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0008 “Assess the extent to which task performance is reduced by the integrated arrival concept” has been assessed as OK.

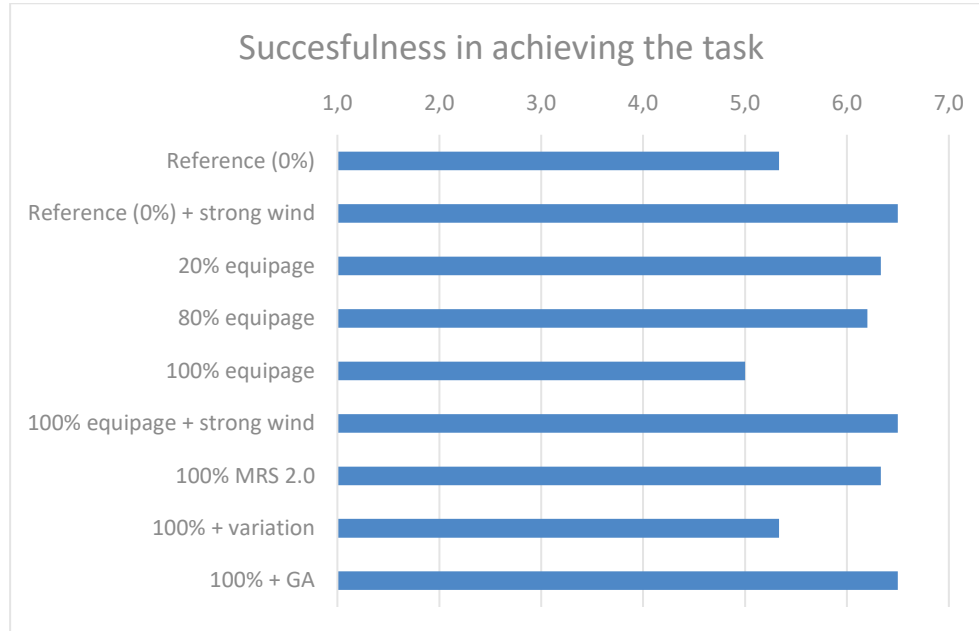


Figure 7-21: ATCO ratings of their own successfulness in accomplishing the task (post-run, n between 2 and 6)

Merging and spacing was performed in a timely manner. The post-run ratings of 'the successfulness in achieving the task' was rated between 5 and 6.5 (scale 1-7) for both conditions, which is concluded to be acceptable.

Nevertheless, one ATCO mentioned it was difficult to monitor the aircraft turning in for final approach and meanwhile dealing with aircraft separation before the merge point. Overall, it was concluded that merging and spacing were performed in a timely manner. Nevertheless, meanwhile monitoring the traffic turning in for final approach was difficult.

7. OBJ-37-W3-DEMOP-HUP1-0009

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0009 “Assess the extent to which workload is made worse by the integrated arrival concept” has been assessed as OK. The NASA-TLX ratings were between 30 and 40. The ratings of the runs with 100% equipage were increased compared to all other runs, contrary to what was expected. This is most likely due to simulation problems. For runs with more variation and with a go-around the workload rating was increased, as expected, but only slightly. For MRS 2.0 no increase was measured. For equipages of 20% and 80%, no increases in average ratings were found. The strong wind did not lead to increased workload, neither in the reference nor in the 100% equipage run, while the number of aircraft per hour remained at the level of 40/40.

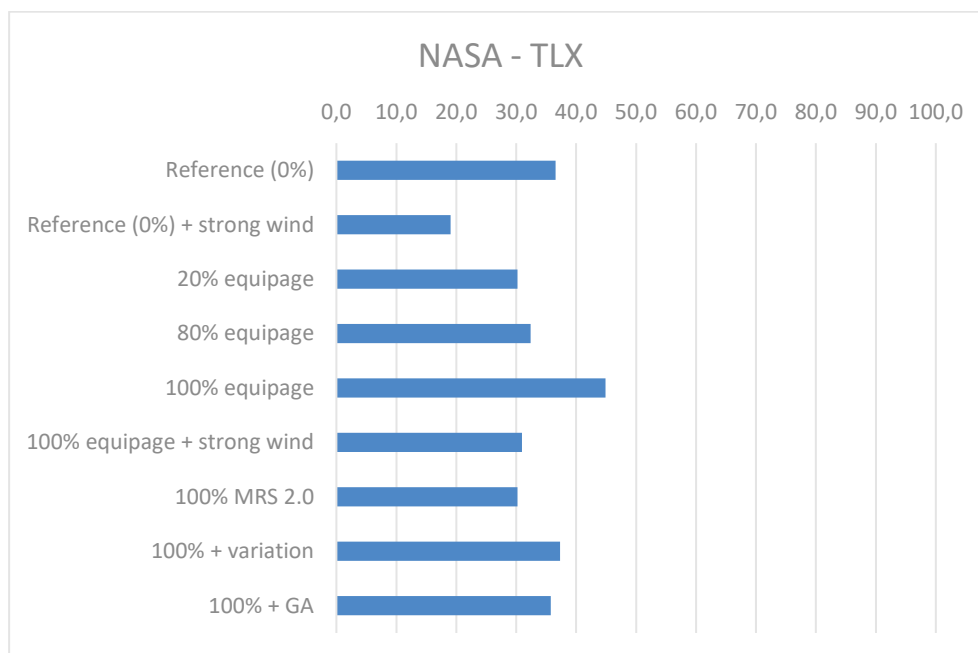


Figure 7-22: ATCO NASA-TLX ratings (post-run, n between 2 and 6)

In conclusion, the average workload ratings seem to be at acceptable levels. Nevertheless, ATCOs mentioned that small disturbances have an impact on workload and that insufficient time remained to monitor the traffic turning towards final approach. The reduction of MRS to 2.0 does not seem to contribute to ATCO workload.

8. OBJ-37-W3-DEMOP-HUP1-0010

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0010 “Assess the impact on ATCOs level of trust in the integrated arrival concept” has been assessed as NOK. The results are not conclusive.

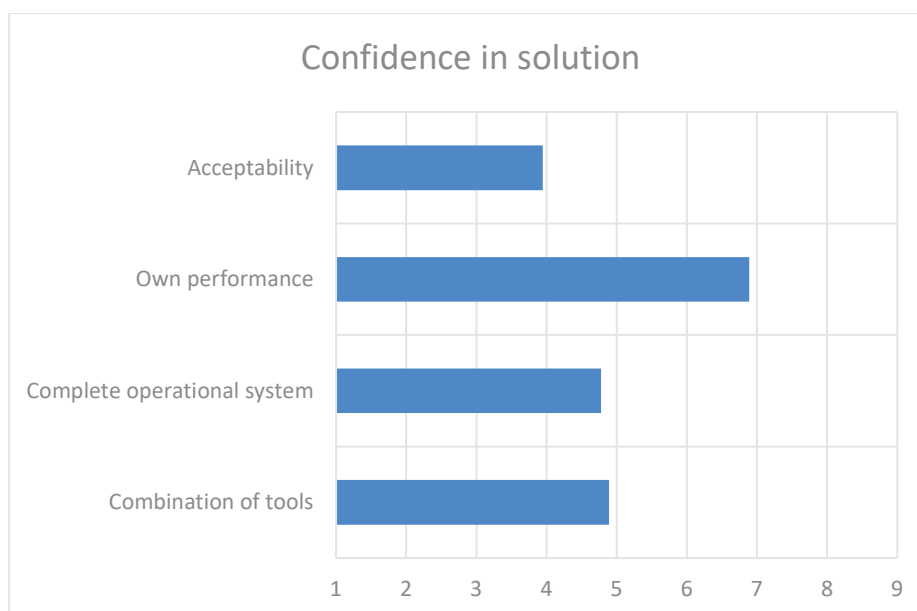


Figure 7-23: ATCO Confidence ratings (end-of-day questionnaire, n=9)

The average confidence in the concept was 4.8 (scale 1-9), in the end-of-day questionnaire, but was also rated at values 1 and 2 (in day 2) and mentioned it was caused by the unexpected behaviour due to simulator issues.

Results were not conclusive. The ATCOs' confidence in the concept was rated neutrally, with the remark that in the simulation the pilots were very collaborative and timely following up instructions, which is not the case in current day operations.

9. OBJ-37-W3-DEMOP-HUP1-0011

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0011 "Assess the impact on individual ATCO situation awareness levels by the integrated arrival concept" has been assessed as OK.

The average SASHA ratings varied between 4.4 and 5.5 (scale 0 – 6). For the 20% equipage the rating was highest and lowest for 100% equipage with increased variation at TMA entry.

On average the ATCO SA is sufficient. Partial equipage of the traffic does not seem to give severe problems of SA. The variation of accuracy of TMA entry seems to have a higher impact on SA.

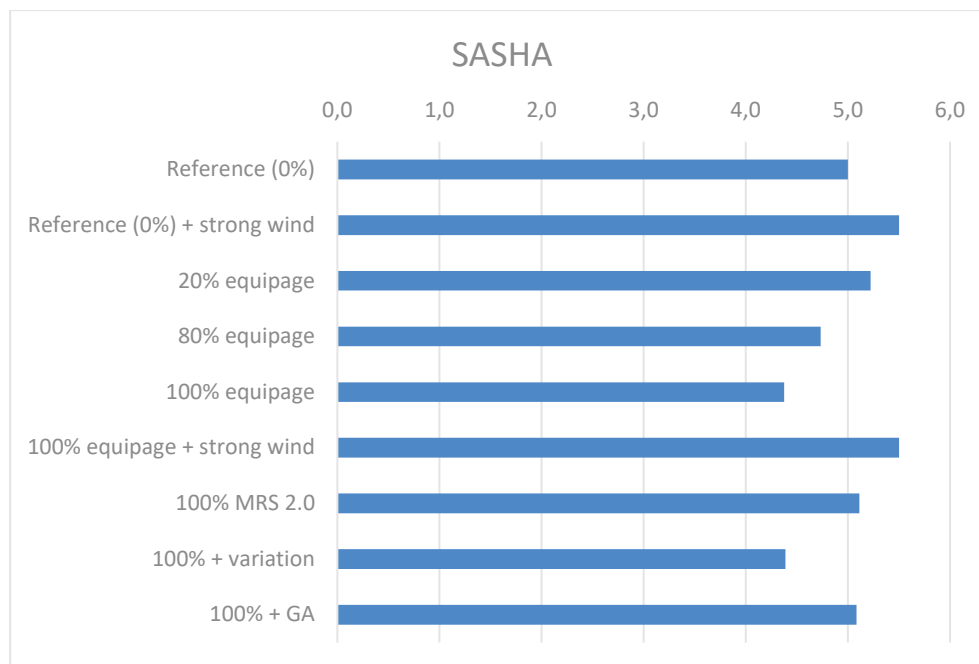


Figure 7-24: ATCO ratings on Situational Awareness (post-run, n between 2 and 6)

Eye tracking was used to register the division of visual attention of the Arrival Controllers ARR1 and ARR2. Only eye gaze on the radar display was registered. It was of interest whether the division of attention would change in comparison to the reference. Also it was investigated what would be the influence of different equipage levels and in the influence of disturbances such as a Go-Around, the reduced accuracy of delivery at TMA entry, and the MRS reduction at final to 2.0 miles.

The data from the runs with strong wind unfortunately delivered data of insufficient quality, due to calibration issues. These data are not included.

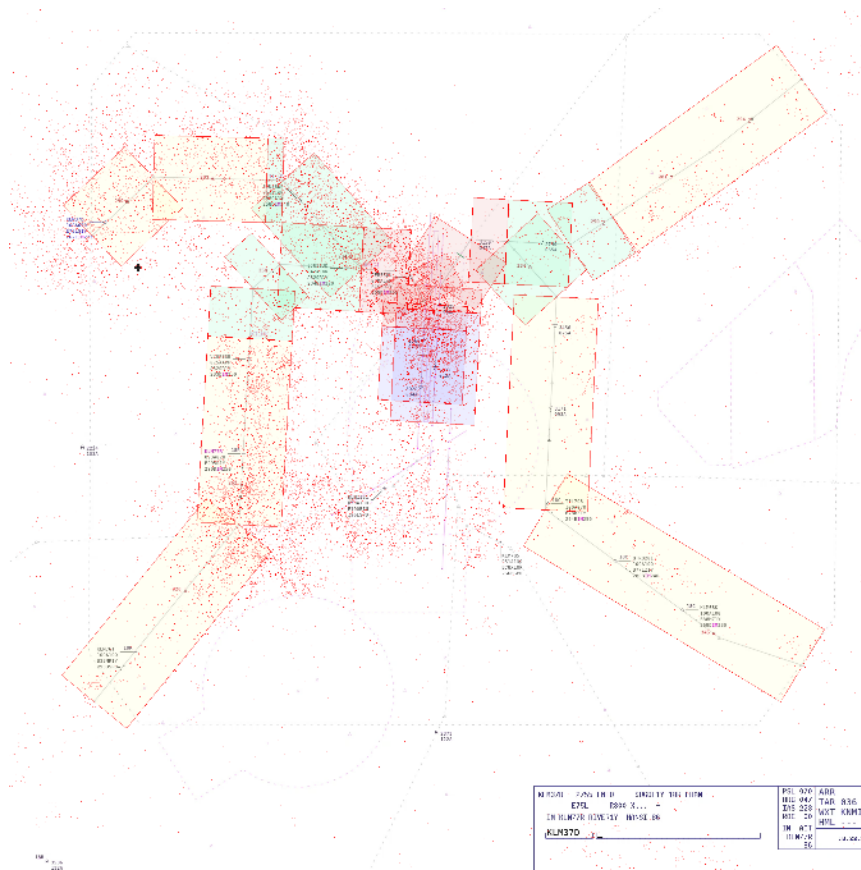


Figure 7-25: The radar display, areas of interest defined for eye tracking: TMA entry (yellow), Merge (green), Turn to final (red) and final (purple).

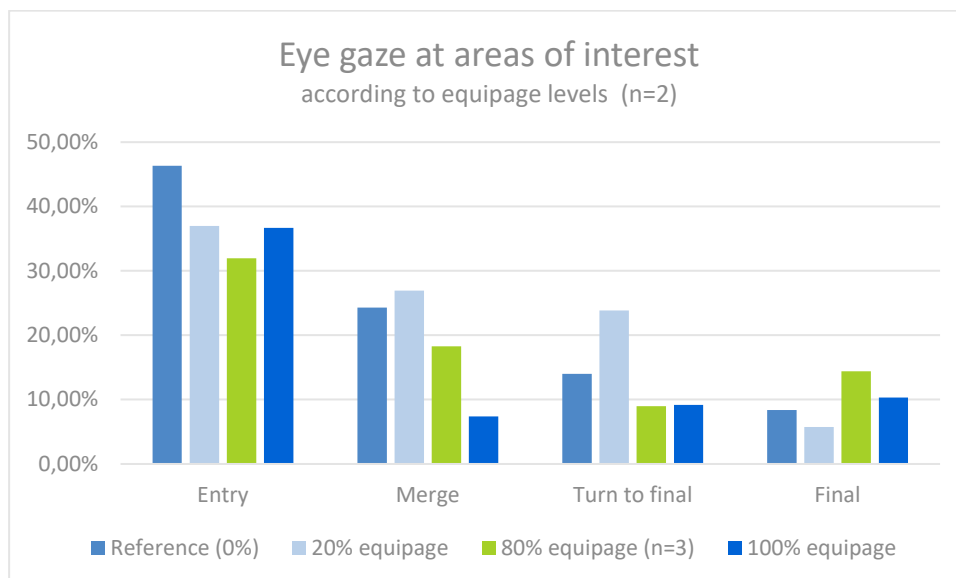


Figure 7-26: Division of attention over the areas of interest for runs with varying equipage levels (n=2 unless other specified)

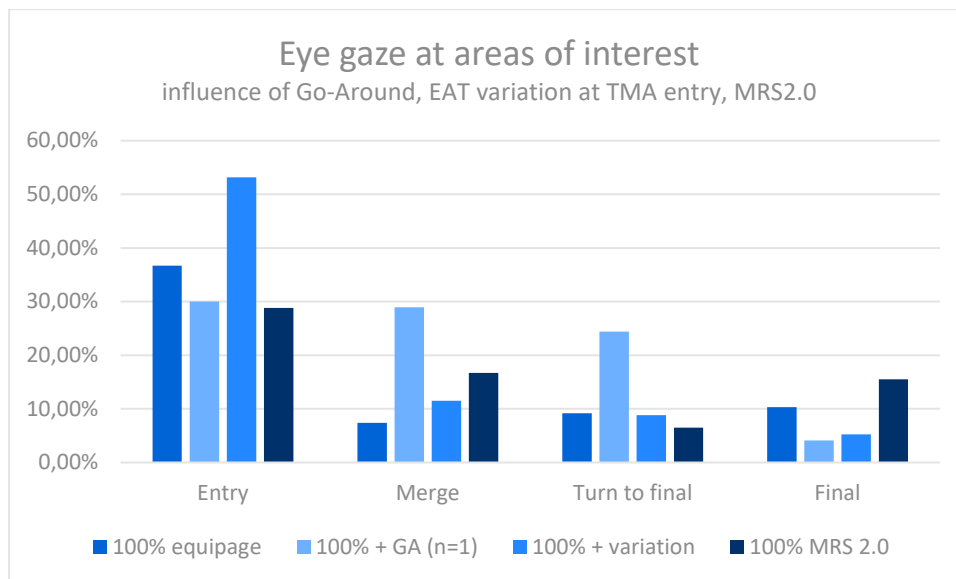


Figure 7-27: Division of attention over areas of interest for runs with a go-around, with reduced accuracy of delivery into TMA, reduced MRS (compared to the nominal solution run (n=2 unless other specified))

10. OBJ-37-W3-DEMOP-HUP1-0012

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0012 “Assess the extent to which the integrated arrival concept complies with the relevant HP Principles” has been assessed as OK. The integrated tools were implemented such that it complied with the HMI philosophy in terms of colour usage and regarding the rationale for additional information in flight labels.

11. OBJ-37-W3-DEMOP-HUP1-0013

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0013 “Assess the extent to which the user interface reduces human performance and service delivery” has been assessed as OK. The HMI usability was rated 4.7 to 6.0 on average (scale 1-7). The HMI usability was rated positively. Nevertheless, both in RTS 1 and 2, potential HMI improvements were identified.

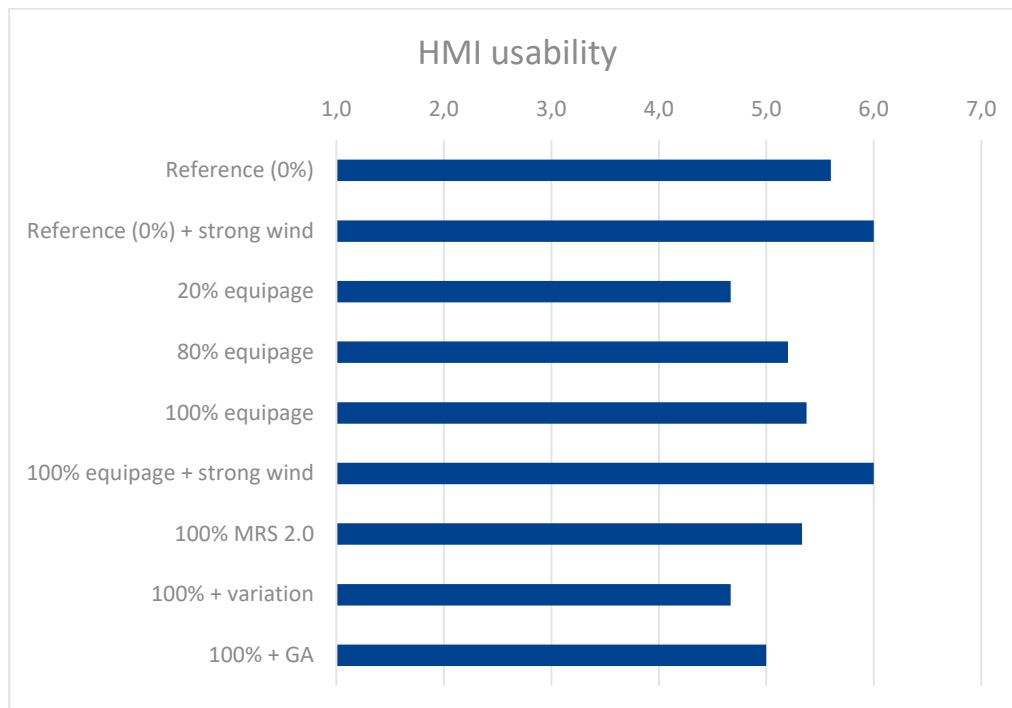


Figure 7-28: ATCO Human Machine Interface Usability ratings (post-run, n between 2 and 6)

Even though the SA ratings reduced between RTS 1 and RTS 2, ATCOs mentioned the HMI had improved. Lower SA ratings are explained by the more challenging scenarios with more variation in the accuracy of delivered flight. It was concluded that the HMI does not negatively impact the human performance.

12. OBJ-37-W3-DEMOP-HUP1-0014

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0014 “Assess the impact on team ATCO situation awareness levels by the integrated arrival concept” has been assessed as OK. In RTS 2, the team SA was rated on average 5.7 (scale 1-7, post-run questionnaire). Nevertheless, the expected effect of the concept on Team SA was on average rated slightly negative (2.6 on scale 1-5, end-of-day questionnaire).

It was concluded that Team SA may reduce slightly in comparison to current day operations but will remain at sufficient levels.

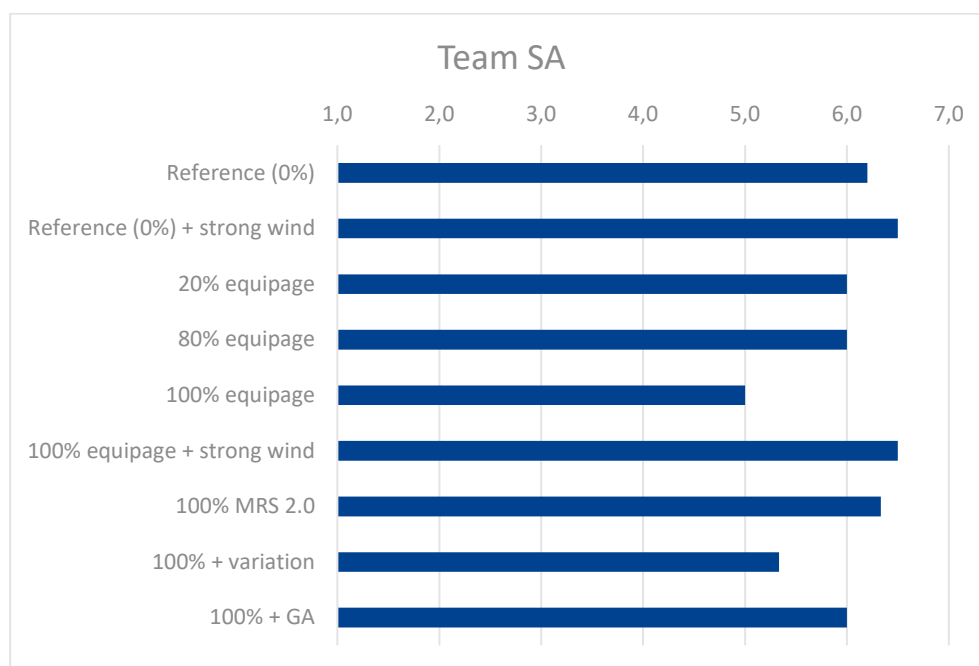


Figure 7-29: ATCO ratings of Team Situational Awareness (post-run, n between 2 and 6)

13. OBJ-37-W3-DEMOP-HUP1-0015

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0015 “The integrated tool does not deteriorate the arrival management process” has been assessed as POK. Abnormal system behaviour was deteriorating the arrival management process in a few runs. This abnormal behaviour was in itself an integration issue but is believed to be solvable in next iterations.

Overall, it is concluded that the integration is complex. Small changes meant to improve the integration proved to have unexpected results. Nevertheless, it is expected that if flights are delivered accurately into the TMA the concept could work, allowing continuous descents at high throughput.

14. OBJ-37-W3-DEMOP-CAP1-0001

Demonstration objective OBJ-37-W3-DEMOP-CAP1-0001 “The runway throughput level shall remain at the same level or increase against the reference scenario” has been assessed as OK as in most cases analysed in this simulation, the throughput has been increased.

The method for calculating the runway throughput relies on dividing the number of “good landings” by the interval between the first and last good landing (in hours), per simulation run. A “good landing” has been defined as a flight which has;

- Horizontally passed the IAF within 2NM
- Horizontally passed the FAF within 0.1NM
- Vertically passed the RWY threshold

The filter protocol to select “good flights” should ensure that go-arounds and unfinished simulated flights are removed from the analysis, as these would corrupt the throughput calculation. The traffic sample between the compared runs were identical to aid the comparison.

The runway throughput in the different runs are presented in Table 7-19 for runway 18R and in Table 7-20 for runway 18C. Furthermore, the simulation time per run between the first and last good landing

was less than one hour. Finally, the first and last timestamps of the “good flights” have a significant impact on the time interval used in the capacity calculation. The used interval varies between 0.5hr and 0.81hr, which is more than 18min difference across the runs.

IM equipage % - In run #1 to #4, the IM equipage rate is varied between 0%, 100%, 20% and 80%. The runway throughput for both runways does not change significantly between the runs. For runway 18R the 80% equipage scored the highest whilst the 20% equipage scored the lowest. For runway 18C, 0% scored the lowest, while 20% scored the highest. No conclusion can be reached besides that the difference between the different equipage rates varies at around 1 aircraft per hour between the different equipage rates.

Effect of wind – In case there is a strong wind condition, including a strong head wind on final, run #8 and #9, it is observed that for 18R runway throughput is decreased by 1.2 aircraft (decrease of 3%). In these runs, 18C was not actively controlled by the controllers. It is observed that run #8 had the highest runway throughput of all runs with the simulated traffic load of 40 aircraft per hour per runway. The throughput of run #9 is similar to the one observed in run #1 and #4.

Variation in EAT adherence – In run #7, for 3 aircraft each on both runways, the EAT adherence was outside of the ± 30 sec. These aircraft on 18R had an EAT adherence of either plus or minus 90 sec and the aircraft on 18C had an EAT adherence of either plus or minus 60 sec. When comparing run #2 (all aircraft with EAT adherence within ± 30 sec), it is noticed that for 18R the throughput is reduced by 2 aircraft (decrease of 6%). In contrary, the throughput on 18C has increased by more than 2 aircraft (increase of 7%). There is not sufficient data to reach a conclusion on the throughput as the traffic samples between run #2 and run #7 were not identical.

Increase traffic load – It is observed that when increasing the planned traffic load from 40 to 43 (increase of 7.5%) and MRS2.0 is considered on final, for both runways the throughput increases as expected as long as the traffic is operating nominally. For runway 18R, when comparing 100% IM rate with a traffic load of 40 and 43 aircraft, in the run with increased traffic load the throughput increased by nearly 6 aircraft (increase of 15%). For runway 18C, the increase was 5 aircraft (increase of nearly 14%).

Run Nr	Nr of good flights	WTC				Time interval [hr] between first and last landing	Throughput per hour	Simulated entry throughput per hour per runway
		H	M	L	J			
1	29	2	27	0	0	0.76	38.40	40
3	28	2	26	0	0	0.75	37.55	40
4	29	2	27	0	0	0.75	38.43	40
2	20	2	18	0	0	0.53	37.57	40
8	29	1	28	0	0	0.73	39.63	40
9	31	1	30	0	0	0.81	38.41	40
7	28	6	22	0	0	0.80	35.15	40

10	33	1	32	0	0	0.76	43.32	43
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Table 7-19: OBJ-37-W3-DEMOP-CAP1-0001 Total throughput per hour per run, runway 18R

Run Nr	Nr of good flights	WTC				Time interval [hr] between first and last landing	Throughput per hour	Simulated entry throughput per hour per runway
		H	M	L	J			
1	26	8	17	0	1	0.74	35.12	40
3	27	8	18	0	1	0.74	36.44	40
4	26	8	17	0	1	0.72	36.12	40
2	18	6	12	0	0	0.50	36.03	40
8	NA							
9	NA							
7	30	2	27	0	1	0.78	38.65	40
10	31	5	26	0	0	0.76	40.98	43

Table 7-20: OBJ-37-W3-DEMOP-CAP1-0001 Total throughput per hour per run, runway 18C

Because the runway throughput calculation only considers “good flights”, thus removing some aircraft out of the equation, and with a fixed number of aircraft (40 or 43 aircraft per hour per runway) in the simulation, it is understandable that the runway throughput does not exactly match the simulated throughput.

15. OBJ-37-W3-DEMOP-CAP1-0002

Demonstration objective OBJ-37-W3-DEMOP-CAP1-0002 “The airspace capacity shall remain at the same level or increase against the reference scenario” has been assessed as OK. In OBJ-37-W3-DEMOP-CAP1-0001, it was observed that when the traffic load is increased, the runway throughput increased as well (reference run #1, solution run #10). To facilitate such an increase, the number of aircraft through the airspace has to be increased. When fixed routes are used, airspace capacity can be compared by evaluating the total number of aircraft on the approach transition. This is presented in Table 7-20 and Table 7-21 for run #1 (reference run), run #2 (solution run with same traffic load as run #1) and run #10 (solution run with increased traffic load). Note that the traffic sample for run #1 and run #2 were identical. For run #10, the traffic sample was slightly different, see the number of Heavy and Medium aircraft in Table 7-19 and Table 7-20.

Run Nr	SUGOL_1Y	RIVER_1Y	Time interval [hr] between first and last landing	Throughput per hour	
				SUGOL_1Y	RIVER_1Y
1 (REF)	17	12	0.76	22.5	15.9
2 (SOL)	12	8	0.53	22.5 (0%)	15.0 (-5%)

10 (SOL)	18	15	0.76	23.6 (+5%)	19.7 (+24%)
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Table 7-21: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft on transition per hour per run, runway 18R

Run Nr	ARTIP_1Y	XXXXX_1Y	Time interval [hr] between first and last landing	Throughput per hour	
				ARTIP_1Y	XXXXX_1Y
1 (REF)	14	12	0.74	18.9	16.2
2 (SOL)	10	8	0.50	20.0 (+6%)	16.0 (-1%)
10 (SOL)	20	11	0.76	26.4 (+40%)	14.5 (-10%)

Table 7-22: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft on transition per hour per run, runway 18C

Comparing run #1 and #2, the airspace capacity is similar. Comparing run #1 and #10, the capacity has increased besides on the XXXXX_1Y transition. This is due to the aforementioned difference between run #1 and #10. Variations to the nominal situations have been simulated for the solution run (EAT adherence variation in run #7, missed approaches in run #5). In order to compare airspace capacity for these runs, a reference run with identical non-nominal situation had to be conducted. As this was not performed, no comments can be made on the airspace capacity for these runs. *However, it can be concluded that in all matched runs, the airspace capacity was at the same level or increased against the reference run.*

When dividing the transitions over the airspace under control (UCO) by the ARR1, ARR2, APP1 and APP2 controller, an indication of the airspace capacity change could be obtained. Table 7-23 to Table 7-26 provide an overview of the total traffic under control by a controller during a time interval from the first aircraft under control until the last change before the run was stopped. It is observed that for the runs with a traffic load of 40 aircraft per hour, for both REF and SOL runs, the number of aircraft UCO was similar for all the runs for each controller. On average ARR1 had 39, ARR2 had 36, APP1 had 55 and APP2 had 54 aircraft under control. When the traffic load is increased, the number of aircraft UCO increased, varying between a 6% increase for the APP1 and 12% increase for the APP2.

Run Nr	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour
1 (REF)	36	0.92	39.1
3 (SOL)	36	0.94	38.5
4 (SOL)	37	0.93	40.0
2 (SOL)	27	0.70	38.8
8 (REF)	36	0.93	38.8
9 (SOL)	38	0.99	38.4
Average			38.9
10 (SOL)	40	0.93	42.9 (+10%)

Table 7-23: OBJ-37-W3-DEMOP-CAP1-0002 Traffic volume in the TMA airspace under control of the ARR1 controller, as determined by the total number of aircraft under control and time interval based on the first aircraft under control until end of the simulation.

Run Nr	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour
1 (REF)	33	0.93	35.6
3 (SOL)	34	0.88	38.6
4 (SOL)	33	0.93	35.5
2 (SOL)	24	0.68	35.5
8 (REF)	NA		
9 (SOL)	NA		
Average			36.3
10 (SOL)	37	0.94	39.3 (+8%)

Table 7-24: OBJ-37-W3-DEMOP-CAP1-0002 Traffic volume in the TMA airspace under control of the ARR2 controller, as determined by the total number of aircraft under control and time interval based on the first aircraft under control until end of the simulation.

Run Nr	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour
1 (REF)	53	0.97	54.4
3 (SOL)	53	0.97	54.4
4 (SOL)	53	0.96	55.1
2 (SOL)	41	0.73	56.1
8 (REF)	53	0.96	55.3
9 (SOL)	56	1.03	54.5
Average			55.0
10 (SOL)	56	0.96	58.1 (+6%)

Table 7-25: OBJ-37-W3-DEMOP-CAP1-0002 Traffic volume in the TMA airspace under control of the APP1 controller, as determined by the total number of aircraft under control and time interval based on the first aircraft under control until end of the simulation.

Run Nr	Traffic volume (UCO)	Time interval [hr]	Traffic volume per hour
1 (REF)	51	0.96	52.9
3 (SOL)	52	0.94	55.1
4 (SOL)	52	0.96	54.4
2 (SOL)	39	0.73	53.4
8 (REF)	NA		
9 (SOL)	NA		
Average			53.9
10 (SOL)	58	0.96	60.4 (+12%)

Table 7-26: OBJ-37-W3-DEMOP-CAP1-0002 Traffic volume in the TMA airspace under control of the APP2 controller, as determined by the total number of aircraft under control and time interval based on the first aircraft under control until end of the simulation.

Figure 7-30 to Figure 7-33 presents the number of aircraft UCO throughout the simulation. In run #1, #3 and #4, the IM equipage was increased from 0% (reference run) to 20% and 80%. In run #4 and #2, a comparison is made between run 80% IM equipage and 100% (solution run). Run #8 and #9 compares the reference and solution run with the inclusion of a strong wind condition. Run #2 and #10 compares two solution runs with an increased traffic load for run #10.

ARR1 – Increasing the percentage of IM equipped aircraft in the traffic sample results in a similar total number of aircraft UCO. There is a variation of 5 to 6 aircraft UCO for most of the simulation duration. With the inclusion of wind, a similar pattern is observed. With the increased traffic load, there is an increased time where the traffic run has 1 aircraft more UCO.

ARR2 – With increasing IM %, again a similar number of UCO is observed. With 100% equipage, it seems that more aircraft are UCO at the same time, followed by a lower number of aircraft UCO. The use of IM instead of speed control on aircraft might have influenced this phenomena. However this phenomena is not observed with 80% equipage. With the increased traffic load, there is an increased time where the traffic run has 2 aircraft more UCO. However peak number of aircraft UCO has not changed.

APP1 – Varied IM equipage results in a similar or slightly lower number of aircraft UCO. Increased traffic load shows similar behaviour as for ARR1 and ARR2.

APP2 – Varied IM equipage shows similar behaviour as APP1. Increased traffic load not observed in the plots. Instead a more constant number of aircraft UCO is observed.

To conclude: Varied IM equipage results in a similar number of aircraft UCO at a certain moment. Increasing traffic load results in more aircraft UCO, however peak number of aircraft UCO is similar to lower traffic load.

ARR1 position

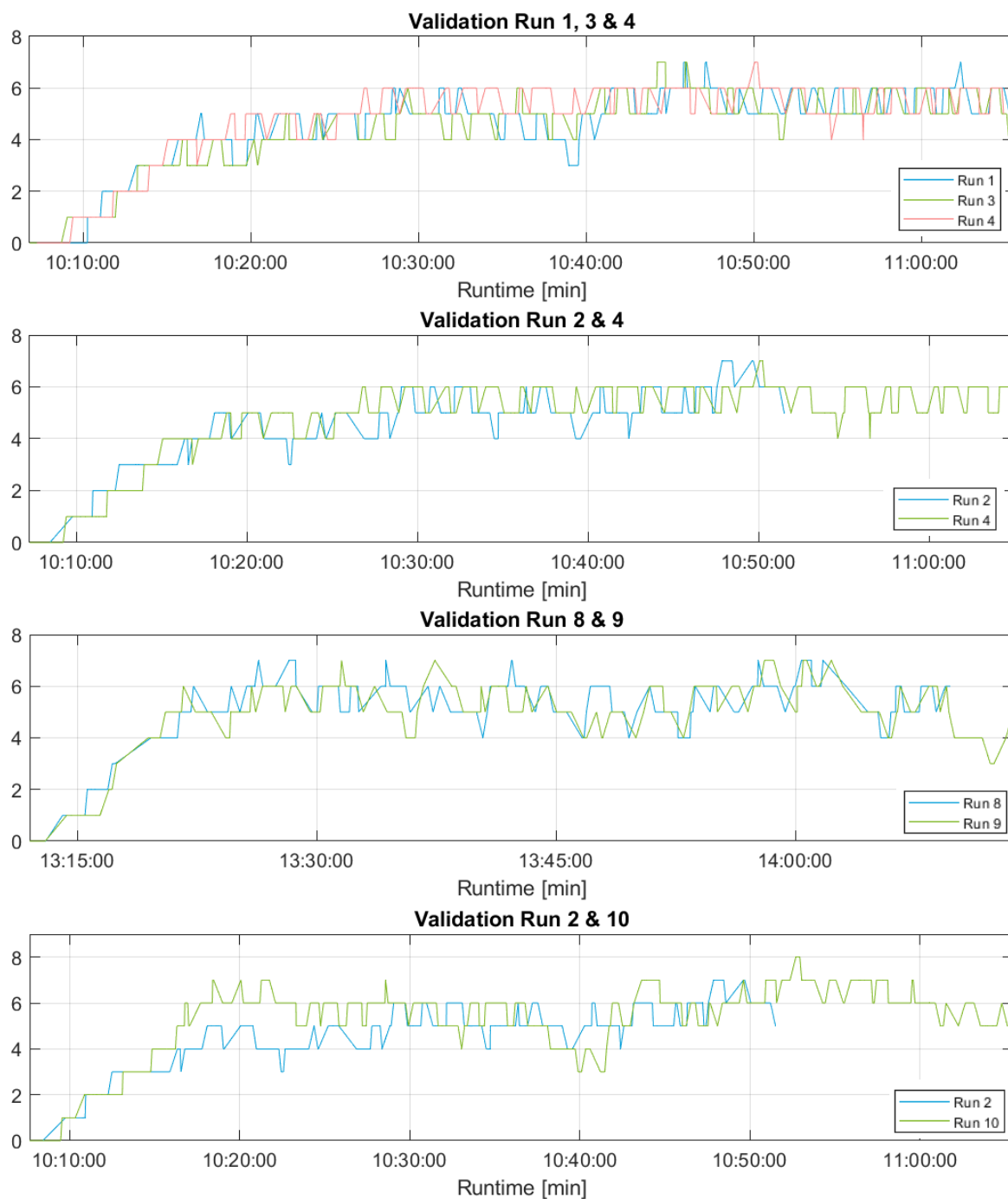


Figure 7-30: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft under control within the airspace under control by the ARR1 controller.

ARR2 position

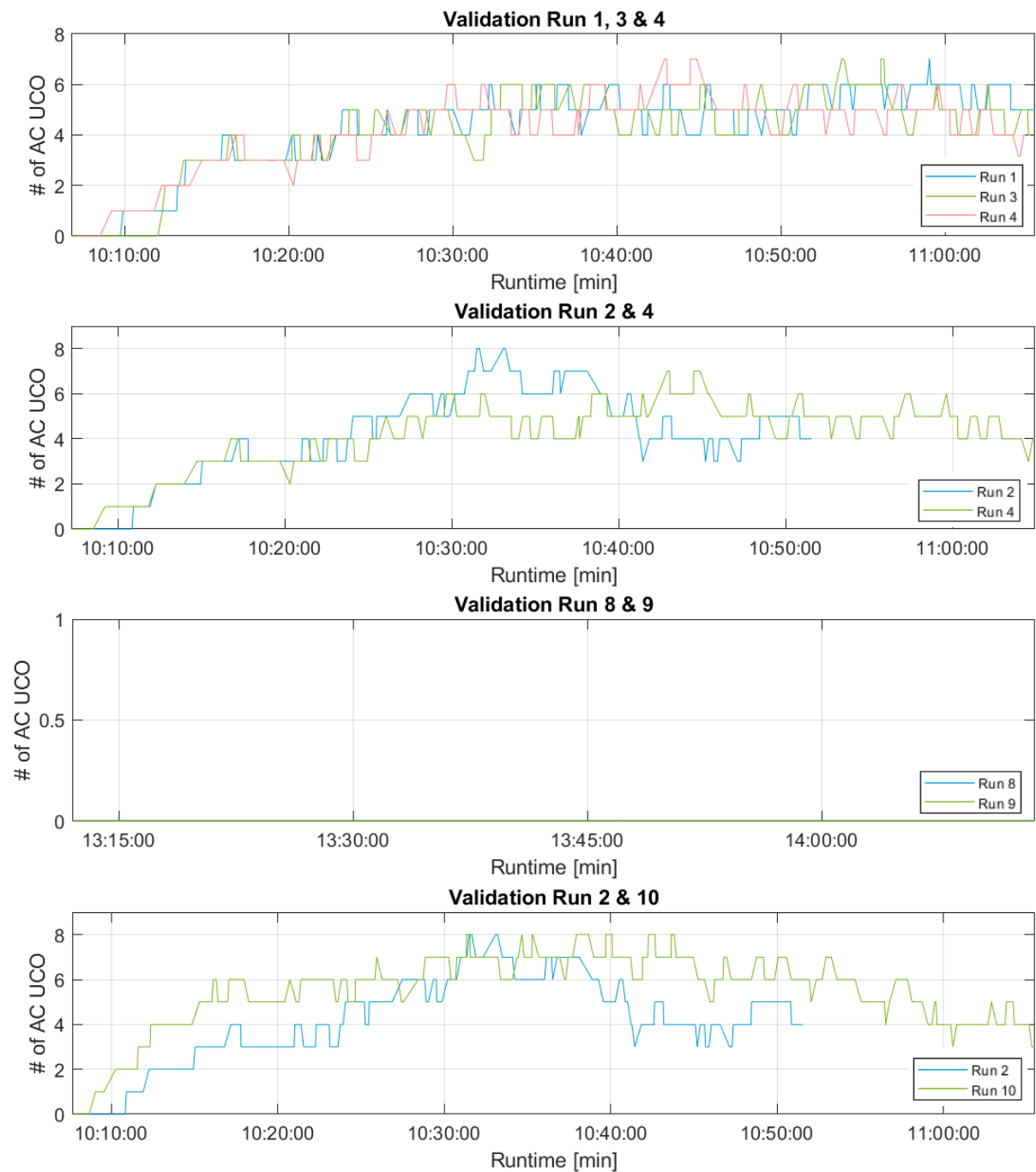


Figure 7-31: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft under control within the airspace under control by the ARR2 controller.

APP1 position

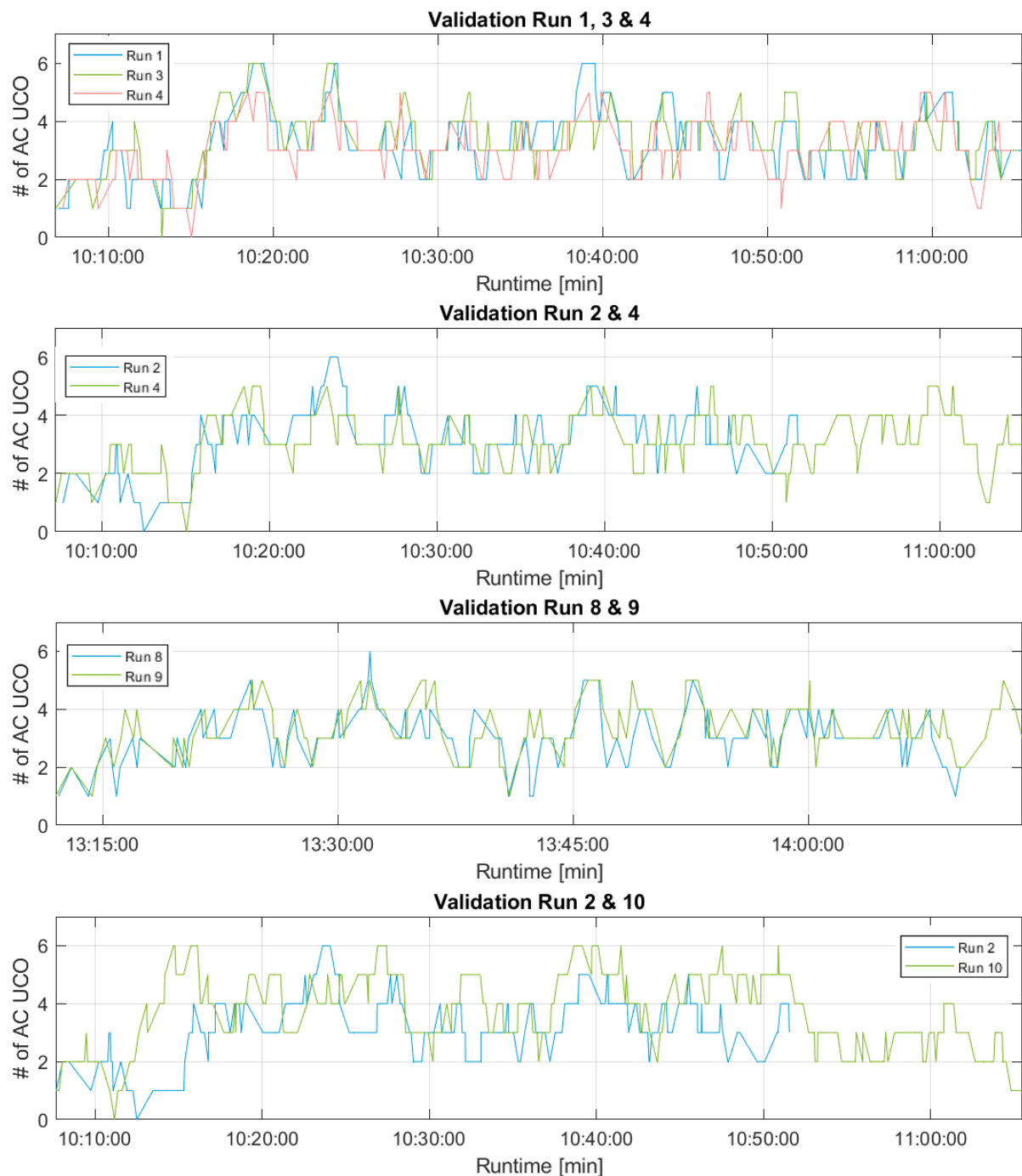


Figure 7-32: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft under control within the airspace under control by the APP1 controller.

APP2 position

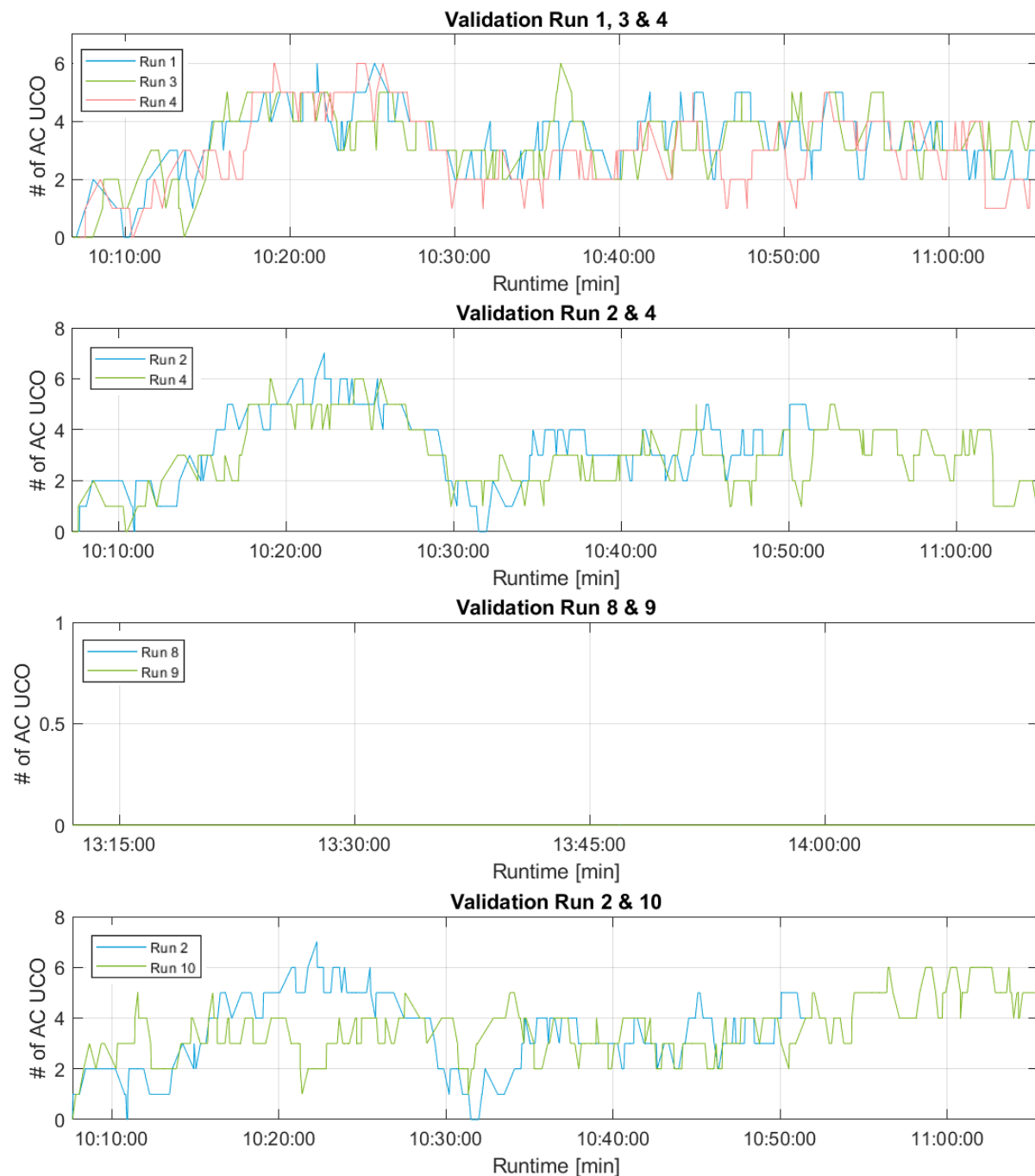


Figure 7-33: OBJ-37-W3-DEMOP-CAP1-0002 Number of aircraft under control within the airspace under control by the APP2 controller.

16. OBJ-37-W3-DEMOP-PRD1-0001

Demonstration objective OBJ-37-W3-DEMOP-PRD1-0001 “The predictability of arriving traffic shall remain at the same level or increase against the reference scenario” has been assessed as OK as the average difference between actual and planned time in the TMA for the solution runs are within seconds compared to the reference run.

The success criteria of this objective is defined as “There is no negative effect on the predictability of the traffic in the TMA by using the integrated tool”. Table 7-27 presents the difference in time between the actual and planned time in the TMA. The planned time in the TMA is determined by the Arrival Manager.

Run Nr	Total Δ in time [sec]	Nr of flights	Avg. Δ [sec]	Δ against reference [sec]
1 (REF)	504	55	9	0
3 (SOL)	249	55	5	-5 (run 1)
4 (SOL)	392	55	7	-2 (run 1)
2 (SOL)	-341	38	-9	-18 (run 1)
10 (SOL)	112	64	2	-7 (run 1)
8 (REF)	441	29	15	0
9 (SOL)	1429	31	46	-31 (run 8)

Table 7-27: OBJ-37-W3-DEMOP-PRD1-0001 Average difference (delta, Δ) between actual and planned time in the TMA for solution runs compared against the reference runs (negative if actual time is less than planned time)

For the runs with strong wind conditions (runs #8 and #9), only the aircraft that landed on 18R have been considered as aircraft for 18C were not actively controlled by the controllers. It is noticed that in the solution run with strong wind conditions (run #9), the largest average difference is observed. This might have been caused by the use of a different Trajectory Predictor between the AMAN and IM system. Slight variation in nominal speeds along the fixed descent profiles resulted in a difference in the expected Target Time Over the merge point and the final approach fix. Based on the observations made during the run, the AMAN Trajectory Predictor was adapted to be more in-line with the IM Trajectory Predictor before the next simulation day, as stated in Appendix B.2.

The results in Table 7-27 presents the KPI PRD1 “Average of difference in actual & Flight Plan TMA arrival durations” introduced in the SESAR Performance Framework [7]. To evaluate the mean of the distribution of the difference between the actual and planned time in the TMA, a modified boxplot is evaluated for each FAR (IAF-runway combination specific) in Figure 7-34. Since the 4th Schiphol IAF is not published, for the sake of this research it has been indicatively named as [XXXXX]. The median, 50% and 90% spread in of the average difference between actual and planned time in the TMA is presented in Table 7-28.

It is observed that in the reference run (run #1) the spread between the 95% of the data is the largest for all FARs except on RIVER. In the solution run (run #2), the spread is the lowest when comparing the runs with the same traffic load. Based on the runs with varied % of IM equipage (20% for run #3, 80% for run #4), it seems that the spread is decreasing with increasing equipage %. For the higher traffic load (run #10), the median of the traffic on runway 18C is similar to run #2. On runway 18R, the 95% spread is larger. However, the total 50% spread is smaller for run #10 and the total median is closer to the 0. This reflects the necessity of traffic to land as much as possible in accordance to the planning in order to accommodate the increased number of traffic.

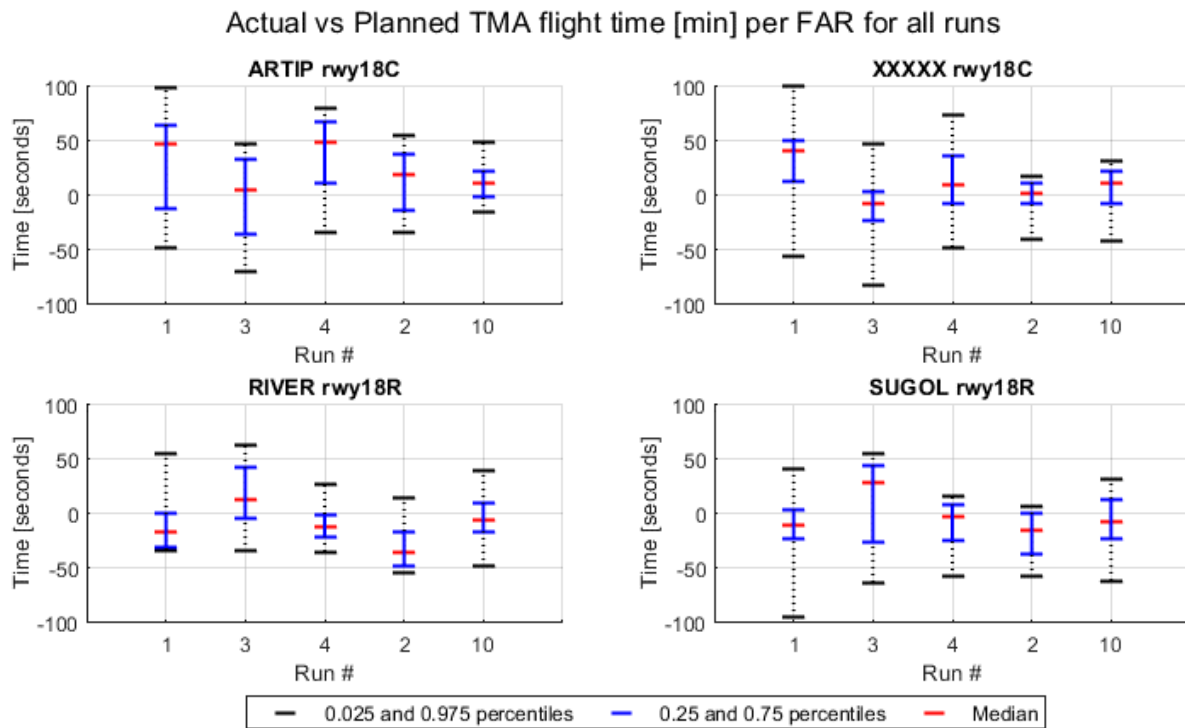


Figure 7-34: OBJ-37-W3-DEMOP-PRD1-0001 Average difference between actual and planned time in the TMA (positive if actual time is larger than planned time).

IAF		Run 1 (REF)	Run 3 (SOL)	Run 4 (SOL)	Run 2 (SOL)	Run 10 (SOL)
ARTIP – 18C	Median (sec)	48	6	48	19	11
	50% spread (sec)	75	69	56	51	23
	95% spread (sec)	147	118	115	89	64
XXXXX – 18C	Median (sec)	41	-7	9	2	11
	50% spread (sec)	37	27	42	17	30
	95% spread (sec)	157	130	121	59	74
RIVER – 18R	Median (sec)	-16	13	-12	-35	-6
	50% spread (sec)	30	47	20	32	26
	95% spread (sec)	89	97	63	69	88
SUGOL – 18R	Median (sec)	-11	29	-3	-15	-7
	50% spread (sec)	26	70	33	37	36
	95% spread (sec)	136	118	73	64	93
Total <i>(absolute values)</i>	Median (sec)	115	55	72	72	35
	50% spread (sec)	169	212	152	138	115

	95% spread (sec)	529	462	371	281	319
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Table 7-28: OBJ-37-W3-DEMOP-PRD1-0001 Median, 50% and 95% of the traffic of the average difference between actual and planned time in the TMA in seconds.

17. OBJ-37-W3-DEMOP-NOI1-0001

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 in the solution reduced by less than 1% against the reference run. However, differences are too small to conclude that the 55 dB noise contour area has improved. The detailed analysis is provided in DEMOR Part IV – Environment Assessment Report [5].

18. OBJ-37-W3-DEMOP-ENV1-0001

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 emission reduced up to 6.7% in the solution run. However, with low IM equipage rates (20%), the CO₂ emission increased by 3.5% with respect to the reference run was observed. The detailed analysis is provided in DEMOR Part IV – Environment Assessment Report [5].

19. OBJ-37-W3-DEMOP-SAF1-0001

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0001 “The number of go-arounds due to insufficient spacing shall not be greater than in the reference scenario” has been assessed as OK.

During the 11 simulation runs in RTS2, there were 2 go-arounds. Both of them occurred in run #5. They were planned (scripted) by the RTS2 organisation and were initiated by the pilot. Therefore, the RTS2 simulation did not include go-arounds that were initiated by the controller.

From observations during the simulations, one controller noted that there was one ‘almost go-around’, in Run #1. The separation was tight, but the aircraft still landed. Run #1 was a reference run. There were also a few losses of separation on final approach in the other runs, which in normal circumstances might have led to an instructed go-around, but did not in this simulation.

The questionnaires did not reveal major concerns regarding this objective. The controllers provided a neutral to positive scoring and in their comments, they noted that the combination of tools provides some predictability for both the pilots and the controllers. One controller noted that a condition is that the pilots understand the procedure; if they don’t, the controller’s workload gets too high.

A detailed analysis outlined several potential reasons why RTS1 did include controller-instructed go-arounds and RTS2 did not. One of the possible reasons was that due to the high traffic density in RTS2, the controllers may have been more hesitant to instruct a go-around to avoid a (minor) loss of separation, because they knew it would be challenging to avoid such loss in the second approach anyway.

Since the solution runs did not include a controller-initiated go-around, and since one reference run included one ‘almost’ go-around, we cannot conclude from the RTS2 results that the number of go-arounds due to insufficient spacing is increased by the combination of tools.

20. OBJ-37-W3-DEMOP-SAF1-0003

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0003 “The interoperability of the different tools in the integrated tool shall not introduce safety issues” has been assessed as Partial OK.

One interoperability issue has been identified.

The FIM system's task is to create spacing between aircraft on fixed routes, but its efficiency depends on the accuracy of the EAT provided by E-AMAN. During the simulation, the actual arrival sequence was sometimes different from the planned sequence due to simulation issues, resulting in illogical pairings and an unpredictable operation. This highlights the need for reliable EAT on the TMA boundary for the FIM system to work properly. However, the likelihood of the E-AMAN system providing unreliable EAT in real-life operations is small and the consequences are likely to be low as the ACC controller, approach planner and flight crew may detect and resolve any issues before the aircraft arrives in the TMA. However, ATCOs are not informed by the ATC systems if the pairing is illogical, resulting in the safety objective not being fully met. The overall score for this system is "Partially OK." In future simulations or demonstrations, it is recommended to add a safety net to the system that warns ATCOs of any interoperability issues between the FIM and E-AMAN systems and algorithms.

Additional testing in simulations is required to provide further evidence on this safety objective.

21. OBJ-37-W3-DEMOP-SAF1-0004

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0004 “There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)” has been assessed as OK.

This objective aims to show that the use of the integrated tool and the Airborne Spacing Flight Deck Interval Management does not lead to an increased number of separation losses (LOS) in the solution scenario (SOL) as compared with the reference scenario (REF).

A more detailed analysis presented each case of LOS in the runs of RTS2 and analysed the severity of the LOS. The LOS due to ROT are also Runway Incursions since the follower aircraft is landing before the leader aircraft has vacated the runway. There were no WTS LOSs.

The results for MRS and ROT are summarised below. Here, A indicates the most serious LOSs (remaining separation is less than 50% of the minimum required separation), B indicates moderate LOS (between 50% and 66%), C indicates minor LOS (between 66% and 99%) and D indicates LOSs that are negligible (99% of the minimum required separation):

Run	A	B	C	D	Summary (MRS)
#8 (REF)	0	0	1	0	1 LOS 2.4 NM 700 ft at MRS=3.0 NM (80%) between an inbound and an outbound flight
#9 (SOL)	0	0	1	0	1 LOS 2.6 NM 750 ft at MRS=3.0NM (87%) between two merging flights
#1 (REF)	0	0	1	0	1 LOS 1.8 NM 600 ft at MRS=2.5NM (72%) before landing
#3 (SOL)	0	0	2	0	1 LOS 2.2NM 700ft at MRS=2.5NM (88%) before landing, and 1 LOS 2.3NM 700ft at MRS=2.5NM (92%) before landing
#4 (SOL)	0	0	0	0	-
#4bis (SOL)	0	0	1	0	1 LOS 1.85NM 600ft at MRS=2.5NM (74%) before landing

#2 (SOL)	0	0	2	0	1 LOS 2.2 NM 700 ft at MRS=2.5 NM (88%) before landing 1 LOS 2.8 NM 0 ft at MRS=3.0NM (93%) after merging point, and 2.9 NM 600 ft a little later
#2bis (SOL)	0	0	0	0	-
#5 (SOL)	0	0	2	1	1 LOS 2.98 NM 700 ft at MRS=3.0NM (99%) 1 LOS 2.7 NM 550 ft at MRS=3.0NM (90%), before final approach segment of F 1 LOS 2.3NM 700ft at MRS=2.5NM (92%) before landing
#7bis (SOL)	0	0	1	0	1 LOS 2.4NM 200ft at MRS=3.0NM (80%) between an inbound and an outbound flight
#10 (SOL)	0	0	0	0	-

Table 7-29: OBJ-37-W3-DEMOP-SAF1-0004 number of Loss of Separation due to MRS observed in the runs, specified per severity of the LOS

Run	A	B	C	D	Summary (ROT)
#8 (REF)	0	0	0	0	-
#9 (SOL)	0	0	0	0	-
#1 (REF)	0	0	2	0	Two category C LOS (84% and 96%) due to ROT
#3 (SOL)	0	0	1	0	One category C LOS (97%) due to ROT
#4 (SOL)	0	0	0	0	-
#4bis (SOL)	0	0	1	0	One category C LOS (86%) due to ROT
#2 (SOL)	0	0	1	0	One category C LOS (85%) due to ROT
#2bis (SOL)	0	0	0	0	-
#5 (SOL)	0	0	1	0	One category C LOS (90%) due to ROT
#7bis (SOL)	0	0	0	0	-
#10 (SOL)	0	0	0	0	-

Table 7-30: OBJ-37-W3-DEMOP-SAF1-0004 number of Loss of Separation due to ROT observed in the runs, specified per severity of the LOS

From this data, it cannot be concluded that the SOL runs had more cases of LOS than the REF runs.

The questionnaires did not reveal major concerns regarding this objective either. The controllers provided a neutral to positive scoring, except in two runs which had to deal with several simulation issues.

Therefore, overall, from RTS2 it cannot be concluded that the use of the integrated tool and the Airborne Spacing Flight Deck Interval Management leads to an increased number of separation losses in the solution scenario as compared with the reference scenario. However, there are some safety concerns that may be due to a lower controllability which may have an impact on risk of LOS.

22. OBJ-37-W3-DEMOP-SAF1-0005

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0005 “The perceived controllability of the operation by ATCO shall not degrade due to the use of the integrated tool” has been assessed as Partially OK.

The execution of a second sequence of real-time simulations helped the controllers to become more familiar with and obtain more experience with the integrated tool, resulting in increased trust. However, some simulation issues arose during the runs, leading to concerns about the perceived controllability in real-world operations. In real operational context, controllers must handle various disturbances such as rain clouds, go-arounds, unexpected aircraft behaviour, and aircraft flying too fast or too slow. Some of these types of situations were also encountered during some of the RTS2 runs (grossly unexpected aircraft/pilot behaviour, difference between actual and planned arrival sequence that was abnormal behaviour), leading to a rapid loss of control and the need to halt the simulation. The main issue is the integration between the AMAN and IM; the concerns warrant further attention in future testing and simulations.

Therefore, at this moment we cannot conclude that objective OBJ-PJ.37-W3-002-SAF-005 is fully met.

B.3.3 Unexpected Behaviours/Results

No unexpected behaviours or results have occurred during the preparations and performance of demonstration exercise EXE-PJ.37-W3-002.

B.3.4 Confidence in the Demonstration Results

1. Level of significance/limitations of Demonstration Exercise Results

Findings are based on 12 measured runs and the feedback from 3 experienced ATCOs for specific use cases within the TMA operational environment of Amsterdam Airport Schiphol. Other comments with regards to the level of significance and limitations are as reported in Appendix A.3.41.

2. Quality of Demonstration Exercise Results

The quality of the exercise results is similar to what has been reported in Appendix A.3.42.

3. Significance of Demonstration Exercises Results

The significance of the exercise result is similar to what has been reported in Appendix A.3.43.

B.4 General findings of the integrated solution

This section elaborates on the general findings of the integrated solution not previously identified in EXE-PJ.37-W3-001 in Appendix A.4 or have been observed due to the adjustments made to the demonstration platform between EXE-PJ.37-W3-001 and EXE-PJ.37-W3-002 as reported in the Demonstration Plan [2].

Figure 7-35 presents a simplified flow diagram of the integrated solution, with blocks with a darker blue outline being the SESAR solutions being integrated, and the blocks with a light blue outline being previously developed SESAR solutions that have been considered in the tool. The arrows and the text

in orange indicate the information exchange. This simplified figure is used to discuss the general findings related to the integration of the different SESAR solutions.

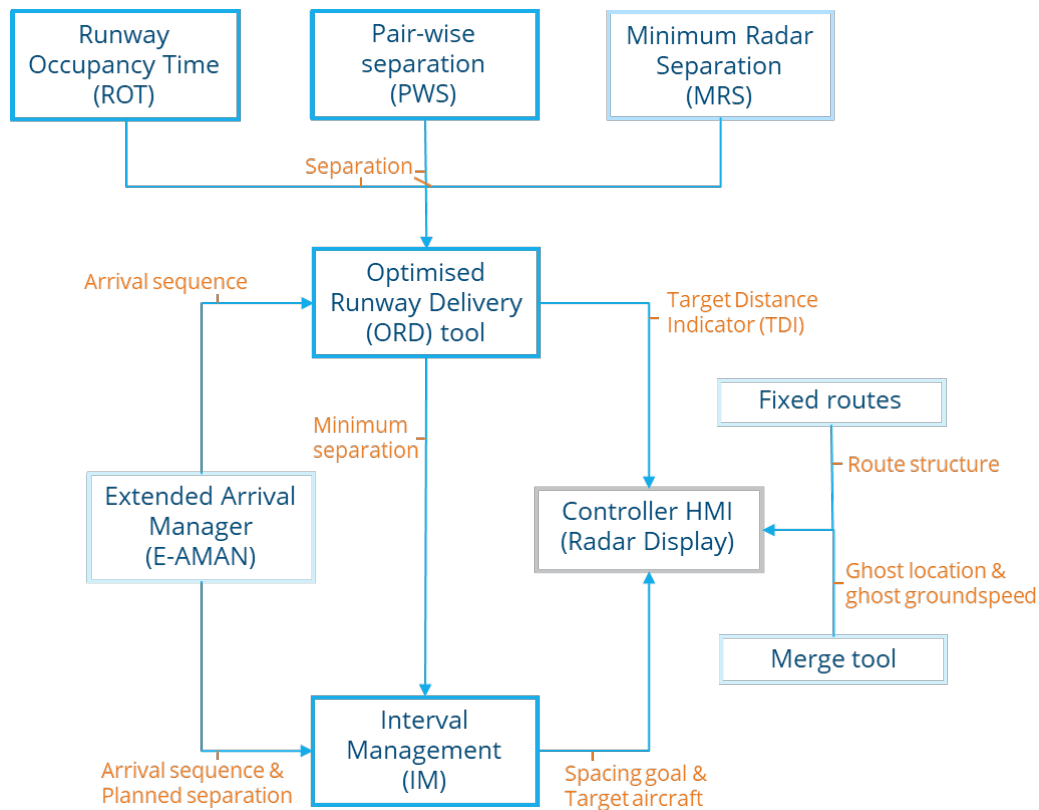


Figure 7-35: Simplified flow diagram between the SESAR solutions up to the presentation to the controller as used in EXE-PJ.37-W3-002.

One of the main goals was to identify gaps/issues when combining solutions. The following observations have been made on the integrated solutions whilst performing the simulation. First an overview of the integration topics is given, and thereafter a description of the observations related to each topic is given.

Integration of SESAR solutions

- ROT enhancement
- Combination of arrival planning and minimum separation in IM spacing goal

Controller position

- Necessary information of the integrated tool to the controllers
- Distance-based merge tool in the integrated solution
- When to provide the IM clearance
- Target Distance Indicators (TDI) along fixed routes
- Gradual versus more abrupt TDI change when established on extended centreline

Arrival planning adherence

- Incidental large EAT adherence manageable
- Knock-on effect when incorrect target aircraft and spacing goal is unnoticed

Interval Management

- Achieve-By-Point and Planned Termination Point

Fixed routes

- Uniform climb-out and IAF altitude
- Fixed routes

Other

- Integrated solution and high traffic load
- IM equipage rate
- Wind conditions

Integration of SESAR solutions

In the integration of **Runway Occupancy Time (ROT)**, **RECAT Pair-wise separation** and MRS into the **Optimised Runway Delivery (ORD) tool**, no integration issues have been identified. The ROT considered in the simulation was a fixed time interval depending on aircraft type. *This time interval could be made more sophisticated by for example adding specific runway and operator characteristics.*

The ORD tool receives the planned arrival sequence from the E-AMAN. Based on the arrival sequence and the separation criteria, the minimum separation is determined. The E-AMAN also provides the arrival sequence and the planned arrival time, e.g. planned separation, to the ground based element of the **Interval Management (IM)** system. In this demonstration, the IM system considers both the minimum separation provided by the ORD tool, and the arrival planning information to determine the IM spacing goal and target aircraft. *The arrival planning information is included in order for the IM operations to not only increase runway capacity by setting the spacing goals to the minimum separation, but also considering operations in accordance to the planning.* This however still resulted in front-loading behaviour, the airspeeds beyond the merge point and in particular on the final approach track were found to be too high.

Controller position

On the Controller Working Position (CWP), the fixed route approach transitions have been made visible for the controllers. In addition, the NTZ and in the aircraft track label, the IM status and EOR status were visible. *The IM status (pending, active) presentation in the aircraft track label was perceived positively. The need for the EOR status in the track label has been received positively, but the need for such addition is dependent on controller preference.*

The FDR controller receives information on the spacing goal and the target aircraft determined by the IM system on the CWP and provides the instruction to the pilot accordingly. In addition, to aid the merging of traffic on two approach transitions, a distance-based ghost presentation on the other fixed route approach transition including the groundspeed is used. *The combination of the fixed route presentation with the merge tool has been received positively by the controllers. However, it should be explored whether the IM instruction could be given by ACC as the arrival sequence is known before entering the TMA. The distance-based merge tool in combination with the IM system was received as sufficient for the need within the integrated solution. There was no particular need to change the tool to a time-based merge tool. It was questioned whether in real-life the merge tool should already be presented so early, the ghost blip was already presented on the long approach transitions when the aircraft was still under control of ACC, also for significant amount of time.*

The ARR controller is presented with the Target Distance Indicators (TDI) determined by the ORD tool after the follower aircraft has passed the merge point of two approach transitions. *The TDIs are presented along the fixed route presentation and was also received positively by the controllers.* For lead/trail aircraft pairs where MRS is the limiting separation criteria, a separation distance of 3.0NM has to be maintained until both aircraft are established on the extended centreline e.g. near the final approach fix. After this point, the MRS reduces to 2.5NM (or 2.0NM), which reduces the minimum separation distance. *In the simulation, the presentation of the TDI would gradually reduce the separation to the applicable separation distance, while also taking into account the compression effect on final, though when the 3 NM is the most stringent the TDI on short final would still indicate a value slightly above 2.5NM (or 2.0NM).* Overall, this was perceived positively, however one could also think of a more abrupt change in TDI presentation once both aircraft are established on the extended centreline.

Arrival planning adherence

The E-AMAN was emulated and delivered the aircraft at the TMA entry with the requested EAT adherence. *In the simulation, it was observed that a good EAT adherence (within $\pm 30s$ at TMA entry) with incidental instances of larger EAT adherences of either plus or minus 60s or either plus or minus 90s was manageable.* Reducing an incidental EAT adherence further, e.g., a few minutes or more, the following aircraft could overtake and the actual arrival sequence would differ from the planned sequence. If the sequence change is unnoticed, there will be a knock-on effect where an incorrect arrival sequence would be used by the ORD tool and IM system, resulting in incorrect spacing goal and target aircraft presentation to the controllers. When this is observed when the aircraft are already in the TMA and on the approach transition, the controllers need to change the target aircraft and accordingly, the spacing goal. *Although the HMI was designed to perform the input with a limited number of clicks on the Touch Input Device (TID), a combination of a new action in addition to the high traffic load makes it difficult to correct an incorrect target aircraft and spacing goal by an FDR or ARR.* However, in actual operation, it should be known at ACC that the arrival sequence has changed due to an aircraft overtaking another. Accordingly, the planning can be updated by the Arrival Planner resulting in a new arrival sequence and arrival planning. This should avoid the need for an FDR to correct for a wrong target aircraft and spacing goal.

Interval Management

Moving the Achieve-By-Point (ABP) to the merge point has been received positively. Continuing IM operations until the Planned Termination Point resulted in higher speeds than observed in current operations. Although the speeds are within the speed brackets of IM operations, the pilots participating in the demonstration revealed that the speeds are higher than that they would like to fly (frontloading). *The IM operation therefore requires further investigation and simulations in order to understand the effect of the spacing goal and traffic load on the IM operations. Ending IM operations earlier would allow controllers to instruct speeds based on the indicators of the ORD tool on final approach.*

Fixed routes

Uniform climb out altitudes and IAF altitudes worked well within the simulation. However unnecessary level flight should be avoided as much as possible in order to reduce fuel burn. In both instances, any change would impact not only the work within the TMA, but also in ACC. To facilitate more efficient outbound operations, one could think of informing the pilot to expect further climb after a certain waypoint or to facilitate continuous climb operations and lifting the maximum rate of climb or

maximum climb angle restriction in cases where there is no traffic. When designing the fixed approach transitions, also consider the SID crossing and do not place an intermediate ‘top of descent’ immediately after the crossing to ensure the ‘descent via’ instruction can be provided in-time.

A route design that took into account specific features for Independent Parallel Approaches was well received.

Others

In general, in nominal conditions, the integrated solution could handle high traffic loads very efficiently. Furthermore, a missed approach while operating with high traffic load could be placed back into the sequence using the available tools. However, this often resulted in dog-legs and thus deviation from the fixed arrival routes. Alternatively, the arrival planning could be shifted, meaning that the aircraft not yet flying in the TMA will be delayed outside the TMA. When multiple aircraft on the same runway perform a missed approach and need to be re-inserted into the sequence, this is more challenging. Thus, it is important to prepare procedures which could be used in case an aircraft cannot be realistically re-inserted into the sequence. In general, the use of fixed routes with a very high traffic load and therefore high pressure on the ATM system, will need additional measures (e.g., tools or working methods) to create a gap in case of challenging disturbances/events, a level of flexibility is needed.

The integrated solution with an IM equipage rate of 20% does not yield the benefit of the integrated solution yet. Some value in between 20% and 80% of the fleet equipped with IM will be required.

Although a limited number of runs have been performed with strong wind conditions, the operation with the integrated solution did not show deteriorated results as compared to less windy conditions.

B.5 Conclusions

The demonstration exercise EXE-PJ.37-W3-002 has been successfully performed. There are no objectives that did not meet the expectations and 7 objectives have been assessed as Partially OK and 14 as OK. 1 objective was inconclusive.

7 Human Performance objectives have been assessed as OK, 5 have been assessed as Partially OK and 1 is inconclusive. The acceptability of the concept was partially OK. ATCOs mentioned that they felt confident provided that speeds of flights reduce gradually towards final, and that traffic is delivered accurately (plus or minus 30 seconds but preferably more accurate). The completeness and acceptability of the integrated solution reduced in comparison to EXE-PJ.37-W3-001 as in this simulation, the concept was evaluated against more challenging situations that required more controller actions. For example, merging a go-around, which was rather challenging in the high volume of traffic. Also some unexpected simulation and technology behaviours may have had an effect. Also, the ATCO rating regarding clarity and consistency of the procedures did not improve with respect to the previous simulation. It is believed that the inconsistency due to technology aspects that resulted in some flights increasing speeds at final approach, led to this decreased rating. This also influenced the clarity and consistency of the working procedures. As there was a large spread in the average confidence in the concept between different simulation days, this objective has been evaluated as inconclusive.

Both Capacity objectives have been assessed as OK as for EXE-PJ.37-W3-002, an identical traffic sample has been used between the runs. The single Predictability objective is assessed as OK. The single Noise and Environmental objective has been assessed as OK, again an identical traffic sample has been used between the runs.

2 Safety objectives have been assessed as OK and 2 objectives as Partially OK. The efficiency of IM operations depends on the accuracy of the EAT adherence provided by the E-AMAN. During EXE-PJ.37-W3-002, incorrect target aircraft and an unpredictable operation occurred, of which the ATCOs were not informed. Therefore, the interoperability of the different tools objective is not fully met. In addition, some disturbances led to a rapid loss of control and the need to end a simulation run prematurely. The controllability concerns warrant further attention in future testing and simulations.

B.6 Recommendations

B.6.1 Recommendations for industrialization and deployment

For Safety, the following recommendations have been formulated (for details, see the Safety Assessment Report [3]):

REC-37-W3-SAF-R1.1: For a more accurate representation of the safety objectives being studied, incorporate a runway controller in future simulations to manage traffic on the final approach segment and collaborate with the arrival (ARR) controller in instances that may result in go-arounds

REC-37-W3-SAF-R1.2: In future simulations it is recommended to incorporate an ACC controller. If a go-around occurs, the ACC or the APP controller should delay the traffic that is still further away from the runway, in order to create some space in the sequence.

REC-37-W3-SAF-R3.1: For future simulations or demonstrations, implement a safety mechanism to alert ATCOs in case of any compatibility issues between the FIM system/algorithm and the E-AMAN system/algorithm, such as illogical aircraft pairings.

REC-37-W3-SAF-R3.2: Consider expanding the coverage of the FIM system to include the ACC airspace, in addition to the TMA airspace. This could provide more time and space for the system to maintain appropriate spacing between aircraft and to create gaps in case an aircraft needs to re-sequenced.

REC-37-W3-SAF-R3.3: Enhance the realism of future simulations or demonstrations by incorporating more realistic speed profiles of aircraft. Refining the FIM algorithms and ensuring seamless transitions between them may be necessary to achieve this.

REC-37-W3-SAF-R4.1: To include a runway controller in the simulations, who controls the traffic on the final approach segment, and who can coordinate with the arrival (ARR) controller regarding situations that may lead up to losses of separation due to WTS, MRS, and ROT. This would provide a more realistic picture regarding the safety objectives studied.

REC-37-W3-SAF-R4.2: The previous recommendation would also create the opportunity to study a safety objective that was omitted from the analysis in this report (i.e. The variability in Clearance to Land margin decreases for ROT constrained pairs).

REC-37-W3-SAF-R4.3: The objectives studied looked at safety up to the level of potential for loss of separation, limited by the nature of real time simulations. In order to assess the risk of a mid-air collision and the risk of wake turbulence related accidents, as is required in SESAR safety reference material (SRM), in a follow on project it is recommended to use Dynamic Risk Modelling to assess the safety benefits of the combination of tools more accurately.

REC-37-W3-SAF-R5.1: Assess the similarity of simulation issues encountered during RTS2 to real-world operational scenarios. In future testing and simulations, include these types of events in scenarios to gauge the operational efficiency and durability of the tools used.

REC-37-W3-SAF-R5.2: Evaluate the ability of controllers to handle non-typical operational disruptions that occur frequently in real-world practice. Incorporate these events into scenarios for future testing and simulations to assess the efficiency and stability of the tools and overall operation during such situations.

For Human Performance, the following recommendations have been formulated (for details, see the Human Performance Assessment Report [4]).

REC-37-W3-HUP-R4.1: Design arrival routes such that turns are 135 degree or larger and that routes to parallel runways are not exactly mirrored (avoid head-on base legs). **Validated in RTS2.**

REC-37-W3-HUP-R4.2: Standardise the altitude at IAF or start the RNP approach at the merge point. **Standardised altitude was validated in RTS2.**

REC-37-W3-HUP-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. **This was validated in RTS 2.**

REC-37-W3-HUP-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.

REC-37-W3-HUP-R6.1: In case of changes in the inbound sequence it is recommended to update the inbound planning (AMAN/Supervisor) or cancel the IM for one (or several) flights, instead of changing IM targets.

REC-37-W3-HUP-R6.2: It is recommended to take a closer look at responsibilities such as monitoring the traffic at final, with high volumes of traffic. Can this reasonably be expected from the ATCO?

REC-37-W3-HUP-R7.1: Design the HMI, such that:

- It is clear which flights are IM capable and which are not; **Validated in RTS2**
- It is clear which flights are applying IM (**validated in RTS2**), and whether it is applied correctly (to the flight preceding on the route);
- It is clear which flights are established on RNP; **Validated in RTS2**
- That ATCO can change the sequence with a minimal number of actions

REC-37-W3-HUP-R7.2: When the actual sequence is different from the planned sequence, the planning is preferably updated (automatically ensuring the right IM target for each flight). If a mix up of IM targets is a possible occurrence, the controller could be made aware of such mix-ups.

REC-37-W3-HUP-R8.1: Consider automated adherence monitoring of the NTZ.

REC-37-W3-HUP-R8.2: The concept should ensure the gradual reduction of speeds of arriving traffic.

REC-37-W3-HUP-R9.1: Divide the work of the FDR between two ATCOs (TWEC/TOC). **Validated in RTS 2.**

REC-37-W3-HUP-R9.2: Expand Non Transition Zone (automated monitoring) for traffic established on RNP (18/18). *Validated in RTS 2*

REC-37-W3-HUP-R10.1: Trust should develop with more experience. Test the concept with, for example:

- Go-arounds: *Validated in RTS2*
- Provide a gap for runway inspection
- Change sequence (e.g. emergency). *Validated in RTS2*
- Runway closure
- Runway change

REC-37-W3-HUP-R11.1: Improve IM alert: *Validated in RTS2*

REC-37-W3-HUP-R11.2: Improve HMI to provide an indication when a flight is established on RNP: *Validated in RTS2*

REC-37-W3-HUP-R11.3: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: *Validated in RTS2*

REC-37-W3-HUP-R14.1: Provide ghost indicator only for flights almost in TMA. *Validated in RTS 2*

B.6.2 Recommendations on regulation and standardisation initiatives

There are no relevant recommendations on regulation and standardisation initiatives from the Integrated Arrival concept.

Appendix C EXE-PJ.37-W3-003 Report

This appendix describes the results for the EXE-PJ.37-W3-001 and presents conclusions and recommendations of this exercise.

C.1 Summary of the Demonstration Exercise #03 Plan

The demonstration exercise is as elaborated in the DEMOP ed.01.00.00 [2].

C.1.1 Exercise description and scope

As in the DEMOP ed.01.00.00 [2].

C.1.2 Summary of Demonstration Exercise #03 Demonstration Objectives and success criteria

As in the DEMOP ed.01.00.00 [2].

C.1.3 Summary of Demonstration Exercise #03 Demonstration scenarios

As in the DEMOP ed.01.00.00 [2]. Furthermore the demonstration runs as executed during the flight trial are given in Table 7-36 in section C.3.2. This table also provides an overview of the demonstration scenarios that have been executed in accordance with the DEMOP.

C.1.4 Summary of Demonstration Exercise #03 Demonstration Assumptions

As in the DEMOP ed.01.00.00 [2].

C.2 Deviation from the planned activities

There were no deviations from the planned activities. Not really a deviation, but worth mentioning is that sometimes -due to operational or flight test reasons- a detail of the set-up of a test run was changed (e.g. the arrival from the south instead of the arrival from the west due to airspace unavailability during certain hours of the flight test campaign); an overview can be found in Table 7-36 in section C.3.2.

C.3 Demonstration Exercise #03 Results

Summary of Demonstration Exercise #03 Demonstration Results

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-37-W3-DEMOP-HUP1-0001	The IM execution is found acceptable by the flight crew of the test aircraft	CRT-37-W3-DEMOP-HUP1-0001	No acceptance issues are identified both during the test flights and debriefings by the flight crew of the IM aircraft	E-R/TMA	The pilots found the IM operations acceptable to be used in operation. The HMI was acceptable to the majority of the pilots with some improvements identified. The pilots found the IM speed guidance acceptable.	OK
OBJ-37-W3-DEMOP-HUP1-0015	The integrated tool does not deteriorate the arrival management process	CRT-37-W3-DEMOP-HUP1-0015	Under nominal conditions, there shall be no need to fall back on the use of vectoring operations while using the integrated tool.	E-R/TMA	Air traffic controllers never intervened with radar vectors or intermediate level-offs. The fixed routes with a fixed descent profile was always adhered to (11 test flights, 61 test runs).	OK
OBJ-37-W3-DEMOP-HUP1-0016	The IM execution is feasible while performing RNP/RNAV procedures with a defined vertical profile	CRT-37-W3-DEMOP-HUP1-0016	Under nominal conditions, there is no need to deviate from the defined horizontal or vertical path or deviate from the IM speeds (for prolonged periods of time)	E-R/TMA	During all runs the aircraft successfully adhered to the defined vertical profile (2.0-deg or 2.5-deg) and nominal speed profile for the lead aircraft and IM speeds for the trail aircraft.	OK

OBJ-37-W3-DEMOP-CAP1-0003	The delivery of aircraft on final shall be improved	CRT-37-W3-DEMOP-CAP1-0003	The use of the on-board FIM capability shall provide a highly accurate (< 9.3 sec spacing error [95%]) delivery of the IM aircraft on final, for both in-trail and merging operations to the same runway.	E-R/TMA	98% of the runs complied with the 9.3-second tolerance at the Planned Termination Point, which was located at the Final Approach Point (based on 11 test flights, 49 test runs)	OK
OBJ-37-W3-DEMOP-SAF1-0006	The use of IM operations shall not result in any unsafe condition during the live trial	CRT-37-W3-DEMOP-SAF1-0006	No major safety issues are identified both during the test flights and debriefings by the flight crew of the IM aircraft	E-R/TMA	Safety was not an issue during the flight trial based on pilot feedback.	OK
OBJ-37-W3-DEMOP-SAF1-0007	The FIM system performs its intended function during the live trial (airworthiness related objective)	CRT-37-W3-DEMOP-SAF1-0007	No functional issues related to the FIM system standard (ED-236A) are identified during the test flights (e.g. non-compliance or other issues with relevant ED-236A requirements).	E-R/TMA	The vast majority of the FIM functions worked as intended. A gap is the limited ADS-B In range observed during the flight trial, this was attributed to the specific antenna installation Furthermore, a very limited number of updated/new FIM MOPS requirements still need to be implemented.	Partially OK

Table 7-31: Exercise 3 Demonstration Results

1. Results per KPA

Human Performance

The main HP findings based on Flight Trial are:

- The acceptability of the IM operations (OBJ-37-W3-HUP1-0003) was rated OK.
- Air traffic controllers never intervened with radar vectors or intermediate level-offs (OBJ-37-W3-HUP1-0015). The fixed routes with a fixed descent profile was always adhered to (11 test flights, 61 test runs). So, flight crews were able to always perform their tasks.
- During all runs the aircraft successfully adhered to the defined vertical profile (2.0-deg or 2.5-deg) and nominal speed profile for the lead aircraft and IM speeds for the trail aircraft (OBJ-37-W3-HUP1-0016). So, flight crews were able to perform their task to fly the IM speeds on the defined routes with fixed descent profiles.
- A few HMI improvements were suggested by pilots.

Capacity

Capacity impact was measured in terms of how accurate the aircraft are delivered at the beginning of the final approach track. The inter-aircraft spacing and in particular how precisely it can be controlled is an important metric. The rationale is the more precisely the inter-aircraft spacing, the smaller the inter-aircraft spacing can be. And therefore, runway throughput can be increased/optimised.

98% of the runs complied with the 9.3-second tolerance at the Planned Termination Point, which was located at the Final Approach Point (based on 11 test flights, 49 test runs). The target was 95%, therefore it is concluded that IM operations on a fixed route network with a fixed descent profile does support high capacity arrival and approach operations.

Operational Efficiency

NA

Environment

NA

Safety

Safety was not an issue during the flight trial.

In terms of airworthiness (system performs its intended function) some work still has to be done. Although the vast majority of the FIM functions worked as intended a few items need further attention:

- A gap is the limited ADS-B In range observed during the flight trial, this was attributed to the antenna installation on the Citation test aircraft.
- A very limited number of updated/new FIM MOPS requirements (EUROCAE ED-236A / RTCA DO-361A) still need to be implemented.

2. Results impacting regulation and standardisation initiatives

The preliminary results of this demonstration exercise have been presented to the joint ADS-B In workgroup of EUROCAE and RTCA (EUROCAE WG-51 SG-3/RTCA SC-186 WG-4) and together with the workgroup it has been concluded that no changes to the FIM standards are required.

C.3.2 Analysis of Exercises Results per Demonstration objective

In the following sections, each demonstration objective is evaluated by a consolidated analysis of the demonstration result, including a rationale of the result, potential deviation with respect to the expected performance benefit (if any) and in case applicable, possible reasons and relationship between the results and the appropriate assumptions.

1. OBJ-37-W3-DEMOP-HUP1-0001

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0001 “The IM execution is found acceptable by the flight crew of the test aircraft” has been assessed as OK.

The demonstration success criteria was “No acceptance issues are identified both during the test flights and debriefings by the flight crew of the IM aircraft”.

The acceptability has been assessed by pilot ratings in the questionnaire (In your opinion, the IM operations were overall acceptable in this flight) on a six-point scale (Figure 7-36). Score 1 – completely disagree, score 2 – mostly disagree, score 3 – slightly disagree, score 4 – slightly agree, score 5 – mostly agree, and score 6 – completely agree.

Furthermore, the human machine interface has also been assessed by pilot ratings in the questionnaire (In your opinion, the EFB DU HMI was acceptable in this flight / In your opinion, the TSC display was acceptable in this flight) on a six-point scale (Figure 7-37).

Finally, the IM speed guidance has been assessed by pilot ratings in the questionnaire (in your opinion, the IM Speed Values were acceptable in this flight / In your opinion, the Number of IM Speed changes was acceptable in this flight) on a six-point scale (Figure 7-38).

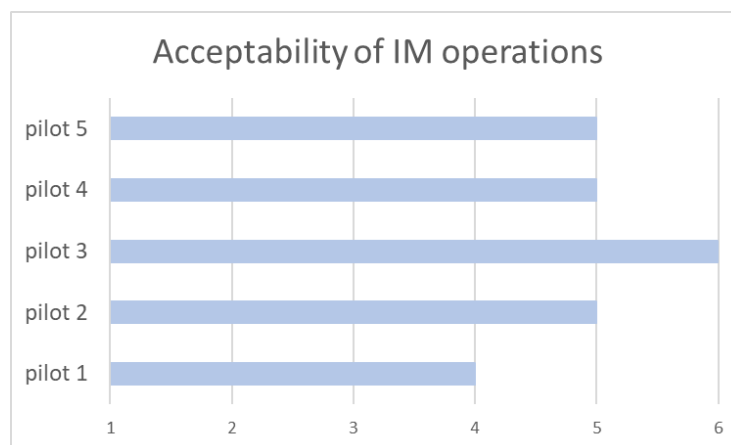


Figure 7-36: Pilot acceptability ratings of the IM operations

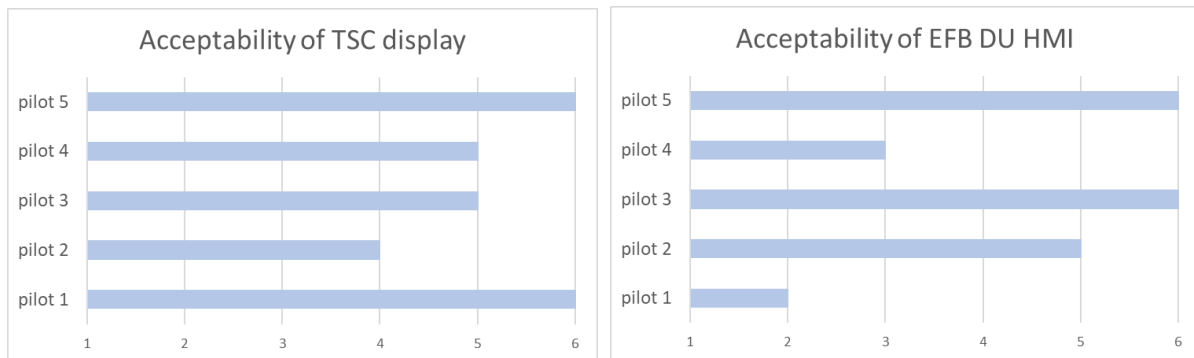


Figure 7-37: Pilot acceptability ratings of the human machine interface



Figure 7-38: Pilot acceptability ratings of IM Speed guidance

IM Operations

The pilots that participated in the demonstration exercise considered acceptability of the IM operations as acceptable to be used in operation in its current form.

Human machine interface

The acceptability of the human machine interface is varied. The display presenting the speed guidance information, the TSC display, was well accepted. However, the ratings of the display used to enter the IM clearance information was rated between mostly disagree (score 2) and completely agree (score 6). The main comment of several pilots was that there were too many pilot entries during the process of setting up the IM operation and the system should have less entry fields. This was found acceptable for R&D purposes, but it should be improved for a production system as it took time to fill in the data and that may impact workload because the data entries were made during an already busy descent phase.

The consolidated pilot feedback on the HMI aspect of the concept:

- Many manual entries required, even besides winds entries: IM type, own route, spacing goal, target aircraft, target route, ABP, PTP. Especially ABP and PTP will, on a given STAR, probably always be the same for all aircraft, so these perhaps can be attributes of the STAR. Assuming own route is known in the FMS, what then remains are the entries of IM Type, target aircraft, target route and spacing goal, and hit ENTER. As the entries will, in an operational setting, require cross-checking and this will need to be done typically just before a STAR clearance (in descent, busy), this can become a CRM and workload issue.

- For example, the system should have less entry fields, e.g. for ABP (PTP) it provides choice: Achieve by (Terminate at) WPT, Achieve Before, Achieve After; and after selecting Achieve by WPT it provides: box with ---NM and an empty box; then selecting the empty box provides the waypoints to select from. It should default be one step: (select waypoint and) the waypoints to select from.
- Lot of possibilities to get most if not all data from FMS and/or CPDLC uplinks, this would dramatically ease the workload required to set up the IM clearance. Also would reduce ATC frequency congestion. Current data entry is on the verge of acceptable.

The consolidated pilot feedback on the implementation (i.e. TSC and EFB):

- Early-late indicator design. The early-late indicator was ambiguous to flight crew (outside-in vs. inside-out). For both the current used early-late indicator (outside-in) as well as for an opposite indicator (180 degrees turned, inside-out), arguments could be made. It should not be used as steering information, so maybe a follow-the-needle principle should not be applied. On the other hand, if all information in the flight deck is based on an inside-out principle, then also the scale should be. In general, adhere to the flight deck design philosophy of an aircraft.
- Location of early-late indicator. The early-late indicator is too prominent on the TSC. It should be displayed elsewhere, not along the speed commands, way less prominent. It should be not used as steering information, only for situation awareness. For example, display it only on the EFB or even better on the Navigation Display.
- A graphical early-late indicator or a textual early-late indicator (ASG and actual spacing) is considered the same information.
- Early/late scale not shown on CROSS clearances outside 30 NM from the ABP. Why not?
- The location of the display presenting the IM speed commands (the TSC display) was not optimal in the PH-LAB, the LH pilot (PF) had more difficulties to detect speed changes compared to the RH pilot (PNF). Suggested solutions: a more central location on the instrument panel or dedicated annunciator lights in each pilot's primary field of view.
 - Background info. FIM MOPS requires that in Execute State, the IM Speed, IM Speed Change Visual Advisory and IM Speed Compliance Monitoring Status Visual Advisory must be displayed in the Forward Field of View (FFOV) to facilitate pilot monitoring.
 - Note: FFOV definition in FIM MOPS is the same as EASA's Primary Field of View definition
 - Definition of Primary Field of View (ref. EASA CS-25): The primary field of view is based on the optimum vertical and horizontal visual fields from the design eye reference point that can be accommodated with eye rotation only. The description below provide an example of how this may apply to head-down displays. With the normal line-of-sight established at 15 degrees below the horizontal plane, the values for the vertical (relative to normal line-of-sight forward of the airplane) are +/-15 degrees optimum, with +40 degrees up and -20 degrees down maximum. For the horizontal visual field (relative to the normal line-of-sight forward of the aircraft), values are +/-15 degrees optimum, and +/-35 degrees maximum.
 - Installation info: TSC was located 55 cm to the right relative to LH pilot normal line-of-sight, distance to instrument panel was 75 cm → horizontal 36.3 degrees relative to normal line-of-sight of LH pilot, this is just outside the maximum Primary Field of View.

- ARM/EXECUTE seems like a double step. Is it not possible to just EXECUTE the clearance in one step?
- No warning at all if spacing is not achieved by the ABP
 - Background info. Infeasibility check was not implemented in the current system because the system was expected to be used in flight tests near to or even exceeding the feasibility criteria and we did not want to automatically suspend the system in these cases.
 - Background info. FIM MOPS: Outside 20 NM of ABP, an indication shall be displayed when system determines that spacing goal cannot be attained at ABP. Within 20 NM it is removed as ATC will have a better understanding of the acceptability of the spacing operation.
- Target aircraft is only visible as designated traffic after arming IM (green outline and extra data above arc/rose display). It would be a nice-to-have feature to display the target a/c as designated traffic already upon target aircraft selection in the IM CLEARANCE: CAPTURE or IM CLEARANCE: CROSS window.
- A name on the window makes it easier to check the right routings of own aircraft and target aircraft. The route check is not needed at waypoint level. Therefore, displaying waypoint lists is not needed, even not desired.

IM Speed guidance

The pilots considered acceptability of the IM speed guidance as acceptable. Only the number of IM speed changes in the last part of the arrival was commented on.

The consolidated pilot feedback on the IM speed guidance aspect of the concept:

- Too many speed changes in the last part of the arrival, sometimes 1 every 5 seconds 200-180-190-180-170-180-185 etc. Even more so it seems that all these small changes don't really do anything to the actual spacing. Ideally there should be no more changes after ~5 or 10NM from the PTP.
- When TARGET DATA IS LOST, or other reason IM is SUSPENDED for a (short) while, it seems logical to at least initially maintain the last IM speed (30 sec or so, amber instead of normal color). However, when in SUSPEND, no speed guidance is given at all (speed command blanks). - NICE TO HAVE, in particular when you have not yet acquired the latest IM speed.
- Speed increases are not optimal, but probably unavoidable (e.g. when too close a low speed is flown and upon attaining the desired spacing a speed increase to the nominal speed is OK). But IM speed commands to increase speed on last miles prior FAP is undesirable, it is strongly recommended to avoid speed speed increases below 220 KIAS (or V_{FTO}). Note that the FIM MOPS does not allow IM speed increases that would result in flaps up selections.

The tables and figures below provide background information on the number and location of IM speed changes. It is obvious and logical that the majority of changes occurred at IM initiation (see relationship of Figure 7-39-Figure 7-41 with Figure 7-42) and after TOLKO, which makes sense as that part of the route included three nominal speed changes (240 to 220, 220 to 190 and 190 to 180). Table 7-32 shows for the more critical (for IM Speed changes) Maintain Stage that on average an IM Speed change occurred every 71 seconds, that is 0.84 speed changes per minute. And for the Achieve Stage (Table 7-33) the on average an IM Speed change occurred every 3 minutes and 22 seconds

(0.30 speed changes per minute). In the Achieve Stage a big difference is observed between the two ABP locations, the reason is that the nominal speed profile until TOLKO has no speed changes, whereas the nominal speed profile down to GG742 has three nominal speed changes.

Table 7-32: IM Speed changes during the Maintain Stage.

IM Operation	Count (number of runs)	Total exposure (hh:mm:ss)	Mean number of IM speed changes per minutes	Mean time between IM Speed changes (hh:mm:ss)
All runs	48	4:56:49	0.84	0:01:11
IM Capture runs	6	0:55:54	0.72	0:01:24
IM Cross runs with ABP TOLKO	34	3:55:34	0.86	0:01:10
IM Cross runs with ABP GG742	8	0:05:21	1.31	0:00:46

Table 7-33: IM Speed changes during the Achieve Stage.

IM Operation	Count (number of runs)	Total exposure (hh:mm:ss)	Mean number of IM speed changes per minutes	Mean time between IM Speed changes (hh:mm:ss)
All runs	42	5:42:42	0.30	0:03:22
IM Cross runs with ABP TOLKO	34	4:00:01	0.19	0:05:13
IM Cross runs with ABP GG742	8	1:42:41	0.54	0:01:50



Figure 7-39: Heatmap of IM Speed changes for IM Capture operations (6 runs)



Figure 7-40: Heatmap for IM Speed changes for IM Cross operations with ABP at TOLKO (34 runs)

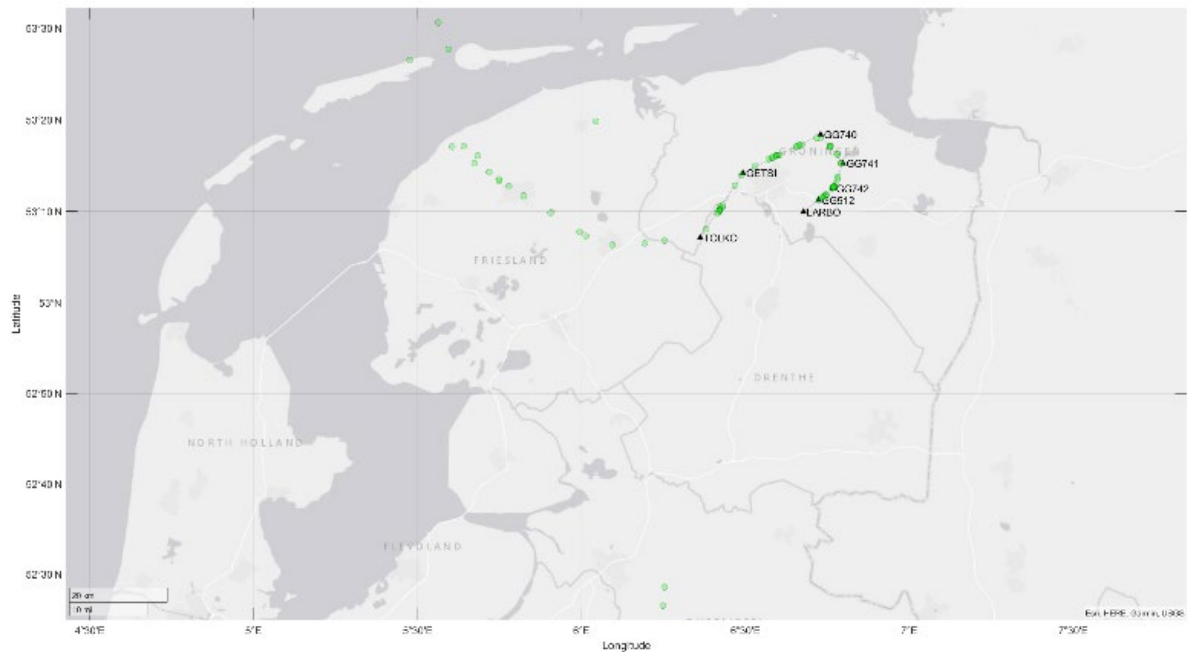


Figure 7-41: Heat map of IM Speed changes for IM Cross operations with ABP at GG742 (9 runs)

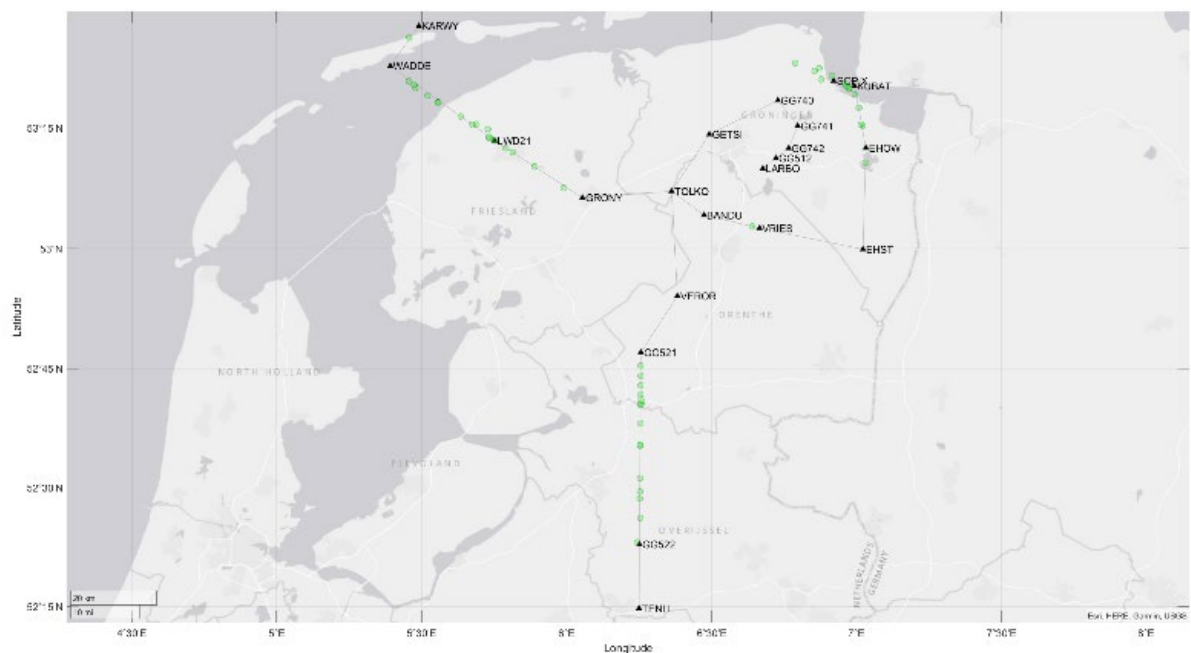


Figure 7-42: Heatmap of the start for all IM operations, defined here as the first IM speed being presented

Training requirements

Though not really related to this human performance objective, a discussion took place with the five pilots about pilot training. The consolidated pilot feedback on training requirements is as follows:

- For the assessment of training requirements a difference is identified between aircraft with and without IM capabilities. This difference can be evaluated against CS-FCD and ORO.FC guidance material.
- CS-FCD.420 and ORO.FC.240 identify Level A-D training requirements as follows:

Level A - Level A differences training is applicable to aircraft with differences that can adequately be addressed through self-instruction. Level A training represents a **knowledge requirement** such that once appropriate information is provided, understanding and compliance can be assumed to be demonstrated.

Level B - Level B differences training is applicable to aircraft with **system or procedure differences** that can adequately be addressed through aided instruction.

Level C - Level C difference training is applicable when **cockpit design differences exist, and affect skills or abilities, as well as knowledge** (CS-FCD), or, Level C differences training is applicable to variants having **'part task' differences that affect skills or abilities as well as knowledge** (ORO-FC) Training objectives focus on mastering individual systems, procedures, or tasks, as opposed to performing highly integrated flight operations and manoeuvres in 'real time'. Level C may also require self-instruction or aided instruction of a pilot, but cannot be adequately addressed by a knowledge requirement alone. Training devices are required to supplement instruction to ensure attainment or retention of pilot skills and abilities to accomplish the more complex tasks, usually related to operation of particular aircraft systems.

Level D - Level D difference training requires **mastery of interrelated skills that cannot be adequately addressed by separate acquisition of a series of knowledge areas or skills that are interrelated**. However, the differences are not so significant that a full type rating training course is required.

- Much depends on the final implementation, but using these guidelines Level B (guided instruction) or Level C (guided instruction with an interactive CBT tool) training seem appropriate to introduce IM Operations. An operator risk assessment should identify the level of training required.

2. OBJ-37-W3-DEMOP-HUP1-0015

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0015 "The integrated tool does not deteriorate the arrival management process" has been assessed as OK as the air traffic controllers never intervened with radar vectors (i.e. heading instructions taking the lead or trail aircraft of the planned fixed route) or intermediate level-offs (i.e. taking the lead or trail aircraft of the planned continuous descent path).

Air traffic control intervened in two cases with a temporary speed instruction, in one case near the merge point TOLKO and in the other case near the intercept of the final approach track. These cases occurred during the early part of the flight test programme, the reasons for these two interventions was that the lead and trail aircraft came close to 5 NM separation, which was the minimum wake turbulence separation (a LIGHT aircraft behind a MEDIUM aircraft).

During the test set-up the minimum spacing goal for the IM operation was 100 seconds based on an ample buffer on top of the 3 NM Minimum Radar Separation and typical speeds to be flown. Note that the nominal value of the spacing goal was 120 seconds, but because of natural variations in the line-

up (i.e. starting condition of the runs) the spacing goal was adapted in either direction to start the run with the desired initial spacing error, an initial spacing error in accordance with the test matrix. As soon as it became clear that a 5 NM wake separation had to be applied by ATC, the minimum spacing goal was increased and thereafter ATC did not intervene anymore with speed instructions.

3. OBJ-37-W3-DEMOP-HUP1-0016

Demonstration objective OBJ-37-W3-DEMOP-HUP1-0016 “The IM execution is feasible while performing RNP/RNAV procedures with a defined vertical profile.” has been assessed as OK. The success criterium for this objectives was “Under nominal conditions, there is no need to deviate from the defined horizontal or vertical path or deviate from the IM speeds (for prolonged periods of time)”.

During all runs the aircraft were able to fly both the defined vertical profile (either a 2.0-deg or 2.5-deg vertical path until the Final Approach Point), the defined nominal speed profile for the lead aircraft and the IM speeds for the trail aircraft. No deviations occurred from either the intended vertical path or intended airspeeds. However, it was noted that sometimes speed brake was used in the last part of the arrival to decelerate to 190 or 180 knots, by both lead and trail aircraft. This is also clear from the feedback of the pilots.

The consolidated pilot feedback on the IM speed guidance aspect of the concept:

- Sometimes speed brake was necessary to create sufficient deceleration. Use of speedbrakes for low-drag airliners may be needed to decelerate on RNAV routes with a fixed vertical angle. It all depends on the procedure design(er): a shallower vertical profile will require less speedbrakes, but also gives less fuel/noise benefits, so a compromise needs to be found.

This use of speedbrakes did not raise pilot acceptance issues, therefore this objective has been assessed as OK also on this aspect.

Finally, the pilots were asked about their opinion on this aspect via the questionnaire (In your opinion, IM speeds could be properly flown while flying a fixed route with a fixed vertical angle). This question was rated on a six-point scale: score 1 – completely disagree, score 2 – mostly disagree, score 3 – slightly disagree, score 4 – slightly agree, score 5 – mostly agree, and score 6 – completely agree. Figure 7-43 shows the results of this question, and it supports the conclusion above.

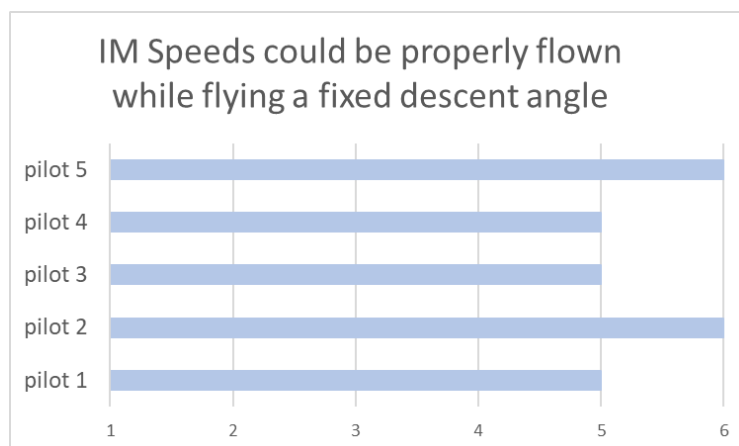


Figure 7-43: Flyability of IM speeds on Fixed Profile Descents

4. OBJ-37-W3-DEMOP-CAP1-0003

Demonstration objective OBJ-37-W3-DEMOP-CAP1-0003 “The delivery of aircraft on final shall be improved” has been assessed as OK as 98.0% of the runs complied with the 9.3-second tolerance of the spacing error at the Planned Termination Point, which was located the Final Approach Point.

The success criterium for this objective was “The use of the on-board FIM capability shall provide a highly accurate (< 9.3 sec spacing error [95%]) delivery of the IM aircraft on final, for both in-trail and merging operations to the same runway”.

During the engineering flights (25-26 April 2022) three flights have been carried out, during those flights 16 test runs were performed, of which 13 were included in the data analysis.

During the measurement flights (14-17 June 2022) eight flight have been carried out, during those flights 45 runs were performed, of which 36 were included in the data analysis.

The reasons to exclude runs from the data analysis were related to line-up and technical implementation issues, never due to ATC interventions.

So, in total 49 runs were part of the data analysis. These runs were a good mix of the test conditions as defined in the DEMOP, for example 6 runs with IM CAPTURE operations, 34 runs with IM CROSS operations with the Achieve-by Point at TOLKO (i.e. the waypoint where the three arrivals merged together and then continued with the approach transition to the final approach segment, see Figure 7-44), and 9 runs with IM CROSS operations with the Achieve-by Point at GG742 (i.e. the waypoint where the intercept of the final approach track occurred, . 2 NM prior to the Final Approach Point).



Figure 7-44: Horizontal path definition of the KARWY arrival (KARWY-TOLKO) and rwy 23 approach transition (TOLKO-GG512) into EHGG.

The results of the runs performed in April and June 2022 are given in Figure 7-45 and Figure 7-46, Figure 7-46, and Table 7-34. Figure 7-45 shows that in three cases the spacing error at the Planned Termination Point (PTP) was very large. Analysis showed that a software issue contributed to this observed performance. The NavDB was missing speed constraints on some arrival routes. This led to incorrect estimates for Traffic to Follow (TTF) arrival times until traffic reaches a waypoint with a valid speed constraint. (The ownship, i.e. the trailing aircraft, is also missing the constraint, but the descent speed limit applies which did match the speed constraint that should have been in the NavDB.) After applying a correction on the estimate for TTF

For example, in one of the runs the initial spacing error, according to the testcard, should have been 'minus 60' seconds (that is 60 seconds early). The actual spacing error presented erroneously to flight crew was 'minus 60.3' seconds, so very close to the intended test condition. However, due to the NavDB error it was offline estimated that the actual initial spacing error was 'minus 90.7' seconds, thus a 30.4 second additional error. At the ABP, TOLKO, only 1.0 second of the erroneous 'minus 60.3' initial error had been corrected, but 31.4 seconds of the actual 'minus 90.7' initial error. Thereafter, another 19.2 seconds of the 'minus 59.3' error at TOLKO was corrected, resulting in 'minus 40.1' seconds (40.1 seconds early) at the PTP. The correction applied the actual 31.4 seconds spacing error reduction to the 'minus 60.3' initial spacing error. Therefore, the corrected spacing error at the ABP is 'minus 28.8' seconds and with the observed 19.2 seconds spacing error reduction after TOLKO, the corrected spacing error at the PTP is 'minus 8.6' seconds. Similarly, the two other outliers have been corrected. All three runs were performed in June with a 'minus 60' second initial error, the lead aircraft on the TENLI arrival and the trail aircraft on the KARWY arrival. Note that the same test condition was also tested in April without the NavDB error and showed good spacing performance. Figure 7-46 shows the results after applying these corrections.

It is concluded that overall 98% of the runs complied with the 9.3-second tolerance, therefore this objective is met as the success criteria is that in at least 95% of the cases the spacing error has to be within 9.3 seconds at the end of the IM operation. The end of the IM operation occurred at the Planned Termination Point, which was always located at the Final Approach Point, GG512. It is noted that in only one run the spacing error exceeded the 9.3-second threshold, this occurred during an IM Cross operation with the Achieve-by Point at GG742. In this run the PTP was crossed 9.9 seconds late. This was one of the earlier runs in which ATC intervened with a speed instruction in the last part of the run due to wake separation (for details see OBJ-37-W3-DEMOP-HUP1-0015 above). At the Achieve-by Point, GG742, located just 2 NM prior to the PTP, the spacing error was 1.2 seconds late. It may be assumed that without ATC intervention the spacing error at the PTP would have been well within the 9.3-second tolerance.

Another method could have been to exclude extreme outliers based on data points that are outside the box (the interquartile range of the box plot) plus or minus three times the value of the interquartile range, a commonly applied method in statistics to identify extreme outliers. For this data set the extreme outliers would be below 'minus 12.1' seconds, therefore the three outliers (reminder: all runs in June with a 'minus 60' second initial error, lead aircraft on TENLI arrival and trail aircraft on KARWY arrival). The results after applying this method is shown in Figure 7-47 and Table 7-35. Basically it leads to the same conclusion, the objective is met at 97.8% compliance with the 9.3-second tolerance. And still with the one run outside this tolerance as a result of the ATC speed intervention.

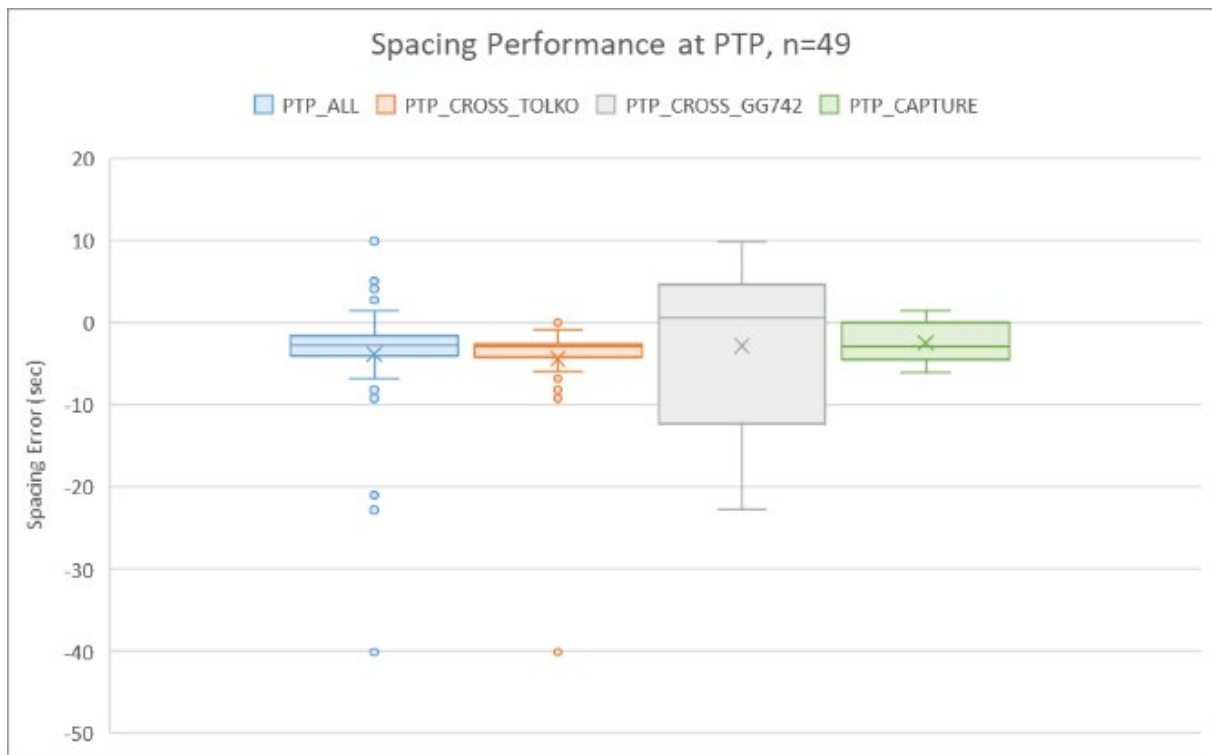


Figure 7-45: Spacing performance at the Planned Termination Point (PTP)

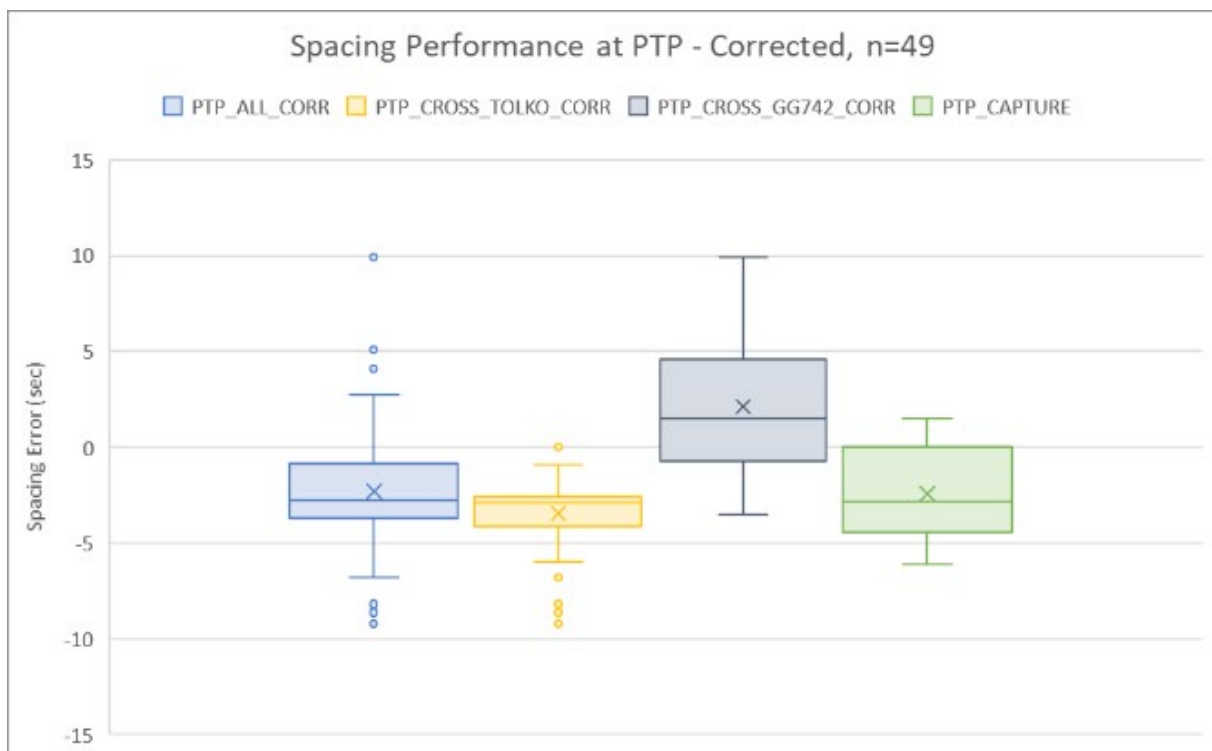


Figure 7-46: Corrected spacing performance at the Planned Termination Point (PTP).

Table 7-34: Corrected spacing performance at the Planned Termination Point (PTP)

IM Operation	Count	Mean (sec)	Standard Deviation (sec)	Percentage within 9.3-sec tolerance
All runs	49	-2.32	3.34	98.0%
IM Capture runs	6	-2.45	2.68	100%
IM Cross runs with ABP TOLKO	34	-3.47	2.15	100%
IM Cross runs with ABP GG742	9	2.10	3.94	88.9%

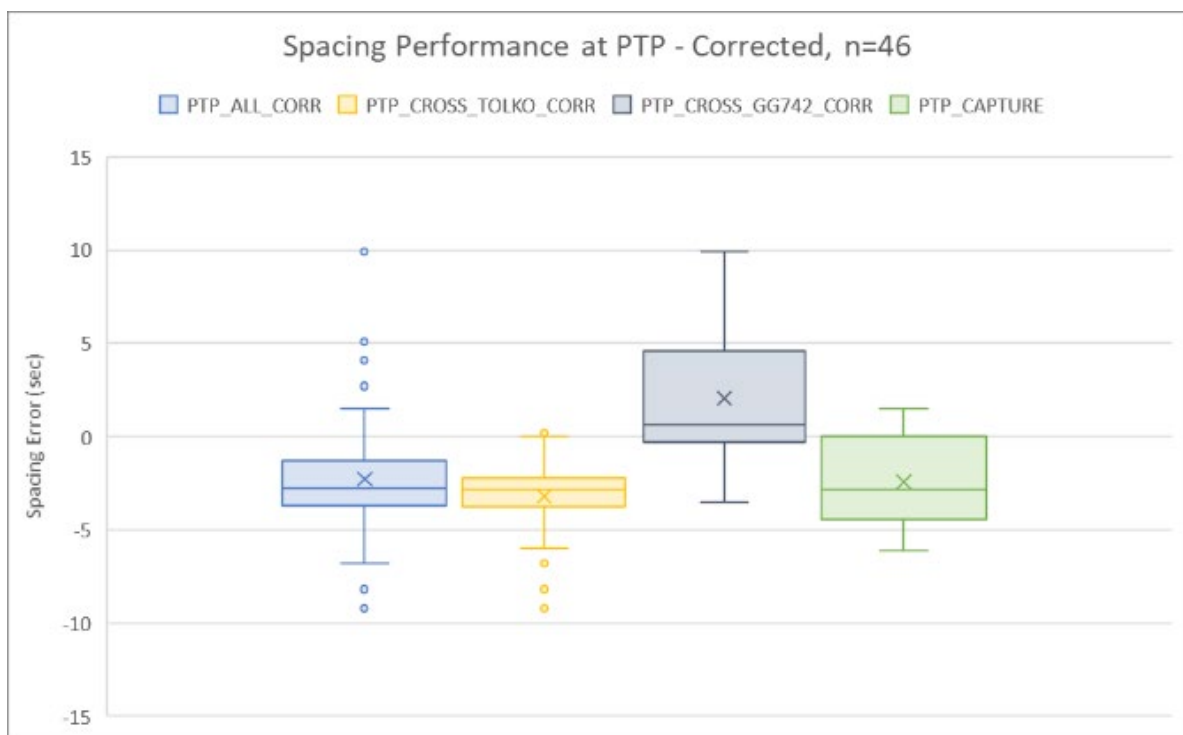


Figure 7-47: Spacing performance at PTP without outliers.

Table 7-35: Spacing performance without extreme outliers at the Planned Termination Point (PTP)

IM Operation	Count	Mean (sec)	Standard Deviation (sec)	Percentage within 9.3-sec tolerance
All runs	46	-2.30	3.26	97.8%
IM Capture runs	6	-2.45	2.68	100%
IM Cross runs with ABP TOLKO	33	-3.31	1.98	100%

IM Operation	Count	Mean (sec)	Standard Deviation (sec)	Percentage within 9.3-sec tolerance
IM Cross runs with ABP GG742	7	2.61	4.34	85.7%

The objective results are supported by the feedback of the pilots. The consolidated pilot feedback on capacity-related aspects of the concept:

- Very good performance! Typically within seconds of the target spacing.

The following table provides an overview of the runs performed during the IM flight trial. Runs 1-12 were planned for and executed during the engineering flights in April 2022. Runs 413-427 were optional and intended to be performed when available flight time permitted so, but possible repeats of other runs had priority. The runs highlighted in green are included in the data analysis.

Table 7-36: Overview of runs performed during the flight trial

DEMOP						Flight	Included in data analysis	Remarks
Run ID	Lead aircraft route	Trail aircraft route	IM Clearance	ABP	Initial spacing error			
1	SOPIX 20X	SOPIX 20X	CAPTURE	-	-20	25-04-2022 FLT001		Used as Run 102 in data analysis
2	SOPIX 25X	SOPIX 25X	CAPTURE	-	+40	25-04-2022 FLT001		Used as Run 104 in data analysis
3	SOPIX 20X	SOPIX 20X	CROSS	TOLKO	+20	25-04-2022 FLT001		Used as Run 107 in data analysis
4	SOPIX 25X	SOPIX 25X	CROSS	TOLKO	-60	25-04-2022 FLT001 25-04-2022 FLT001		Used as Run 112 in data analysis Used as Run 112 in data analysis
5	SOPIX 20X	KARWY 20X	CROSS	TOLKO	+40	26-04-2022 FLT001		Used as Run 113 in data analysis
6	SOPIX 20X	KARWY 25X	CROSS	GG742	+20	26-04-2022 FLT001 26-04-2022 FLT001		Run aborted Run aborted

DEMOP						Flight	Included in data analysis	Remarks
						26-04-2022 FLT002		Run aborted
7	SOPIX 25X	TENLI 25X	CROSS	TOLKO	-20	26-04-2022 FLT002		Used as Run 123 in data analysis
8	SOPIX 25X	TENLI 20X	CROSS	GG742	-60	26-04-2022 FLT002		Used as Run 203 in data analysis
						26-04-2022 FLT002		Used as Run 121 in data analysis
9	TENLI 20X	KARWY 20X	CROSS	TOLKO	+40	26-04-2022 FLT001		Used as Run 413 in data analysis
10	TENLI 20X	KARWY 25X	CROSS	GG742	+20	26-04-2022 FLT002		Used as Run 204 in data analysis
11	KARWY 25X	TENLI 25X	CROSS	TOLKO	-20	26-04-2022 FLT001		Used as Run 426 in data analysis
12	KARWY 25X	TENLI 20X	CROSS	GG742	-60	26-04-2022 FLT001		Used as Run 203 in data analysis
101	SOPIX 20X	SOPIX 20X	CAPTURE	-	+40	14-06-2022 FLT001	YES	
102	SOPIX 20X	SOPIX 20X	CAPTURE	-	-20	25-04-2022 FLT001	YES	
103	SOPIX 20X	SOPIX 20X	CAPTURE	-	-60	14-06-2022 FLT001	YES	
104	SOPIX 25X	SOPIX 25X	CAPTURE	-	+40	25-04-2022 FLT001	YES	
105	SOPIX 25X	SOPIX 25X	CAPTURE	-	-20	14-06-2022 FLT001	YES	
106	SOPIX 25X	SOPIX 25X	CAPTURE	-	-60	14-06-2022 FLT001	YES	
107	SOPIX 20X	SOPIX 20X	CROSS	TOLKO	+40 +20	25-04-2022 FLT001	YES	Initial spacing error +20 instead of +40
						14-06-2022	NO	Lead aircraft did not properly intercept the

DEMOP						Flight	Included in data analysis	Remarks
						FLT001		final approach track, large lateral route deviation.
					+40	15-06-2022 FLT002	YES	Repeat
108	SOPIX 20X	SOPIX 20X	CROSS	TOLKO	-20	14-06-2022 FLT002	YES	
109	SOPIX 20X	SOPIX 20X	CROSS	TOLKO	-60	14-06-2022 FLT002	YES	
110	SOPIX 25X	SOPIX 25X	CROSS	TOLKO	+40	14-06-2022 FLT002	YES	
111	SOPIX 25X	SOPIX 25X	CROSS	TOLKO	-20	14-06-2022 FLT002	YES	
112	SOPIX 25X	SOPIX 25X	CROSS	TOLKO	-60	25-04-2022 FLT001	YES	Additional run with -40 sec initial spacing error
					-40	25-04-2022 FLT001	YES	
113	SOPIX 20X	KARWY 20X	CROSS	TOLKO	+40	26-04-2022 FLT001	YES	
114	SOPIX 20X	KARWY 20X	CROSS	TOLKO	-20	14-06-2022 FLT002	YES	
115	SOPIX 20X	KARWY 20X	CROSS	TOLKO	-60	14-06-2022 FLT002	YES	
116	SOPIX 25X	KARWY 25X	CROSS	TOLKO	+40 +20	15-06-2022 FLT001	YES	Due to the line-up the initial spacing error was limited by the minimum spacing goal.
117	SOPIX 25X	KARWY 25X	CROSS	TOLKO	-20	15-06-2022 FLT001	NO	Run aborted.
						15-06-2022 FLT001	YES	
118	SOPIX 25X	KARWY 25X	CROSS	TOLKO	-60	15-06-2022 FLT001	YES	
119	SOPIX 25X	TENLI 20X	CROSS	TOLKO	+40	15-06-2022	YES	

DEMOP						Flight	Included in data analysis	Remarks
						FLT001		
120	SOPIX 25X	TENLI 20X	CROSS	TOLKO	-20	15-06-2022 FLT001	YES	
121	~~SOPIX 25X~~ SOPIX 20X	TENLI 20X	CROSS	TOLKO	~~-60~~ -40	26-04-2022 FLT002 15-06-2022 FLT001	YES NO	Initial spacing error -40 instead of -60 due to repeat of previous run. Run aborted.
	SOPIX 25X	TENLI 20X			-30	16-06-2022 FLT001	YES	Due to rather poor ADS-B range the initial spacing error was set at -30 seconds.
122	SOPIX 20X	TENLI 25X	CROSS	TOLKO	+40	15-06-2022 FLT002	YES	
123	~~SOPIX 20X~~ SOPIX 25X SOPIX 20X	TENLI 25X	CROSS	TOLKO	-20	26-04-2022 FLT002 16-06-2022 FLT002 16-06-2022 FLT002	YES NO YES	Run aborted. Repeat.
124	SOPIX 20X	TENLI 25X	CROSS	TOLKO	~~-60~~ -30	15-06-2022 FLT002	YES	Due to rather poor ADS-B range the initial spacing error was set at -30 seconds.
201	~~SOPIX 20X~~ TENLI 20X	KARWY 20X	CROSS	GG742	+40	26-04-2022 FLT002 17-06-2022 FLT002	NO YES	Software issue encountered. Repeat.
202	SOPIX 20X	KARWY 20X	CROSS	GG742	-20	26-04-2022 FLT002	YES	
203	~~SOPIX 20X~~	~~KARWY 20X~~	CROSS	GG742	-60	26-04-2022 FLT001	YES	

DEMOP						Flight	Included in data analysis	Remarks
	TENLI 20X	KARWY 25X						
	SOPIX 25X	TENLI 20X				26-04-2022 FLT002	YES	
						15-06-2022 FLT002	NO	Software issue encountered.
	TENLI 20X	KARWY 20X				17-06-2022 FLT002	YES	Repeat. Extreme outlier regarding spacing performance at PTP.
204	SOPIX 25X TENLI 20X TENLI 25X	KARWY 25X	CROSS	GG742	+40 -40 +25	26-04-2022 FLT002 17-06-2022 FLT001	YES YES	Due to the line-up the initial spacing error was limited by the minimum spacing goal.
205	SOPIX 25X KARWY 25X	KARWY 25X SOPIX 25X	CROSS	GG742	-20	15-06-2022 FLT002 17-06-2022 FLT001	NO YES	Software issue encountered. Route of lead and trail aircraft reversed.
206	SOPIX 25X TENLI 25X	KARWY 25X KARWY 25X	CROSS	GG742	-60	17-06-2022 FLT001 17-06-2022 FLT002	NO YES	Software issue encountered. Repeat with lead aircraft on TENLI arrival. Extreme outlier regarding spacing performance at PTP.
316	TENLI 20X	KARWY 25X	CROSS	TOLKO	+40	16-06-2022 FLT001 16-06-2022 FLT001	NO YES	Run aborted. Repeat.
317	TENLI 20X	KARWY 25X	CROSS	TOLKO	-20	16-06-2022 FLT001	YES	

DEMOP						Flight	Included in data analysis	Remarks
318	TENLI 20X	KARWY 25X	CROSS	TOLKO	-60	16-06-2022 FLT001	YES	Extreme outlier regarding spacing performance at PTP
319	KARWY 25X	TENLI 20X	CROSS	TOLKO	+40	16-06-2022 FLT001	YES	
320	KARWY 25X	TENLI 20X	CROSS	TOLKO	-20	16-06-2022 FLT002	YES	
321	KARWY 25X	TENLI 20X	CROSS	TOLKO	-60	17-06-2022 FLT001	YES	
413	TENLI 25X	KARWY 20X	CROSS	TOLKO	+40			
414	TENLI 25X	KARWY 20X	CROSS	TOLKO	-20	16-06-2022 FLT002	YES	
415	TENLI 25X	KARWY 20X	CROSS	TOLKO	~~-60~~ -30	16-06-2022 FLT002	YES	Due to rather poor ADS-B range the initial spacing error was set at -30 seconds.
419	KARWY 20X	TENLI 20X	CROSS	TOLKO	+40	26-04-2022 FLT001	YES	
420	KARWY 20X	TENLI 20X	CROSS	TOLKO	-20			
421	KARWY 20X	TENLI 20X	CROSS	TOLKO	-60			
422	KARWY 20X	TENLI 25X	CROSS	TOLKO	+40			
423	KARWY 20X	TENLI 25X	CROSS	TOLKO	-20			
424	KARWY 20X	TENLI 25X	CROSS	TOLKO	-60			
425	KARWY 25X	TENLI 25X	CROSS	TOLKO	~~+40~~ +30	17-06-2022	YES	Due to rather poor ADS-B range the initial spacing error was set at +30 seconds.
426	~~KARWY 25X~~ TENLI 25X	~~TENLI 25X~~ KARWY 25X	CROSS	TOLKO	-20	26-04-2022 FLT001	YES	Routes of lead and trail aircraft reversed
427	KARWY 25X	TENLI 25X	CROSS	TOLKO	~~-60~~ -30	17-06-2022 FLT002	YES	Due to rather poor ADS-B range the initial spacing error was set at +30 seconds.

5. OBJ-37-W3-DEMOP-SAF1-0006

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0006 “The use of IM operations shall not result in any unsafe condition during the live trial” has been assessed as OK.

The demonstration success criteria was “No major safety issues are identified both during the test flights and debriefings by the flight crew of the IM aircraft”.

The safety has been assessed by pilot ratings in the questionnaire (In your opinion, the IM operations in this flight were safe) on a six-point scale (Figure 7-48). Score 1 – completely disagree, score 2 – mostly disagree, score 3 – slightly disagree, score 4 – slightly agree, score 5 – mostly agree, and score 6 – completely agree. The figure shows that safety was not an issue during the flight trial, pilot 2 added a remark in the questionnaire that setting up the (simulated) clearance requires quite some head-down time to enter the required parameters.

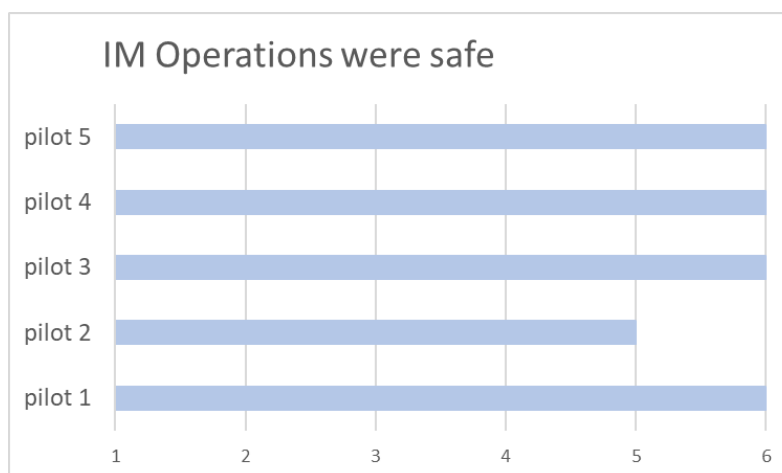


Figure 7-48: Safety of IM operations

The consolidated pilot feedback on safety-related aspects of the concept:

- The 3 NM limit for OFF ROUTE determination, and consequently auto suspend, was found too wide. RNP1 routes and parallel approaches may be designed with less route spacing.
- If the ABP lies beyond the merge point, how do you know if separation is assured, e.g. in a scenario where you have to increase spacing because you are currently too close?
- Contingencies were not examined in the trial. Such contingencies can have an effect on the overall concept, e.g. IM guidance is lost in an aircraft and the aircraft involved is part of a sequence of aircraft each on a dependent IM arrival. These type of contingencies are best evaluated in separate (ATC simulator) trials. Contingencies can also relate to the cockpit environment and affect pilot workload or the ability to perform IM operations. Failure conditions may include display failures, loss of IM capability, or undetected erroneous guidance is presented. Such contingencies must be evaluated against AMC 20-25, AMC 25-11 or even CS25.1329 requirements depending on the installation, either in a flight simulator or in subsequent flight trials.

6. OBJ-37-W3-DEMOP-SAF1-0007

Demonstration objective OBJ-37-W3-DEMOP-SAF1-0001 “The FIM system performs its intended function during the live trial (standardization related objective).” has been assessed as POK.

The demonstration success criteria was “No functional issues related to the FIM system standard (ED-236A) are identified during the test flights (e.g. non-compliance or other issues with relevant ED-236A requirements)”.

This objective has been assessed by pilot ratings in the questionnaire (In your opinion, the IM Equipment functioned properly in this flight) on a YES/NO scale (Figure 7-49). Score 0 – NO and score 1 – YES. The results show that most pilots found the FIM equipment had functioned properly, except for one. This pilot remarked in the questionnaire that ADS-B reception was inadequate and that in runs with the ABP just before the FAF/FAP gave errors. Pilot 5 noted a similar remark: a number of times we had to redo the IM setup, because the target data was lost or frozen. This behaviour is related to a software issue encountered in runs 203, 205 and 206 (see also Table 7-36). If only based on the pilot ratings the demonstration objective would have been assessed as OK.

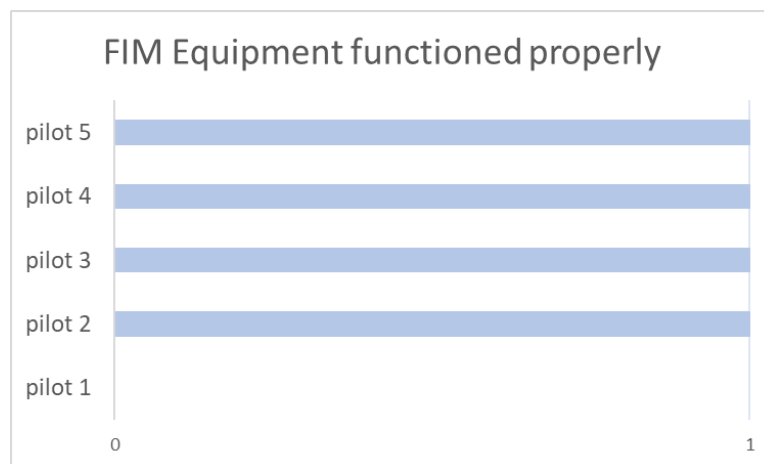


Figure 7-49: FIM Equipment performs its intended function

However, the objective has also been assessed based on in-flight observations. The observations led to the following list of items.

- The vast majority of the FIM functions worked as intended.
- ADS-B In range issue
 - Target aircraft position was frequently only visible at a range of 35-45 NM. In the standards a range of 70-90 NM is assumed, this has also been demonstrated during the NASA ATD-1 flight test of 2017. The ADS-B In range is implicitly defined by FIM MOPS requirement IM.001, requiring the FIM system to be interfaced to an Extended Range A3 class of ADS-B receiver equipment, as defined in DO-20C/ED-102B. A note says that this requirement is derived in ED-195B/DO-328B (FIM SPR) performance analysis to support initiation of IM Operations when traffic is 70 NM from ownship (also known as trailing aircraft / IM aircraft) in high density traffic conditions.
 - The Honeywell investigation into the performance of the system ruled out several possible causes. The equipment tested within specification in a lab environment which tells us there are not problems with the directional antenna, TCAS unit, or cabling at an individual level. While there was one known cable connector issue on the aircraft, this doesn't seem problematic enough to fully explain the poor performance.
 - The bottom antenna did seem to lose the signal before the top, so part of the performance issue may be attributed to the shading of the bottom antenna, particularly when the target is nearly co-altitude or the IM aircraft is turning, but again

this doesn't seem sufficient to explain the difference in performance between the NLR flight tests and previous NASA ATD-1 flight tests. There may still be some other unknown installation issue specific to the NLR aircraft that cannot be detected now that the equipment has been uninstalled from the airplane.

- In summary, after extensive analysis the conclusion is that the poor ADS-B In range must be related to the specific aircraft installation, most likely the antenna locations, possibly also RF interference. Other possible causes were investigated and excluded (e.g. out of specification delays and losses of signal strength due to antenna cables/connectors, transmit power levels, receiver sensitivity, antenna performance evaluated in an anechoic chamber, performance of the tray plus the antenna leads).
- It is recommended to address this system performance gap by setting up a test/exercise to demonstrate adequate ADS-B In range performance. As part of this demonstration on an aircraft, the RF performance should be verified after installation and before starting the flight test.
- System behaviour - use of recorded history (during initiation of IM Capture) sometimes resulted in unexpected/undesired spacing.
 - When activating IM Capture, the FIM system looks at the history of the target aircraft, for example the 2-min history is relevant for a run with a Spacing Goal of 120 sec.
 - The target aircraft history was not always 'stable' on the arrival, it included the target aircraft set-up phase, for example an orbit near the beginning of the arrival route.
 - It is a test set-up artefact, making a 360-degree turn prior to starting IM. But could it happen in daily operations, e.g. leaving a holding and quickly thereafter starting an IM Capture operation? If so, this should either be part of the controller training on the issuing IM Capture clearances or for the FIM system to consider using backward prediction rather than recorded history when starting certain IM clearances. The latter is now addressed by new requirements in the FIM MOPS ED-236A/DO-361A. The new traffic alignment requirements in the FIM MOPS (section 2.2.4.5.2.2) explicitly define how to calculate MSI all the way until ownship (i.e. the trailing aircraft executing the IM operation) reaches the target aircraft position at the time of traffic alignment, see FIM MOPS requirement IM.113.
 - Note: these requirements were not (yet) implemented in the prototype FIM system.
 - It is recommended to update the FIM software to comply with the new traffic alignment requirements of the FIM MOPS.
- System behaviour – early waypoint sequencing resulting in the need for data re-entries
 - A problem (software issue) was identified for waypoint sequencing. The procedures in these flight tests had a challenging sequence of waypoints that were difficult for the FIM equipment.
 - The line-up for the SOPIX arrival is 'close' to legs of the TOLKO approach transition further down the route
 - The line-up for the TENLI and KARWY arrivals typically consisted of flying outbound, sometimes crossing legs of the TOLKO approach transition and also flying 'close' to the inbound legs of the arrival, then a U-turn, and then on the arrival procedure for the actual test run inbound Groningen Airport Eelde.

- Crossing legs and flying 'close' to legs, which are both located further down the route, are considered as test set-up artefacts. Although similar situations may occur in actual flight operations, for example the pilots mentioned that at most aerodromes it is common to define a holding pattern at the Initial Approach Fix (IAF), ATC will use these holdings to meter traffic from the IAF when the traffic supply temporarily exceeds airport capacity. In the IM implementation used in the test, the IM part starts at one of the IAFs (KARWY, SOPIX, TENLI). It is not uncommon to receive the clearance to proceed inbound past the IAF when flying the outbound leg of a holding fix.
- It is recommended that the FIM software should be improved to be more robust regarding waypoint sequencing and should have an easier option for restoring waypoints that should not have been sequenced.
- The IM execution automatically suspended a number of times.
 - IM sometimes auto suspended for a (short) while due to TGT DATA LOST (observed during the Engineering flights in April 2022)
 - The target aircraft SDA is only broadcasted at 2.4-2.6 seconds.
 - In marginal ADS-B In reception conditions this parameter timed out.
 - The FIM software was updated to avoid coasting out SDA, this is in accordance with the additions made to DO-317C/ED-194B, the Aircraft Surveillance Applications (ASA) MOPS. In DO-317C/ED-194B the SDA and SIL metrics do not have coasting requirements, as it was not deemed needed.
 - IM sometimes auto suspended in the final miles to Planned Termination Point located at the beginning of the final approach track.
 - Case 1: Target Aircraft had landed, this was accompanied by a TGT DATA LOST message
 - Case 2: Target Aircraft performed a missed approach, turned 90-deg to the left between FAP and 4DME, this was accompanied by a TGT OFF ROUTE message
 - Case 3: Target Aircraft performed a missed approach to prepare for the set-up of the next test run. When the target aircraft more than 10,000 ft above ownship (also known as trailing aircraft / IM aircraft) the system auto suspended, accompanied by a TGT DATA LOST message.
 - For all cases there was state history data of the target aircraft up to PTP, but still IM was suspended prior to PTP
 - Case 1 and 3 would be resolved by just ignoring what traffic reports after it sequences the PTP, which is not explicitly addressed for time-based clearances in the FIM MOPS. The FIM MOPS (requirement IM.011) states that traffic shall be available as an ADS-B source track, and this could/should be interpreted as the current state and not the state history of the traffic. The availability of sufficient traffic history data is not explicitly addressed in the FIM MOPS.
 - Case 2 is addressed by the updated FIM MOPS requirement IM.139 (and note). The update says don't perform traffic path conformance during maintain/after traffic sequences the Traffic Reference Point (TRP). Note that the TRP and ABP were co-located in this flight test.
 - It is recommended to update the FIM software to ignore what traffic reports after it sequences the PTP for time-based IM clearances. However, this is not a critical issue and it is therefore proposed to address/discuss it in the standards (FIM MOPS requirement IM.011) whenever the FIM MOPS will be revised for others reasons.

- And it is recommended to update the FIM software to comply with the updated traffic path conformance requirements of the FIM MOPS.
- For some flight test runs, the data showed the assigned spacing goal was not met at the Achieve-by Point, despite nominal initial conditions.
 - The team determined the cause was within the aircraft's navigation database, which the FIM algorithm uses to build trajectories and speed profiles for the ownship (the trailing aircraft executing the IM operation) and target aircraft. The problem was some approach procedures into Eelde Airport were missing the initial speed constraint, and the impact was the trajectory calculations included inaccurate assumptions for aircraft descent speed.
 - Because the approach procedure was missing the speed constraint, the algorithm instead used the aircraft's descent speed. For the ownship, the descent speed was known and correct because the default value was correct in the configuration data file, however for the target aircraft, the descent speed used an assumed value that was too high for the procedure, and the accuracy of the algorithm suffered.
 - The missing speed constraints in the navigation database were a regression introduced during a database update.
 - The lesson learned is to regression test every element within the navigation database after an update, even elements that are not purposely changed in the software update.

Most items have been presented to the joint ADS-B In workgroup of EUROCAE and RTCA (EUROCAE WG-51 SG-3 and RTCA SC-186 WG-4) and together with the workgroup it has been concluded that no changes to the FIM standards are needed. Therefore this objective has been assessed as POK, mainly because of (1) a few software issues that need to be resolved, (2) a few requirements that need to be complied with and (3) the ADS-B reception range is still considered to be a gap.

C.3.3 Unexpected Behaviours/Results

No unexpected behaviours or results have occurred during the preparations and performance of demonstration exercise EXE-PJ.37-W3-003.

C.3.4 Confidence in the Demonstration Results

1. Level of significance/limitations of Demonstration Exercise Results

The large number of test flights (11) and test runs (61 of which 49 were included in the data analysis) in actual flight operations - using different route geometries, different vertical descent profiles, and different initial conditions and performed under different wind conditions (from calm wind to strong wind conditions) - provided results that are highly representative.

One issue/gap that needs further work is the ADS-B In range performance, ADS-B In is an enabler for IM operations and as such a large ADS-B In range is important to maximize the opportunities to initiate IM operations, and therefore the ability of IM to correct larger initial spacing errors.

2. Quality of Demonstration Exercise Results

The large number of test flights (11) and test runs (61 of which 49 were included in the data analysis) in actual flight operations – again using different route geometries, different vertical descent profiles, and different initial conditions and performed under different wind conditions (from calm wind to strong wind conditions) - provide a high level of confidence in the demonstration results and the accuracy of those results. Also the use of an industrial based avionics prototype as developed and tested by Honeywell (also in other projects) contributed to the confidence in the results.

3. Significance of Demonstration Exercises Results

The operational significance is high due to the high realism of the exercise being a flight trial in a real operating environment.

C.4 Conclusions

The demonstration exercise EXE-PJ.37-W3-003 has been successfully performed. There are no objectives that did not meet the expectations. 1 out of 6 objectives have been assessed as Partially OK (POK) mainly related to the FIM software that need some further, minor amount of improvements and the ADS-B reception range gap. The remaining objectives has been assessed as Fully OK (OK).

The integrated solution was found to be well developed and was successfully demonstrated from an aircraft point of view. The flyability of fixed routes with a fixed profile descent in combination with IM speed guidance was successfully demonstrated as well as the IM spacing performance (key objective OBJ-37-W3-DEMOP-CAP1-0003). The demonstrated IM spacing performance was impressive.

C.5 Recommendations

C.5.1 Recommendations for industrialization and deployment

The following list of recommendations have been derived from the flight trial, for more details see Appendix C.3.2.

REC-37-W3-SAF-R7.1: It is recommended to address the ADS-B IN system performance gap by setting up a test/exercise to demonstrate adequate ADS-B In range performance, with an improved antenna installation and possibly a decreased RF interference at the aircraft level. As part of this demonstration on an aircraft, the RF performance should be verified after installation and before starting the flight test.

REC-37-W3-SAF-R7.2: It is recommended to update the FIM software to comply with the new traffic alignment requirements of the FIM MOPS

REC-37-W3-SAF-R7.3: It is recommended that the FIM software should be improved to be more robust regarding waypoint sequencing and should have an easier option for restoring waypoints that should not have been sequenced.

REC-37-W3-SAF-R7.4: It is recommended to update the FIM software to ignore what traffic reports after it sequences the PTP for time-based IM clearances. However, this is not a critical issue and it is therefore proposed to address/discuss it in the standards (FIM MOPS requirement IM.011) whenever the FIM MOPS will be revised for others reasons.

REC-37-W3-SAF-R7.5: It is recommended to update the FIM software to comply with the updated traffic path conformance requirements of the FIM MOPS.

REC-37-W3-SAF-R7.6: It is recommended to perform a live trial in Europe with a (limited) number of airliner's aircraft being equipped with a FIM system that is approved under TSO-C195c (and therefore complies with the system requirements of EUROCAE ED-236A Change 1 / RTCA DO-361A Change 1) and an ATC centre/sector actively supporting and using IM operations. This operational trial could seamlessly be continued (i.e. deployed) in that ATC environment. Prerequisite is the availability and usage of a PBN route structure in that part of the airspace.

C.5.2 Recommendations on regulation and standardization initiatives

The main outcome of the flight trial has been presented to the joint ADS-B In workgroup of EUROCAE and RTCA (EUROCAE WG-51 SG-3, RTCA SC-186 WG-4) and together with the workgroup it has been concluded that no changes to the FIM standards are needed.

Note that (draft) FAA TSO-C195c refers to and makes applicable the requirements of the FIM MOPS (RTCA DO-361A Change 1, which is technically to EUROCAE ED-236A Change 1). Therefore, also no recommendations on this regulation.

Appendix D Demonstration Exercise EXE-PJ.37-W3-004 Report

This appendix describes the results for the EXE-PJ.37-W3-004 and presents conclusions and recommendations of this exercise.

D.1 Summary of the Demonstration Exercise EXE-PJ.37-W3-004 Plan

The Demonstration Exercise is as elaborated in the DEMOP [2]. No major deviations have taken place. The minor deviations are described in Appendix D.2.

D.1.1 Exercise description and scope

A Real Time Simulation was conducted to assess extended OSD tool support for applying refined and reduced route spacings on departure, including a TMA data-feed to dynamically reduce the departure flow rate if the flow rate into the TMA is predicted to exceed a pre-defined threshold.

The departure flow rate from the airport may increase due to the application of reduced and refined route separations, therefore also increasing the flow rate into the TMA sectors. If the TMA traffic management tool (SYSMAN) predicts that this increased departure traffic flow will exceed a pre-defined threshold and thus increase TMA controller workload to an unacceptable level (e.g., during busy periods), the tool advises a temporary reduction in the departure flow rate until the situation has been resolved. This is akin to the application of a Minimum Departure Interval (MDI) in current operations, but the MDI is no longer limited to integer minutes.

The SESAR solution track covered by this exercise is PJ.37-W3-01B.

Operational Scope

The operational scope of this exercise is to assess the operational feasibility of applying refined and reduced route spacings on departure with an extended OSD tool. The exercise also assesses the operational feasibility of dynamically reducing the aircraft departure flow rate based on information provided by an emulated TMA data-feed to the extended OSD tool if the flow rate into the TMA is predicted to exceed a pre-defined threshold.

The RTS was configured for London Heathrow, which is classified as a Very Large Airport according to the Airports' classification scheme in SESAR 2020 [10] Heathrow has two dependent parallel runways operating primarily in segregated mode, with up to six arrival aircraft per hour landing on the departure runway in Tactical Enhanced Arrival Mode (TEAM) operations and operates in the complex London Terminal Manoeuvring Area (TMA) with several other large busy airports.

Actors and processes

The Demonstration Exercise was based on a Real Time Simulation technique with human-in-the-loop: the platform layout was based on the Heathrow Tower Simulation suite, setup for two ATCOs (Ground Movement Controller Position and Departure Runway Controller Position that are the TWR Runway Controller for 09R and TWR Runway Controller for 27R). In addition, a TMA controller was present during one of the simulation days as an expert observer to assess the Heathrow departures traffic from a TMA perspective.

Tower ATC

The Departure Runway Controller Position viewed the new route countdown timer on the ADIS display and used it as guidance to determine when to provide take-off clearance for a follower aircraft for departure pairs where route separation was the most constraining separation. They assessed the operational feasibility of applying the reduced and refined route separations, as well as separations that are dynamically adjusted based on information received from an emulated TMA data-feed. The controllers also assessed the acceptability of the tool HMI.

The Departure Runway Controller Position also used a separate wake countdown timer on the ADIS display to determine when to provide take-off clearance for a follower aircraft for pairs requiring wake separation (when wake separation was the most constraining separation).

The Ground Controller facilitated the logical order and feed of aircraft to the runway holding point with support from the ground movement radar (A-SMGCS) and the Electronic Flight Progress Strip (EFPS) display.

Note that, similarly to PJ.02-01 RTS5, there was no A-CDM, DMAN or TSAT systems as part of the Demonstration Exercise. Therefore, in order to ensure the departure sequence order optimisation process was reflected in the traffic samples, the actual time the aircraft crossed the simulation start-up taxiway position on the sampled recorded operational day was used as the start-up time at the start-up taxiway position in the simulation. In this way the A-CDM/DMAN sequence order optimisation decisions made on the recorded operational day were reflected into the simulated traffic samples.

Key demonstration objectives and scenarios

The exercise addressed the following key demonstration objectives to support route spacing reduction and refinement on departure, which could be dynamically adjusted based on information from an emulated TMA data-feed: OPF Operational Feasibility, HUP Human Performance, CAP Capacity, OPE Operational Efficiency, ENV Environment, CEF Cost Efficiency and SAF Safety. The key demonstration objectives for this exercise are listed in Section D.1.2.

To assess the operational feasibility of the PJ.37-W3-01B with and without the TMA data feed (Solution Scenarios) a comparative assessment has been conducted against two Reference Scenarios:

1. RECAT-EU 6-CAT wake time separations with OSD tool organisation (no route spacing tool support).
2. PWS-D solution organisation based on 103x103 PWS and 20-CAT PWS wake time separations with OSD tool support (no route spacing tool support).

Four Solution Scenarios were tested:

1. Time-Based RECAT-EU with extended OSD tool support with a TMA data-feed.
2. Time-Based PWS-D with extended OSD tool support with a TMA data-feed.
3. Time-Based RECAT-EU with extended OSD tool support without a TMA data-feed.
4. Time-Based PWS-D with extended OSD tool support without a TMA data-feed.

This resulted in two comparative organisations for the Demonstration Exercise, each containing one Reference Scenario and two Solution Scenarios. Further details on the Reference and Solution scenarios are found in D.1.3.

Demonstration technique and platform to be used.

The demonstration technique is a Real Time Simulation which was run on an enhanced version of an emulation of the Industrial Based Platform (IBP) for the OSD tool provided by INDRA and integrated into the NATS Ace Simulation environment. An emulated TMA data-feed from SYSMAN was also provided to the system.

D.1.2 Summary of Demonstration Exercise EXE-PJ.37-W3-004 Demonstration Objectives and Success Criteria

This section lists the Demonstration Objective, and associated success criteria, grouped by themes

Operational Feasibility Demonstration Objectives

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
OPF	OBJ-37-W3-DEMOP-OPF-0001	To provide evidence that the ITARO Departures Solution is operationally feasible for the Aerodrome when integrated in a realistic environment in segregated mode.	The ITARO Departures Solution is shown to be operationally feasible for the Aerodrome when the IBP is tested in a realistic environment. The OSD and extended OSD Tool design and usability is considered appropriate by users.

Human Performance Demonstration Objectives

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
HUP	OBJ-37-W3-DEMOP-HUP1-0017	Assess the ability of controllers to follow operating methods	V3. Tasks are effectively achieved.
	OBJ-37-W3-DEMOP-HUP1-0018	Assess the credibility of potential human errors, the associated risk and identify mitigations if appropriate	V3. Number of errors in the solution not significantly higher than in reference scenario, taking into account error type & operational impact.
	OBJ-37-W3-DEMOP-HUP1-0019	Assess the extent to which task performance is impacted by the concept solution	V3. Tasks are effectively achieved
	OBJ-37-W3-DEMOP-HUP1-0009	Assess the extent to which workload is impacted by the concept solution	V3. Level of workload within acceptable limits ('acceptable limits' to be defined with regard to the tool used for the assessment).
	OBJ-37-W3-DEMOP-HUP1-0021	Assess the impact on situation awareness by the concept solution	V3. User is able to perceive and interpret task relevant information and anticipate future events/actions.

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
	OBJ-37-W3-DEMOP-HUP1-0022	Assess the extent to which automating SID separation calculations enables controllers to make quicker decisions	V3. Task allocation is found to be consistent with good deliverables of 16.5.1 Please note: deliverable 16.5.2 is SESAR's Guidance Materials on HP Automation Support (Edit 00.01.00). This document provides guidance material on automation design and evaluation that HF specialists can apply to airborne and ground operational and technical projects involving automation.
	OBJ-37-W3-DEMOP-HUP1-0023	Assess the extent automating airborne time detection improves human performance	V3. The task allocation is consistent with deliverable of 16.5.2. Please note: deliverable 16.5.2 is SESAR's Guidance Materials on HP Automation Support (Edit 00.01.00). This document provides guidance material on automation design and evaluation that HF specialists can apply to airborne and ground operational and technical projects involving automation.
	OBJ-37-W3-DEMOP-HUP1-0024	Assess users' mode switching capability	V3. There are no excessive cognitive demands or potential for error in transition tasks.
	OBJ-37-W3-DEMOP-HUP1-0026	Assess the extent to which actors can acquire mental models	V3. Understanding of the technical system's behaviour is consistent with the operator's task demands.
	OBJ-37-W3-DEMOP-HUP1-0027	Assess the extent to which the accuracy of the system meets HP requirements	V3. Information accuracy experienced as sufficient by the end user.
	OBJ-37-W3-DEMOP-HUP1-0028	Assess the extent to which the timeliness of the system meets HP requirements	V3. Timeliness of information is judged as being sufficient.
	OBJ-37-W3-DEMOP-HUP1-0029	Assess the credibility of the benefit and identify how to realise the benefit if appropriate	V3. Information provided allows task achievement.
	OBJ-37-W3-DEMOP-HUP1-0030	Assess the credibility of the issue, the associated risk and identify mitigations if appropriate	V3. Information provided allows task achievement.
	OBJ-37-W3-DEMOP-HUP1-0031	Assess the extent to which the user interface impacts	V3. End user experiences integrated interface including any new system components as sufficiently usable.

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
		human performance and service delivery	
	OBJ-37-W3-DEMOP-HUP1-0033	Assess the extent to which the concept solution complies with the relevant HP Principles	V3. Number and/or severity of errors is within acceptable limits.
	OBJ-37-W3-DEMOP-HUP1-0034	Assess the impact the user interface has on individual situation awareness levels	V3. End user is able to perceive and interpret task relevant information and anticipate future events/actions
	OBJ-37-W3-DEMOP-HUP1-0035	Assess the impact the user interface has on team situation awareness levels	V3. Team is able to perceive and interpret task relevant information and anticipate future events/actions.
	OBJ-37-W3-DEMOP-HUP1-0036	Assess the credibility of an interference risk	V3. Interferences between existing and required new knowledge & skills are identified.

Capacity Demonstration Objective

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
CAP	OBJ-37-W3-DEMOP-CAP1-0004	To assess the improvement in departure runway capacity due to the ITARO Departures Solution versus the Reference Scenario.	Evidence shows an increase in maximum hourly operational runway throughput for departures in the Solution Scenario versus the Reference Scenario.

Table 7-37: Capacity Demonstration Objective related to PJ.37-W3-01B

Operational Efficiency Demonstration Objectives

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
OPE	OBJ-37-W3-DEMOP-PRD1-0002	To assess the improvement in predictability per flight for the Aerodrome due to the ITARO Departures Solution versus the Reference Scenario.	Evidence shows a decrease in taxi out variability for departing aircraft in the Solution Scenario versus the Reference Scenario.
	OBJ-37-W3-DEMOP-PRD1-0003	To assess the predictability per flight for the TMA due to the ITARO Departures Solution versus the Reference Scenario.	Evidence shows a more consistent delivery of aircraft into the TMA in the Solution Scenario versus the Reference Scenario.
	OBJ-37-W3-DEMOP-PUN1-0001	To assess the impact on ANSP-attributed holding delay at the Aerodrome as a result of the	There is evidence to show that the ANSP-attributable delay at the Aerodrome is reduced in the Solution

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
		ITARO Departures Solution versus the Reference Scenario.	scenario verses the reference scenario.

Table 7-38: Operational Efficiency Demonstration Objective related to PJ.37-W3-01B

Environment Demonstration Objective

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
ENV	OBJ-37-W3-DEMOP-ENV1-0002	To assess the impact of the ITARO Departures Solution on the average fuel burn per flight versus the Reference Scenario.	There is evidence to show there is a reduction in the average fuel burn per flight in the Solution Scenario versus the Reference Scenario.

Table 7-39: Environment Demonstration Objective related to related to PJ.37-W3-01B

Cost Efficiency Demonstration Objective

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
CEF	OBJ-37-W3-DEMOP-CEF1-0001	To assess the increase to Aerodrome ATCO productivity in terms of flights handled per unit time in the ITARO Departures Solution versus the Reference Scenario.	Evidence shows an increase in the number of flights handled by an Aerodrome ATCO per hour in the Solution Scenario versus the Reference Scenario.

Table 7-40: Cost Efficiency Demonstration Objective related to PJ.37-W3-01B

Safety Demonstration Objective

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
SAF	OBJ-37-W3-DEMOP-SAF1-0008	To assess the impact of the ITARO Departures Solution on operational safety in the Tower compared to the Reference Scenario.	CRT-37-W3-DEMOP-SAF1-0008: There is evidence that the level of safety for the Tower controllers operations is maintained and not negatively impacted with the ITARO Departures Solution compared to the Reference Scenario. CRT-37-W3-DEMOP-SAF1-0008: There is evidence that the ITARO Departures Solution does not increase the number of minor wake under-separations and decreases the number of large wake under-separations (i.e., those with potential for severe wake encounters and / or loss of separation) compared to the Reference Scenario

OBJ KPA category	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
			CRT-37-W3-DEMOP-SAF-0008: There is evidence that the ITARO Departures Solution does not increase the number of route under spacing events relative to the target distance spacing and compared to the Reference Scenario.
	OBJ-37-W3-DEMOP-SAF1-0009	To assess the impact on safety by the associated procedures	Evidence is gathered regarding the impact on safety and associated procedures that the ITARO Departures Solution has.
	OBJ-37-W3-DEMOP-SAF1-0009	Understand the equipment requirements, e.g., corrupt data, hardware failures.	Evidence is gathered regarding equipment requirements and the ITARO Departures Solution

Table 7-41: Safety Demonstration Objectives related to PJ.37-W3-01B

D.1.3 Summary of Demonstration Exercise EXE-PJ.37-W3-004 Demonstration scenarios

To assess the impact of the PJ.37-W3-01B, a comparative assessment has been conducted between the Reference and Solution Scenarios, which are described in Sections 1 and 2, respectively.

1. Reference Scenarios

Two Reference Scenarios were considered in the Demonstration Exercise:

- RECAT-EU 6-CAT wake time separations with OSD tool organisation (no route spacing tool support).
- PWS-D solution organisation of 103x103 PWS and 20-CAT PWS wake time separations with OSD tool support (no route spacing tool support).

Airport Information

The operational environment used for the simulation is based on London Heathrow Airport. London Heathrow Airport (IATA: LHR, ICAO: EGLL) is a major international airport in West London, England, United Kingdom. Heathrow is the busiest airport in the United Kingdom and the busiest airport in Europe by passenger traffic. Heathrow is also the third busiest airport in the world by total passenger traffic, handling more international passengers than any other airport around the globe.

Heathrow airport is classified as Very Large Airport Sub-Operational Environment, hosting more than 250 000 annual movements, according to the latest S2020 Airport classification scheme [10].

Heathrow comprises two runways: 09L/27R (north) and 09R/27L (south). Terminals are mainly located between the runways, except for Terminal 4, which is located south of Runway 09R/27L. The airport layout is depicted in Figure 7-50:

Considering the scope of the PJ.37-W3-01B RTS and Heathrow segregated mode usage of runways, only the departure runway and limited arrival ground movements were emulated in the simulation and two runway configurations were simulated in the Reference Scenarios organisation:

Reference scenarios organization	Departure Runway	Arrivals on Departure Runway	Characteristics
REF09R	09R	09R Segregated Mode: Up to 6 arrivals on the departure runway	Departure operations on Runway 09R Arrivals traffic crossing to Terminal 4 and Cargo from arrivals runway (09L)
REF27R	27R	27R Segregated Mode:	Departure operations on Runway 27R No arrival traffic simulated (on either 27R or 27L)

Table 7-42: Reference scenarios organisation

As the PJ.37-W3-01B RTS was designed to compare experimental factors and tool configurations to each runway independently, no comparative assessments across runways have been planned considering the different configurations of holding points and entry taxiways for each runway, the different relative positions and thus taxiway route distances from each stand to the holding points of each runway, and the different demands for crossing traffic for each runway.

Table 7-43 indicates the easterly and westerly SIDs that were emulated in the Reference Scenarios REF09R and REF27R, respectively:

Reference scenarios organisation	Departure Runway	SIDs
REF09R	09R	ULTIB; BPK; DET; CPT; GASGU; MODMI
REF27R	27R	MAXIT; DET; CPT; GOGSI; BPK; UMLAT

Table 7-43: PJ.37-W3-01B RTS SIDs.

Figure 7-51 gives an overview of the easterly and westerly SIDs from Heathrow.

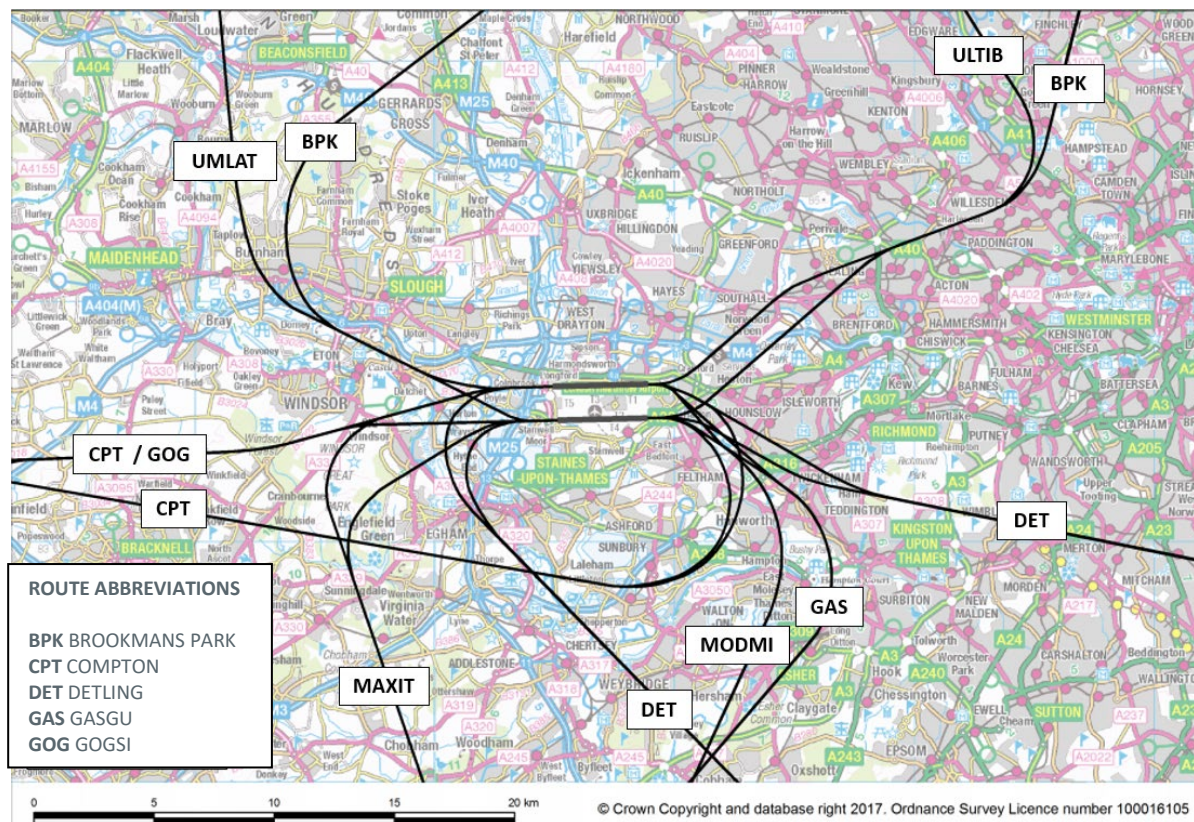


Figure 7-51: Heathrow Easterly and Westerly SIDs (REF09R and REF27L, respectively).

Separation Schemes

The PJ.37-W3-01B Departure Exercise EXE-PJ.37-W3-004 assessed the impact of reduced route spacings supported by the extended OSD tool, as a comparative assessment against the deployed route spacings at Heathrow today.

All SID pairs have an associated procedural time separation, which is dependent on the divergence of the SIDs, ranging between 1 minute to 3 minutes. Note that the 1 minute for early diverging SIDs is actually a spacing rather than a separation and is applied in the event of non-RSVA conditions and a failure of the Aerodrome Traffic Monitor (ATM) radar.

In some instances, ATCOs are able to apply alternative forms of reduced separation in lieu of the procedural time separations. For example, RSVA (Reduced Separation in the Vicinity of an Aerodrome) is a permitted form of reduced separation within the immediate vicinity of an airfield provided the ATCO has uninterrupted visual contact with the aircraft. Alternatively, the ATCO may use the “3NM and increasing” procedure for SID pairs that require two minutes procedural time separation and are on diverging tracks. This procedure requires advanced use of the ATM radar to ensure a minimum departure interval of 3NM and increasing is achieved.

Note that route spacings were **not** supported by the OSD tool in the Reference Scenarios (in line with RTS5 in SESAR 2020 PJ.02-01 Wave 1).

In addition to the route spacing requirements, the Reference Scenarios employed the RECAT-EU 6-CAT and PWS-D wake time separations, both supported by the OSD tool developed in Wave 1.

The RECAT-EU 6-CAT wake time separations used in the Reference Scenario are summarised in Table 7-44:

Departures Wake Separation		Time-Based Turbulence Minima	Super Heavy "A"	Upper Heavy "B"	Lower Heavy "C"	Upper Medium "D"	Lower Medium "E"	Light "F"
Lead Aircraft RECAT EU Wake Category	Super Heavy "A"			100 s	120 s	140 s	160 s	180 s
	Upper Heavy "B"					100 s	120 s	140 s
	Lower Heavy "C"					80 s	100 s	120 s
	Upper Medium "D"							120 s
	Lower Medium "E"							100 s
	Light "F"							80 s

Table 7-44: RECAT-EU 6 Category Wake Category Based Separations for Departures

The PWS-D scheme consists of 103x103 PWS and 20-CAT PWS wake time separation minima. Note that these are the PWS-D separation minima derived in PJ.02-01-06 and not the minima used in the Wave 1 RTS5 Validation Exercise.

The time separation minima obtained for RECAT 20-CAT are shown in Table 7-45:

	A1	A	B1	B2	B	C1	C2	C3	C4	C	D1	D	E1	E2	E3	E	F1	F2	F3	F
A			100.0	100.0	100.0	120.0	120.0	120.0	120.0	120.0	140.0	140.0	160.0	160.0	160.0	160.0	180.0	180.0	180.0	180.0
A1			100.0	100.0	100.0	120.0	120.0	120.0	120.0	120.0	140.0	140.0	160.0	160.0	160.0	160.0	180.0	180.0	180.0	180.0
B									60.0	60.0	100.0	100.0	120.0	120.0	120.0	120.0	140.0	140.0	140.0	140.0
B1									60.0	60.0	100.0	100.0	110.0	120.0	120.0	120.0	140.0	140.0	140.0	140.0
B2									60.0	60.0	90.0	100.0	110.0	120.0	120.0	120.0	130.0	140.0	140.0	140.0
C									60.0	60.0	80.0	80.0	100.0	100.0	100.0	100.0	120.0	120.0	120.0	120.0
C1									60.0	60.0	80.0	80.0	100.0	100.0	100.0	100.0	120.0	120.0	120.0	120.0
C3									60.0	60.0	60.0	70.0	90.0	100.0	100.0	100.0	110.0	120.0	120.0	120.0
C2									60.0	60.0	60.0	70.0	90.0	90.0	100.0	100.0	100.0	110.0	120.0	120.0
C4									60.0	60.0	60.0	60.0	60.0	70.0	90.0	90.0	90.0	100.0	100.0	120.0
D																	90.0	100.0	120.0	120.0
D1																	70.0	90.0	120.0	120.0
E																			100.0	100.0
E1																			100.0	100.0
E2																			100.0	100.0
E3																			100.0	100.0
F																			80.0	80.0
F1																			80.0	80.0
F2																			80.0	80.0
F3																				

Table 7-45: RECAT 20-CAT time separation minima.

Reference Scenario Organisation Characteristics

Table 7-46 summarises the Reference Scenarios organisation characteristics:

Reference scenarios organisation	Departure Runway	Arrival Runway	Characteristics
REF09R_RECAT-EU	09R	09R Segregated Mode: Up to 6 arrivals on the departure runway.	RECAT-EU 6 CAT wake time separations with OSD tool support. Heathrow Easterly route spacing requirements in minutes not supported by OSD tool.
REF09R_PWS-D	09R	09R Segregated Mode: Up to 6 arrivals on the departure runway.	PWS-D organisation of 103x103 PWS & 20-CAT PWS wake time separations with OSD tool support. Heathrow Easterly route spacing requirements in minutes not supported by OSD tool.
REF27R_RECAT-EU	27R	27R Segregated Mode:	RECAT-EU 6 CAT wake time separations with OSD tool support. Heathrow Westerly route spacing requirements in minutes not supported by OSD tool.
REF27R_PWS-D	27R	27R Segregated Mode:	PWS-D organisation of 103x103 PWS & 20-CAT PWS wake time separations with OSD tool support. Heathrow Westerly route spacing requirements in minutes not supported by OSD tool.

Table 7-46: Reference scenarios organisation characteristics

Controller Working Positions

The focus of the PJ.37-W3-01B Real Time Simulation were those roles that are involved in the tactical delivery of aircraft onto the runway and into the air and so there was no need to simulate the full departures process from pushback.

The departure traffic started up on the taxiways used on the sampled operational days for the departure runway-in-use rather than on stand prior to pushback, and therefore only the following roles were required to be simulated:

- One Ground Movement Controller (GMC) responsible for clearing the traffic to the runway holding points.
- One Tower Runway Controller responsible for clearing the traffic from line-up clearance onto the runway, through clearance to take-off, through becoming airborne to being delivered to the required separation, to being 'handed over' to the TMA Departure Controller with the required separation. Note that since there was no active TMA Departure Controller position in the RTS, the aircraft were considered as handed over when the Air Departures Controller provided the change of frequency and this was acknowledged by the pseudo pilot position.

As the arrivals were scripted movements in the RTS, no Tower Arrivals Controller was required.

A TMA Departure Controller attended one day of the simulations as an expert observer to provide feedback on the reduced departure spacings and the likely impact to TMA sectors.

The only measured position was the Tower Runway Controller since it is considered to be the main impacted actor of using the new extended OSD Tool, whether with or without the emulated TMA data-feed.

Traffic Samples

The traffic samples used for SESAR PJ.37-W3 01B were re-used from SESAR PJ.02-01 and exercise RTS5, with a small number of adjustments, as these were considered suitable for the demonstration aims of EXE-004.

The adjustments included:

- Updates to some airlines, for example, where they are no longer in operation.
- Updates to some aircraft types, for example, where they are no longer typically observed at Heathrow.
- Any necessary updates to SID names.
- Changes to some of the assigned SIDs to ensure the traffic sample was sufficient for generating same and/or similar SID pairs to adequately test the PJ.37-W3-01B concept, whilst keeping the sample realistic.

The traffic samples for PJ.02-01 and exercise RTS5 were prepared in accordance with SESAR 2020 guidelines, taking into consideration Heathrow 2022 traffic pressure, aircraft type and SID route mix.

It was necessary to have traffic samples that showed a sufficient pressure of traffic to test the Reference and Solution Scenarios, therefore, traffic samples were based on recorded operational days from May 2018, when RECAT-EU 6 CAT for departures was already in operation, and when traffic levels were busy pre-Covid19.

The traffic samples were populated from recorded operational days of baseline RECAT-EU 6-CAT for departures wake separation delivery without any significant departure flow control constraints.

Recorded operational periods of RWY 27R operations and RWY 09R operations were used to populate the traffic samples where there is a mix of A388, Heavy and Medium aircraft types such that there is an adequate number of both wake and route separated pairs.

From the analysis conducted in SESAR PJ.02-01, such representative periods of operation are 09:00 to 10:00 and 11:00 to 12:00.

In order to ensure the departure sequence order optimisation process was reflected in the traffic samples, the actual time the aircraft crossed the simulation start-up taxiway position on the sampled recorded operational day was used as the start-up time at the start-up taxiway position in the simulation. In this way the A-CDM/DMAN sequence order optimisation decisions made on the recorded operational day were reflected into the simulated traffic samples.

For RWY 09R, the sampled traffic also included the arrival crossing traffic to Terminal 4 and the Cargo Terminal south of RWY 09R.

The matched measured exercise runs were of 1-hour duration. It was necessary to provide a departure aircraft flow rate representative of future traffic, with sufficient departure traffic for 1-hour measured matched exercise runs. It was anticipated that more efficient route separations supported by use of the extended OSD Tool may increase the departure rate by up to around 5%, and so to ensure that there was sufficient departure traffic, the sampled traffic start up times were adjusted progressively by 5% which is by 1 minute every 20 minutes or by 3 minutes an hour.

As each traffic sample was used several times over the comparative exercise runs, an issue that needed to be managed was the learning effect and lack of/reduction of attention due to being exposed to the same traffic sample. This was addressed by producing two variants of the traffic sample with different departure flight callsigns and with different traffic sample names so as to disguise that the same traffic sample is being used several times.

Met samples

Wind profiles* were required to simulate the Reference and Solution Scenarios, in particular in relation to the operation of the extended OSD Tool, which aims to support the controller in achieving the target distance spacing for route-separated pairs with provision of tool support for the airborne-to-airborne departure separation time.

The nominal wind conditions simulated were:

- Low total wind conditions (Up to a 5kt runway surface tailwind component) (27R only).
- Moderate headwind conditions (Approximately a 10kt runway surface headwind component) (27R only).
- Strong headwind conditions (Approximately a 20kt to 25kt runway surface headwind component) (27R only).
- Northerly crosswind (09 and 27).
- Southerly crosswind (09 and 27).

The wind profiles were required to support exercise runs with RWY 09R and thus with an easterly headwind component and to support exercise runs with RWY 27R and thus with a westerly headwind component, with up to a 5kt tailwind component at the runway surface.

The NATS Ace Simulation system supports specifying wind profiles with the runway surface wind conditions and the wind conditions aloft altitude banding. The NATS Ace Simulation system can also support scripted wind profile changes during an exercise run to provide realistic variation in the wind conditions. In this way, changeable wind profiles could be supported across matched exercise runs. These wind profiles define the two-minute average wind direction and wind speed for the runway surface wind conditions and for the banded wind conditions aloft. Additionally, the instantaneous runway surface wind conditions with the associated wind direction and wind speed variability could be emulated for the active two-minute average wind conditions on the emulated Tower Runway Controller Meteorological Conditions HMI.

The prepared wind profiles used were based on a subset of those used in SESAR PJ.02-01 RTS5, which were in turn based on recorded operational data from July 2016 to June 2017. The wind profiles for RTS5 were populated using recorded operational data from the deployed TBS System at Heathrow. The TBS system uses downlinked Enhanced Mode S data to generate a wind conditions aloft profile on final approach, and runway surface anemometer data for the runway surface wind conditions.

The wind profiles for arrivals were considered suitable for use on departure since:

- There is no dedicated system for measuring winds on departures.
- There is still some local proximity to the geographical area between arrivals and departures so the wind speed and direction should be similar.
- The height above ground can be inferred from the deployed TBS system and then applied to the departures profile as needed.

Three additional met samples were also tested with varying levels of cloud and static wind profiles:

1. Cloud overcast at 500ft for full duration of exercise (to represent non-RSVA conditions). Static light tailwind conditions.
2. Transitioning cloud between 500ft to 3000ft and back to 500ft (to represent transition in and out of RSVA conditions). Static moderate headwind conditions.
3. Transitioning cloud between 3000ft to 500ft and back to 3000ft (to represent transition in and out of non-RSVA conditions). Static southerly crosswind conditions.

2. Solution Scenarios

Four Solution Scenarios have been considered in the Demonstration Exercise:

1. Time-Based RECAT-EU with extended OSD tool support with an emulated TMA data-feed.
2. Time-Based PWS-D with extended OSD tool support with an emulated TMA data-feed.
3. Time-Based RECAT-EU with extended OSD tool support without a TMA data-feed.
4. Time-Based PWS-D with extended OSD tool support without a TMA data-feed.

Airport Information

The airport environment was the same as for the Reference Scenarios (see Section 1).

Runway Usage and Standard Instrument Departures (SIDs)

Runway usage and SIDs were the same as for the Reference Scenarios (see Section 1).

Separation Schemes

SID Spacings

The PJ.37-W3-01B Departure Exercise EXE-PJ.37-W3-004 aimed to assess the impact of reduced route spacings supported by the extended OSD tool, as a comparative assessment against the deployed route spacings employed at Heathrow today (see Section 1) without extended OSD tool support.

The PJ.37-W3-01B Departures Solution proposes delivering the following distance-based route spacings in the Heathrow environment:

- 3.5NM straight-line lateral spacing for diverging SIDs that require 120s procedural separation (in general this applies to SIDs that diverge by less than 45 degrees)⁷.
- 5NM straight-line lateral spacing for the same or similar SIDs.
- 5NM straight-line lateral spacing for the special cases currently requiring 180s.
- Note that there was no tool support for SID pairs that have a 60s procedural spacing today (generally those which diverge by more than 45 degrees immediately after take-off). This is because the spacing that is applied to these pairs is already very efficient and difficult to optimise further with the extended OSD tool.

For EXE-PJ.37-W3-004, the spacing delivery point was defined to be when the follower aircraft reached 1.5NM lateral distance from the stop-end of the runway. Separation has been measured as a straight-line lateral distance in all cases.

Since aircraft departure separations and spacings are applied as times rather than distances in the Heathrow operating environment, all target distance spacings were converted by the extended OSD tool to time spacings for display on the countdown timer on the Tower Runway Controller's HMI (if operationally deployed, this would be displayed on the EFPS in the case of Heathrow, but due to simulation limitations, the countdown timers were displayed on the ADIS for the RTS).

The conversion from a target distance spacing to a target time spacing was carried out using an algorithm that considers the effect of the wind profile and leader/follower aircraft types⁸ on the time to fly to the agreed Spacing Delivery Point in the TMA for each SID. The calculated time spacing was displayed on a countdown timer on the ADIS display.

Some of the Solution exercise runs contained an emulated departure flow restriction on one of the SIDs for a proportion of the exercise run. This was to emulate a scenario where SYSMAN predicts that the departure flow rate along a specific SID will become too high and that the departure intervals need to be increased temporarily (i.e., a refined version of an MDI in current operations). For Sol2 runs,

⁷ Due to the complex nature of the SID structure, it is challenging to define a clear set of rules describing which SIDs qualify for 3.5 NM separation. The decision was made based on current operational experience in consultation with ATC experts.

⁸ Note that the extended OSD tool algorithm may use aircraft grouped at a Wake Turbulence Category level for the purpose of calculating the required time separation.

where the emulated TMA data-feed was included, the route countdown timer reflected the SID flow restriction if this was greater than the calculated route spacing.

Wake Separations

The Solution Scenarios employed the RECAT-EU and PWS-D wake time separations in addition to the reduced route spacings, all supported by the extended OSD tool.

Solution Scenario Organisation Characteristics

Table 7-47 summarises the Solution Scenarios organisation characteristics:

Reference organisation	scenarios	Departure Runway	Arrival Runway	Characteristics
SOL09R_RECAT-EU_extended OSD_with_TMA		09R	09R Segregated Mode: Up to 6 arrivals on the departure runway.	RECAT-EU 6 CAT wake time separations with extended OSD tool support. Reduced Heathrow Easterly route spacing requirements with extended OSD tool support. Dynamic changes to route spacing requirements based on an emulated TMA data-feed.
SOL09R_PWS-D_extended OSD_with_TMA		09R	09R Segregated Mode: Up to 6 arrivals on the departure runway.	PWS-D organisation of 103x103 PWS & 20-CAT PWS wake time separations with extended OSD tool support. Reduced Heathrow Easterly route spacing requirements with extended OSD tool support. Dynamic changes to route spacing requirements based on an emulated TMA data-feed.
SOL09R_RECAT-EU_extended OSD_without_TMA		09R	09R Segregated Mode: Up to 6 arrivals on the departure runway.	RECAT-EU 6 CAT wake time separations with extended OSD tool support. Reduced Heathrow Easterly route spacing requirements with extended OSD tool support. No dynamic changes to route spacing requirements without an emulated TMA data-feed.

Reference organisation	scenarios	Departure Runway	Arrival Runway	Characteristics
SOL09R_PWS-D_extended OSD_without_TMA		09R	09R Segregated Mode: Up to 6 arrivals on the departure runway.	PWS-D organisation of 103x103 PWS & 20-CAT PWS wake time separations with extended OSD tool support. Reduced Heathrow Easterly route spacing requirements with extended OSD tool support. No dynamic changes to route spacing requirements without an emulated TMA data-feed.
SOL27R_RECAT-EU_extended OSD_with_TMA		27R	27R Segregated Mode:	RECAT-EU 6 CAT wake time separations with extended OSD tool support. Reduced Heathrow Westerly route spacing requirements with extended OSD tool support. Dynamic changes to route spacing requirements based on an emulated TMA data-feed.
SOL27R_PWS-D_extended OSD_with_TMA		27R	27R Segregated Mode:	PWS-D organisation of 103x103 PWS & 20-CAT PWS wake time separations with extended OSD tool support. Reduced Heathrow Westerly route spacing requirements with extended OSD tool support. Dynamic changes to route spacing requirements based on an emulated TMA data-feed.
SOL27R_RECAT-EU_extended OSD_without_TMA		27R	27R Segregated Mode:	RECAT-EU 6 CAT wake time separations with extended OSD tool support. Reduced Heathrow Westerly route spacing requirements with extended OSD tool support. No dynamic changes to route spacing requirements without an emulated TMA data-feed.

Reference organisation	scenarios	Departure Runway	Arrival Runway	Characteristics
SOL27R_PWS-D_extended OSD_without_TMA		27R	27R Segregated Mode:	PWS-D organisation of 103x103 PWS & 20-CAT PWS wake time separations with extended OSD tool support. Reduced Heathrow Westerly route spacing requirements with extended OSD tool support. No dynamic changes to route spacing requirements without an emulated TMA data-feed.

Table 7-47: Solution scenario organisation characteristics

Controller Working Positions

The controller working positions were the same as for the Reference Scenarios (see Section 1 for more details).

Traffic samples

The same traffic samples as in the Reference Scenarios were used for the Solution Scenarios (see Section 1 for more details).

Met samples

The same wind profiles as in the Reference Scenarios were used for the Solution Scenarios (see Section 1 for more details).

3. Summary of Demonstration Exercise Runs

The various Reference and Solution Scenario Demonstration Exercise runs are provided in Table 7-48.

Date	Run	Scenario Category	Runway [dep]	Wind condition
12/09/22	1	RECAT with OSD Tool	09R	Southerly Cross Wind
	2	RECAT with extended OSD Tool – emulated TMA data feed; Abnormal	09R	Southerly Cross Wind
	3	RECAT with extended OSD – with emulated TMA data feed	09R	Southerly Cross Wind
	4	RECAT with extended OSD - no TMA data feed	09R	Southerly Cross Wind
13/09/22	1	PWS with extended OSD Tool - No TMA data feed	27R	Northerly Cross Wind
	2	PWS with extended OSD Tool – emulated TMA data feed	27R	Northerly Cross Wind
	3	PWS with OSD Tool	27R	Northerly Cross Wind
	4	PWS with extended OSD Tool – emulated TMA data feed; Abnormal	27R	Northerly Cross Wind
14/09/22	1	RECAT with OSD	09R	Southerly Crosswind static scenario; 35 mins transition into low cloud; 50mins transition out of low cloud
	2	RECAT with OSD Tool	09R	Southerly Crosswind static scenario; 35 mins transition into low cloud; 50mins transition out of low cloud
	3	RECAT with extended OSD – with emulated TMA data feed	09R	Southerly Crosswind static scenario; 35 mins transition into low cloud; 50mins transition out of low cloud
	4	PWS with OSD Tool	27R	Moderate Headwind
15/09/22	1	PWS with extended OSD Tool - No TMA data feed	27R	Moderate Headwind

Date	Run	Scenario Category	Runway [dep]	Wind condition
	2	PWS with extended OSD Tool – emulated TMA data feed	27R	Moderate Headwind
	3	RECAT with OSD tool	27R	Low Tailwind static scenario; low clouds at 500 feet for entire exercise
	4	RECAT with extended OSD Tool - No TMA data feed	27R	Low Tailwind static scenario; low clouds at 500 feet for entire exercise
16/09/22	1	PWS with extended OSD Tool – emulated TMA data feed	27R	Strong Headwind static scenario; low clouds at 500 feet for entire exercise
	2	PWS with OSD tool	27R	Strong Headwind static scenario; low clouds at 500 feet for entire exercise
	3	PWS with extended OSD Tool – emulated TMA data feed	27R	Strong Headwind static scenario; low clouds at 500 feet for entire exercise
	4	PWS with extended OSD Tool - no TMA data feed	27R	Strong Headwind static scenario; low clouds at 500 feet for entire exercise
20/09/22	1	PWS with OSD tool	27R	Strong Headwind
	2	PWS with extended OSD Tool – emulated TMA data feed; Abnormal	27R	Northerly Cross Wind
	3	PWS with extended OSD Tool – emulated TMA data feed; Abnormal	27R	Strong Headwind
	4	PWS with extended OSD Tool - no TMA data feed	27R	Strong Headwind
21/09/22	1	PWS with extended OSD Tool – emulated TMA data feed	09R	Northerly Crosswind
	2	PWS with extended OSD Tool - no TMA data feed	09R	Northerly Crosswind
	3	PWS with OSD tool	09R	Northerly Crosswind
	4	PWS with OSD tool	09R	Northerly Crosswind

Date	Run	Scenario Category	Runway [dep]	Wind condition
22/09/22	1	PWS with extended OSD Tool - no TMA data feed	09R	Northerly Crosswind
	2	RECAT with OSD Tool	27R	Moderate Headwind static scenario; slow transition into low cloud, update every 10 minutes
	3	RECAT with extended OSD – no TMA data feed	27R	Moderate Headwind static scenario; slow transition into low cloud, update every 10 minutes
	4	RECAT with extended OSD - with emulated TMA data feed	27R	Moderate Headwind static scenario; slow transition into low cloud, update every 10 minutes
23/09/22	1	RECAT with extended OSD – no TMA data feed	27R	Low Tailwind static scenario; low clouds at 500 feet for entire exercise
	2	RECAT with OSD Tool	27R	Low Tailwind static scenario; low clouds at 500 feet for entire exercise
	3	RECAT with extended OSD - with emulated TMA data feed	27R	Low Tailwind static scenario; low clouds at 500 feet for entire exercise
	4	RECAT with extended OSD Tool – emulated TMA data feed; Abnormal	27R	Low Tailwind
26/09/22	1	RECAT with extended OSD – no TMA data feed	27R	Low Tailwind static scenario; low clouds at 500 feet for entire exercise
	2	RECAT with extended OSD Tool – emulated TMA data feed; Abnormal	09R	Southerly Crosswind
	3	RECAT with OSD tool	27R	Low Tailwind static scenario; low clouds at 500 feet for entire exercise
	4	RECAT with extended OSD - with emulated TMA data feed	27R	Low Tailwind static scenario; low clouds at 500 feet for entire exercise

Table 7-48: EXE-PJ.37-W3-004 demonstration /simulation scenario overview.

D.1.4 Summary of Demonstration Exercise #04 Demonstration Assumptions

The assumptions which hold for the PJ.37-W3-01B Departure simulation EXE-PJ.37-W3-004 are summarised in the following table:

Identifier	Title	Type of Assumption	Description	Justification	Impact on Assessment
ASS-37-W3-DEMOR-004-001	Aircraft performance capabilities	Technology	Median performance characteristics as defined by aircraft type in the RTS are sufficiently representative of real aircraft performance .	For realistic simulation environment, and for the ATCOs to effectively assess the algorithm.	High
ASS-37-W3-DEMOR-004-002	Generalisation	RTS Design	Heathrow scenarios (Runways 27R and 09R) are representative of other aerodromes.	To enable RTS results to be extrapolated to other aerodromes.	Medium
ASS-37-W3-DEMOR-004-003	Data Collection	Statistical significance	Where statistical tests cannot be performed due to low sample size, it is assumed that outcomes are still valid indications of real effects associable with the solution.	To enable reliable Demonstration findings to be drawn from the RTS results, taking into consideration any limitations of the demonstration.	High
ASS-37-W3-DEMOR-004-004	Traffic Sample Injection Order	Demonstration Analysis	The simulation start up point of aircraft in the traffic samples are at specific points along the taxiway rather than starting at the stand and follow the actual order taken from operational data from this point onwards.	The concept is not expected to impact on the departure phase between the aircraft leaving the stand and arriving at its holding point.	Medium
ASS-37-W3-DEMOR-004-005	Simulation Configuration	RTS Design	Deviations of CWP setup and other hardware used in the RTS are not introducing significant errors into results, in particular when conducting relative research (reference vs. solution scenario)	To enable an accurate, reliable, informed and meaningful assessment of the concept.	High

Table 7-49: Demonstration Assumptions overview

D.2 Deviation from the planned activities

Several deviations to the planned activities have occurred, as elaborated in the paragraphs below.

The following deviations with respect to the Demonstration Plan [2] are listed below:

Assumptions:

- The assumptions as listed in D.1.4 have been updated from those that were listed in the DEMOP to add further detail and clarity. As they have been amended from the DEMOP the assumptions have also been provided with updated identifiers.

Human Factors Objectives:

- Following on from the production of the DEMOP it was felt from the HF practitioner that the number of Human Performance objectives in the DEMOR was too great, and there would not be sufficient time to report the evidence on all objectives individually. Therefore, the Human Performance objectives were consolidated down to 18, whilst ensuring all of the Human Factors themes were covered adequately.

Operational Feasibility Objective

- Following on from production of the DEMOP, reference to the OSD tool was removed from the Success Criterion as the OSD tool is not being validated as part of EXE-PJ.37-W3-004.

Safety Objectives:

- Following on from the production of the DEMOP, there was a splitting and slight re-wording of the success criteria for the following Safety Objective success criteria CRT-37-W3-DEMOP-SAF1-0008 (additional words are underlined below). This was to ensure that the risk of a Loss of Separation due to optimised route spacing was also assessed.

CRT-37-W3-DEMOP-SAF1-0008: There is evidence that the ITARO Departures Solution does not increase the number of minor wake under-separations and decreases the number of large wake under-separations (i.e., those with potential for severe wake encounters and / or loss of separation) compared to the Reference Scenario

CRT-37-W3-DEMOP-SAF1-0008: There is evidence that the ITARO Departures Solution does not increase the number of route under spacing events relative to the target distance spacing and compared to the Reference Scenario.

- It was agreed that the criteria for minor or major under-separations on the initial departure path in the simulation would be re-defined from:
 - Major under-separation = >10 seconds
 - Minor under-separation = <10 seconds; to:
 - Major under-separation = Infringement of 3NM (LoS)
 - Minor under-spacing = Spacing above 3NM but below target distance spacing.

This change was to reflect that the route spacings are defined as target distance spacings rather than times in the PJ.37-W3-01B Departures solution.

For diverging SID pairs (with a target distance separation of 3.5NM) a minor under-spacing would be $\geq 3\text{NM}$ and $< 3.5\text{NM}$.

For same and similar SID pairs (with a target distance separation of 5.0NM) a minor separation would be $\geq 3\text{NM}$ and $< 5\text{NM}$.

This will be measured using the scientific logs (which can be used to assess the distance between the follower and leader aircraft when the follower aircraft reaches its Delivery Point at 1.5NM from the stop-end of the runway). However, there is a caveat attached to this, that the speed profiles flown by the aircraft in the simulation are often not realistic, therefore this is captured as a simulation limitation in Section 4.5.1.

- Departure-related runway incursions were removed from the measured Success Criteria since it was agreed with the participating controllers that this would not be affected by the PJ.37-W3-01B Departures solution.
- It was also agreed that the following safety evidence should be captured during the simulation from debriefs and questionnaires in addition to the scientific logs recorded in the simulation:
 - During failure/non-nominal scenarios, is the Controller continue to handle the traffic safely and efficiently.
 - Can the Controller notice if the tool is displaying corrupt data (where the information being displayed is still believable but corrupt).
 - Is there any increased potential for wake separation infringement, Controller misinterpretation of the HMI and the potential for other sources of Human Error.

Punctuality Objective

- The success criteria wording for the Punctuality objective as amended from 'Evidence is collected to understand impact on ANSP-attributable delay at the Aerodrome from the Solution Scenario versus the Reference Scenario' to 'There is evidence to show that the ANSP-attributable delay at the Aerodrome is reduced in the Solution scenario versus the reference scenario' to make it consistent with the success criteria with the other performance objectives.
- The Punctuality objective was not able to be measured quantitatively as per the SESAR definition as the RTS data did not contain the relevant information in the scientific logs. Therefore, this objective status is 'not assessed' although a subjective argument is provided, based on expert opinion.

Changes to Demonstration timetable

- Prior to the first Simulation day, a timetable was produced based on the Controllers that had been rostered to attend the simulation. The timetable ensured that a matched experimental design could be completed, as well as some non-matched runs to test non-nominal and failure scenarios. Due to various reasons which are described below, there were a number of changes that were required to be made as the simulation progressed that deviated away from the original timetable. However, it should be noted that according to the statements of the controllers, these had no effects on the measured position:
 - Day 6 of the simulation was timetabled for Monday the 19th of September, however due to this day becoming a public Bank holiday due to the Queens funeral, an

additional day was added the following week, meaning that the simulation ended on Monday the 26th September rather than the 23rd.

- On Day 1 (12th September) of the simulation, one of the controllers was called away for a short period for operational reasons. Therefore, a member of the Demonstration team sat in the GMC position. This was deemed acceptable as the GMC was not a measured position and was not considered to have had a significant impact on the outcome of the demonstration results. In addition, the order of the runs was switched around (Run ID 12 became Run ID 13 and vice versa to ensure the matched runs could be still be completed when the second Controller was available.
- On Day 2 (13th September) of the simulation, a second Controller became unavailable due to operational reasons. Therefore, a member of the Demonstration team sat in the GMC position for all of the runs that day. As mentioned in the previous point, this was deemed acceptable as the GMC was not a measured position and was not considered to have had a significant impact on the outcome of the demonstration results. Also, on this day the order of the runs were switched around from the original timetable, so that the Matched runs could be conducted around the second Controller being available.
- On Day 3 (14th September) of the simulation, the first run of the day was planned to be the first run of a triple matched set. However, at the end of the run, it was realised that the controller had been applying a flow restriction to the incorrect SID. Therefore, this run was repeated for the second run of the day, and the triple matched pair then became a double match.
- On day 4 (15th September) a member of the Demonstration team sat in the GMC position for the second half of the run, and for the final few minutes of the third run due to the GMC Controller being called away for operational reasons.
- On Day 5 (16th September) the first run of the day was planned to be the first run of a triple matched set. However, at the end of the run, it was realised that the controller had been applying a flow restriction to the incorrect SID throughout the exercise. Therefore, the third run of the day (that has been scheduled to be a non-nominal run) was forfeit and the first one was repeated to enable the tripled matched runs to be completed.
- On day 9 (23rd September) one Controller was unable to attend the simulation as originally rostered due to personal circumstances, therefore the GMC position was manned by a Trainee Lighting Panel Operator (LPO). Similarly to the Demonstration team member stepping in for the GMC position, it was not considered to have an impact on the outcome of the demonstration results.
- On day 10 (26th September) one Controller was called away for operational reasons and therefore a member of the Demonstration team stepped in as GMC for a portion of the first run and for half of the second run.

D.3 Demonstration Exercise #04 Results

D.3.1 Summary of Demonstration Exercise EXE-PJ.37-W3-004 Demonstration Results

For a summary of Demonstration Exercise EXE-PJ.37-W3-004 results see Section 4.3.

D.3.2 Analysis of Demonstration Exercise EXE-PJ.37-W3-004 Results per objective

This section presents the results and analysis of Demonstration Exercise EXE-PJ.37-W3-004 per Demonstration Objective. The results in this section are collected from 12 matched sets.

As described in section D.1.3, a comparative assessment has been conducted between the Reference and Solution Scenarios:

Reference Scenarios:

1. RECAT-EU 6-CAT wake time separations with OSD tool organisation (no route spacing tool support).
2. PWS-D solution organisation based on 103x103 PWS and 20-CAT PWS wake time separations with OSD tool support (no route spacing tool support).

Solution Scenarios:

1. Time-Based RECAT-EU with extended OSD tool support with an emulated TMA data-feed.
2. Time-Based PWS-D with extended OSD tool support with an emulated TMA data-feed.
3. Time-Based RECAT-EU with extended OSD tool support without a TMA data-feed.
4. Time-Based PWS-D with extended OSD tool support without a TMA data-feed.

This resulted in two comparative organisations for the Demonstration Exercise, each containing one Reference Scenario and two Solution Scenarios.

Table 7-50 below shows the Run Record for the EXE-PJ.37-W3-004 Demonstration Exercise and details which runs were compared. In total there were 12 matched sets.

The colour coding corresponds to the different matched sets that were conducted:

1	RECAT triple non-integer
2	PWS triple integer
3	RECAT Double non-integer
4	PWS triple integer
5	RECAT Double no MDI
6	PWS Triple non-integer
7	PWS double no MDI
8	PWS triple integer
9	PWS double no MDI
10	RECAT triple non-integer
11	RECAT triple non-integer
12	RECAT Triple integer

Note that non-integer refers to a flow restriction applied to a particular SID with a granularity of less than a minute, e.g. 3m 30s.

Date	Run #	Reference or Solution	Runway	Traffic Sample/Met ID	Met Conditions	Flow Restriction	ATC O Pair #	Air Deps ATCO	GMC ATCO
12/09/22	1	RECAT with OSD	09R	32-09R_11_B_SXZ	Southerly Cross Wind	TMA 5 -09R - 11.05 - 11.45 (DET 1/3.5 MDI)	1	1a	1b
	3	RECAT with extended OSD – with emulated TMA data feed	09R	32-09R_11_B_SXZ	Southerly Cross Wind	TMA 5 -09R - 11.05 - 11.45 (DET 1/3.5 MDI)	1	1a	1b
	4	RECAT with extended OSD - no emulated TMA data feed	09R	32-09R_11_B_SXZ	Southerly Cross Wind	TMA 5 -09R - 11.05 - 11.45 (DET 1/3.5 MDI)	1	1a	1b

Date	Run #	Reference or Solution	Runway	Traffic Sample/Met ID	Met Conditions	Flow Restriction	ATC O Pair #	Air Deps ATCO	GMC ATCO
13/09/22	1	PWS with extended OSD Tool – No emulated TMA data feed	27R	04-27R_09_A_NXZ	Northerly Cross Wind	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	2	2a	Demonstration
	2	PWS with extended OSD Tool – with emulated TMA data feed	27R	04-27R_09_A_NXZ	Northerly Cross Wind	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	2	2a	Demonstration
	3	PWS with OSD Tool - no emulated TMA data feed	27R	04-27R_09_A_NXZ	Northerly Cross Wind	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	2	2a	Demonstration
14/09/22	2	RECAT with OSD	09R	34-09R_11_A_SXS	Southerly Crosswind static scenario; 35 mins transition into low cloud; 50mins transition out of low cloud	TMA 5 -09R - 11.05 - 11.45 (DET 1/3.5 MDI)	3	3a	3b
	3	RECAT with extended OSD – with emulated TMA data feed	09R	34-09R_11_A_SXS	Southerly Crosswind static scenario; 35 mins transition into low cloud; 50mins transition out of low cloud	TMA 5 -09R - 11.05 - 11.45 (DET 1/3.5 MDI)	3	3a	3b
	4	PWS with OSD	27R	07-27R_09_B_MDZ	Moderate Headwind	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	3	3b	3a
	1	PWS with extended OSD Tool - No emulated TMA data feed	27R	07-27R_09_B_MDZ	Moderate Headwind	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	4	4a	4b
15/09/22	2	PWS with extended OSD Tool – with emulated TMA data feed	27R	07-27R_09_B_MDZ	Moderate Headwind	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	4	4a	Demonstration
	3	RECAT with OSD Tool - No emulated TMA Data Feed	27R	11-27R_11_A_LTZ	Low Tailwind static scenario; low clouds at 500 feet for entire exercise	TMA1A	4	4b	4a
	4	RECAT with extended OSD Tool - No emulated TMA data feed	27R	11-27R_11_A_LTZ	Low Tailwind static scenario; low clouds at 500 feet for entire exercise	TMA1A	4	4b	4a
16/09/22	2	PWS with OSD Tool - no emulated TMA data feed	27R	36-27R_11_A_SHS	Strong Headwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	5	5a	5b

Date	Run #	Reference or Solution	Runway	Traffic Sample/Met ID	Met Conditions	Flow Restriction	ATC O Pair #	Air Deps ATCO	GMC ATCO
	3	PWS with extended OSD Tool – with emulated TMA data feed	27R	36-27R_11_A_SHS	Strong Headwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	5	5a	5b
	4	PWS with extended OSD Tool - No emulated TMA data feed	27R	36-27R_11_A_SHS	Strong Headwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	5	5a	5b
20/09/22	1	PWS with OSD Tool - No emulated TMA data feed	27R	13-27R_11_A_SHZ	Strong Headwind	TMA1A	2	2b	2a
	4	PWS with extended OSD Tool - No emulated TMA data feed	27R	13-27R_11_A_SHZ	Strong Headwind	TMA1A	2	2b	2a
21/09/22	1	PWS with extended OSD - with emulated TMA data feed	09R	21-09R_09_A_NXN	Northerly Crosswind	TMA 4 - 09R - 09.05 - 09.35 (CPT 1/4 MDI)	5	5a	5b
	2	PWS with extended OSD Tool - No emulated TMA data feed	09R	21-09R_09_A_NXN	Northerly Crosswind	TMA1B	5	5b	5a
	3	PWS with OSD Tool - no emulated TMA data feed	09R	21-09R_09_A_NXN	Northerly Crosswind	TMA 4 - 09R - 09.05 - 09.35 (CPT 1/4 MDI)	5	5a	5b
	4	PWS with OSD Tool – no emulated TMA data feed	09R	21-09R_09_A_NXN	Northerly Crosswind	TMA1B	5	5b	5a
22/09/22	1	PWS with extended OSD Tool – no emulated TMA data feed	09R	21-09R_09_A_NXN	Northerly Crosswind	TMA 4 - 09R - 09.05 - 09.35 (CPT 1/4 MDI)	5	5a	5b
	2	RECAT with OSD	27R	37-27R_09_B_MDS	Moderate Headwind static scenario; slow transition into low cloud, update every 10 minutes	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	5	5b	5a
	3	RECAT with extended OSD - no emulated TMA data feed	27R	37-27R_09_B_MDS	Moderate Headwind static scenario; slow transition into low cloud, update every 10 minutes	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	5	5b	5a
	4	RECAT with extended OSD – with emulated TMA data feed	27R	37-27R_09_B_MDS	Moderate Headwind static scenario; slow transition into low cloud, update every 10 minutes	TMA 2 - 27R - 09.05 - 09.35 (CPT 1/4 MDI)	5	5b	5a
23/09/22	1	RECAT with extended OSD Tool - no emulated TMA data feed	27R	33-27R_11_A_LTS	Low Tailwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	5	5a	Trainee

Date	Run #	Reference or Solution	Runway	Traffic Sample/Met ID	Met Conditions	Flow Restriction	ATC O Pair #	Air Deps ATCO	GMC ATCO
	2	RECAT with OSD Tool	27R	33-27R_11_A_LTS	Low Tailwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	5	5a	Trainee
	3	RECAT with extended OSD Tool – with emulated TMA data feed	27R	33-27R_11_A_LTS	Low Tailwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	5	5a	Trainee
	1	RECAT with extended OSD Tool - no emulated TMA Data Feed	27R	33-27R_11_A_LTS	Low Tailwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	6	6a	6b
26/09/22	3	RECAT with OSD - no emulated TMA data feed	27R	33-27R_11_A_LTS	Low Tailwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	6	6a	6b
	4	RECAT with extended OSD - with emulated TMA data feed	27R	33-27R_11_A_LTS	Low Tailwind static scenario; low clouds at 500 feet for entire exercise	TMA 3 -27R - 11.35 - 12.00 (DET 1/3.5 MDI)	6	6a	6b

Table 7-50: Run Record for Demonstration Exercise #04

Note in Table 36 any reference to the TMA data-feed supply was through an emulation of TMA data.

1. Analysis of Operational Feasibility Objective

OBJ-37-W3-DEMOP-OPF1-0001

To provide evidence that the ITARO Departures Solution is operationally feasible for the Aerodrome when integrated in a realistic environment in segregated mode.

CRT-37-W3-DEMOP-OPF1-0001

The ITARO Departures Solution is shown to be operationally feasible for the Aerodrome when the IBP is tested in a realistic environment.

The OSD and extended OSD Tool design and usability is considered appropriate by users.

The Operational Feasibility demonstration objective was assessed by three methods:

- Post-exercise debrief discussion with controller participants.
- End-of-day controller questionnaires.
- Post-simulation Expert Workshop discussion.

In order to assess the Operational Feasibility of the solution scenario concept and tool, the key benefits and impacts of the solution scenario are summarised here and grouped into key themes. In addition, a number of issues to be addressed in future iterations of the project are described and where appropriate, recommendations are set out to address them.

Overall Operational Feasibility of PJ.37-W3-01B Departures Solution

The RTS and follow-on post-simulation workshop gathered sufficient evidence from NATS ATCOs to suggest that the PJ.37-W3-01B Departures Solution is operationally feasible for the aerodrome and that the extended OSD tool design and usability is considered appropriate for end users.

Figure 7-52 summarises the results from the end-of-day questionnaire on Operational Feasibility and includes the response of the TMA Observer as well as the participating Tower Controllers.

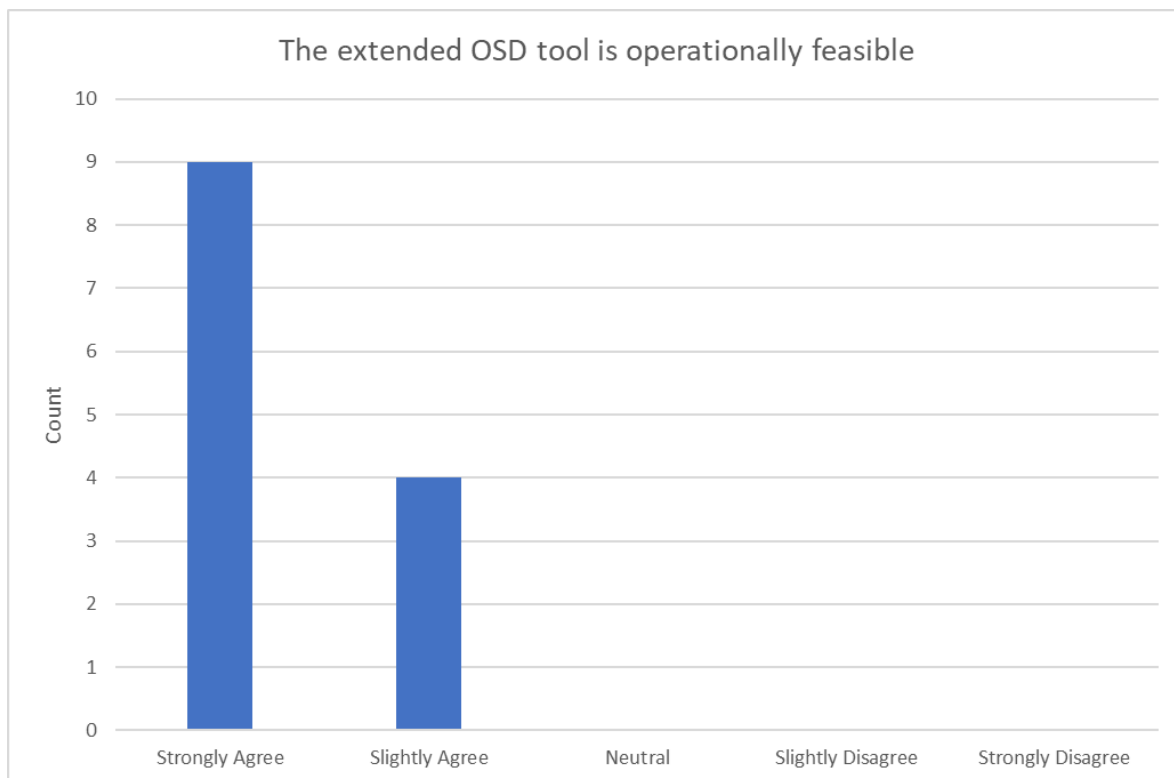


Figure 7-52: Results from end-of-day questionnaire: Operational Feasibility of PJ.37-W3-01B Departures Solution (combined results for Tower and TMA ATCOs).

Figure 7-52 shows that the majority of participating ATCOs strongly agreed with the statement “The extended OSD tool is operationally feasible” in the end-of-day questionnaire and no participating ATCOs disagreed with it. This included the TMA Observer who commented “As the distance the tool is aiming for is adaptable, I see no reason that is not feasible at this stage.”

Comments in the end-of-day questionnaire on the Operational Feasibility of the concept and tool included “Like the concept. Allows for flexibility in departure spacing. Needs HMI updating” and “Reduces workload”.

ATCO Departure Delivery Performance

During the debrief discussions and in the post-simulation workshop, the ATCOs agreed that the extended OSD tool will help less experienced ATCOs to gain confidence in applying spacing reductions, particularly in non-RSVA conditions. They felt this would have the benefit of “bringing the bottom up” in terms of ATCO departure delivery performance, i.e., improve the performance of ATCOs at the lower end of the performance scale.

It was also agreed amongst the ATCOs that the extended OSD tool would help to provide a more consistent flow of traffic into the TMA. One controller mentioned in the post-simulation workshop that “if the tool is reducing everyone to the same numbers in terms of departure separation, then it should be more consistent.”

The controller participants also agreed that an increase in consistency of departure delivery will result in increased predictability to the operation. One controller commented during a debrief session that

“the tool will provide a baseline standard of operations to ATCOs to provide predictability” and another commented that the extended OSD tool would result in a “massive benefit down the line in terms of predictability”. The controllers felt that the tool will provide more robust operations as ATCOs would have more confidence in applying reduced spacings and it would ensure that a minimum number of aircraft would be departed each hour.

It was suggested that the extended OSD tool will be particularly beneficial for Heathrow easterly operations where there is a broad range in departure time spacings applied by different ATCOs.

Efficiency of route spacings provided by extended OSD tool

Figure 7-53 summarises the results from the end-of-day questionnaire on the efficiency of the route spacings provided by the extended OSD tool route countdown timer.

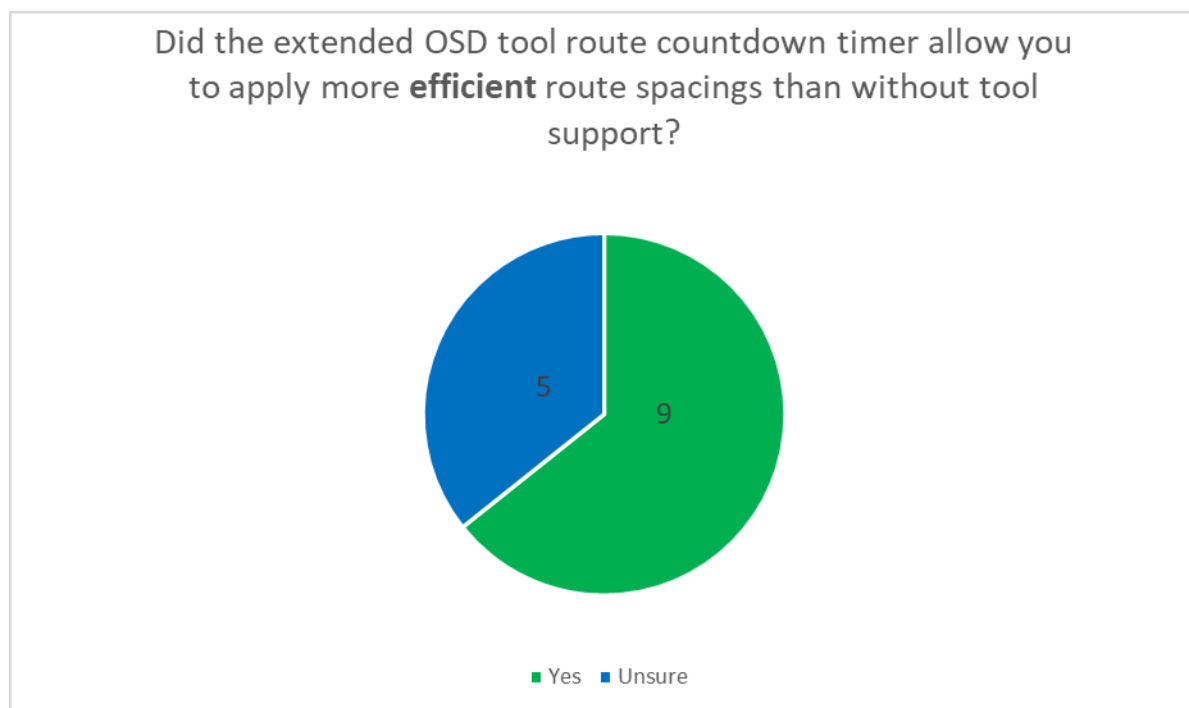


Figure 7-53: Results from end-of-day questionnaire: Efficiency of route spacings provided by extended OSD tool.

Figure 7-53 shows that the majority of participating ATCOs agreed that the extended OSD tool allowed for more efficient route spacings.

The ATCOs commented that they found the tool to provide most benefit on same or similar-SID pairs where the tool allowed them to reduce below the procedural time separation, but some benefit was also observed for some diverging SIDs, e.g., GOGSI/CPT versus MAXIT (see Figure 7-54 below). The controllers commented that for these types of SIDs where there is a portion of common initial departure track before the SIDs diverge (~4NM in the case of GOGSI/CPT versus MAXIT), there is a lot of variation in the departure times applied in the current operation, which is based on the ATCO’s estimation of the time needed to achieve MRS in the prevailing wind conditions and subject to the expected climb performance of the leader and follower aircraft.

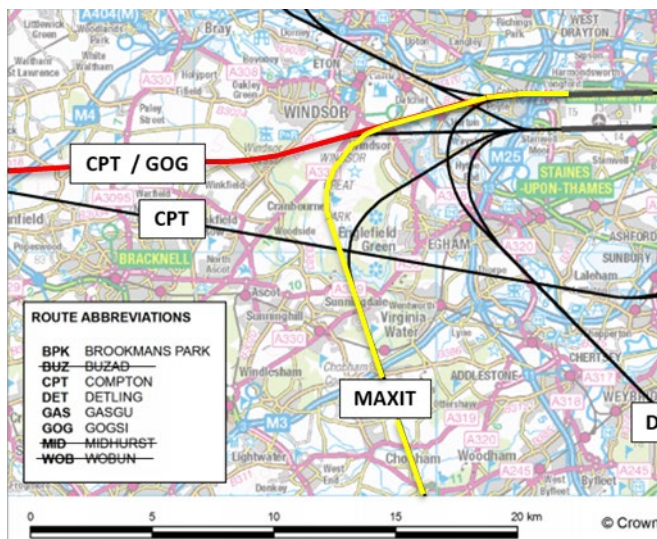


Figure 7-54: Example of diverging westbound GOG/CPT versus southbound MAXIT SIDs.

One ATCO fed back that this was particularly the case for diverging SID pairs “where the leader goes out more widely than the follower”, i.e., the leader follows a SID which follows a turn whilst the follower is on a SID which follows a straight-out path.

One ATCO raised a concern during a debrief session that if the route countdown timer was displaying a larger time than an ATCO would typically apply for a SID pair then there is a risk that the ATCO could get “lazy” and follow the tool rather than applying a permitted Reduced Separation. However, others felt that this was unlikely as most controllers try to be as efficient as possible and maximise runway throughput.

The range of departure time spacings delivered by the ATCO when the extended OSD tool was in use has been compared against the Reference Scenario on a SID-pair basis for each runway direction.

The different categories used for the analysis are as follows:

REF Runs – The Reference Scenario of either PWS or RECAT-EU with the OSD Tool.

SOL1 Runs – Solution Scenario of either PWS or RECAT-EU with the extended OSD tool, with no TMA Data Feed support.

SOL2 Runs – Solution Scenario of either PWS or RECAT-EU with the extended OSD tool and the support of the emulated TMA Data Feed.

Note that the following criteria have been applied to the data:

- Only SID pairs flown in the Solution Runs are included, i.e., if a SID pair was flown in the Reference Scenario, but not either of the Solution Scenarios, it has been excluded.
- All pairs where wake separation was the largest constraint have been excluded.
- All pairs subject to a flow restriction have been excluded.
- All SID pairs where there were less than five data points in either REF, SOL1 or SOL2 have been excluded.
- Aircraft pairs which receive tool support from the route countdown timer (i.e., pairs with a procedural time separation ≥ 2 minutes), but where a reduced form of separation was applied by the controller, such as RSVA, are included.

In addition, it should be noted:

- The delivered separation time displayed reflects the time delivered by the controller rather than the time displayed by on the route countdown timer, i.e., the results include the effect of controller delivery to the tool.
- The route countdown timer is capped at 120s unless there is an applicable flow restriction.

The above criteria have resulted in there being an insufficient number of data points to provide a meaningful comparison between the REF, SOL1 and SOL2 scenarios for any of the same and similar SID pairs for either easterly or westerly operations.

Figure 7-55 shows a comparison of the delivered departure time spacing between REF, SOL1 and SOL2 for diverging SID pairs on westerly operations. The number above each box represents the sample size.

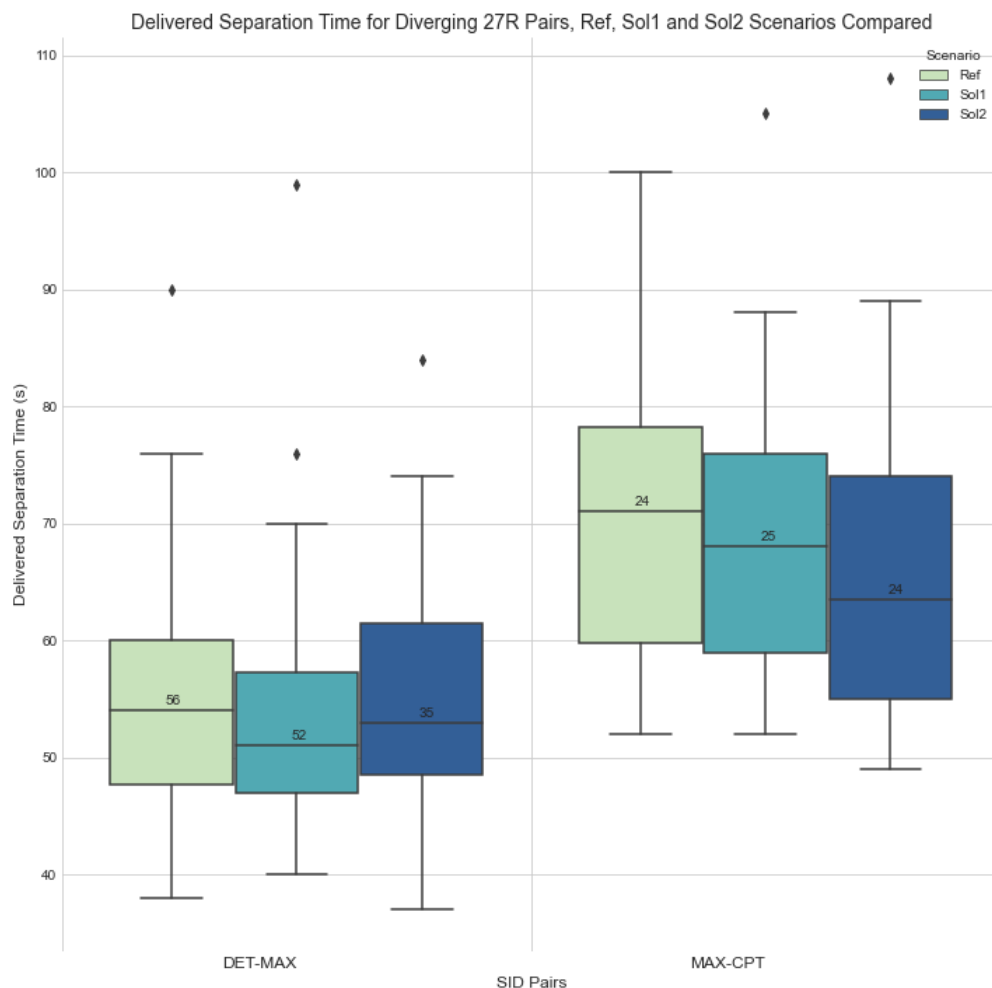


Figure 7-55: Distributions of delivered separation times for diverging SID pairs for westerly operations. Data is only shown for SID pairs flown in the solution runs.

Figure 7-55 shows that the median departure time spacing delivered by the ATCO was lower in the Solution Scenarios than the Reference Scenario for both the DET-MAX and MAX-CPT SID pairs, which

provides supporting evidence that the extended OSD tool assists the ATCO in applying more efficient route spacings. However, it should be noted that in the case of DET-MAX, the ATCOs were consistently applying a form of Reduced Separation, i.e., not following the route countdown timer, whereas for MAX-CPT it was not possible to use RSVA and therefore the route countdown timer was followed more often.

A comparison of the *range* of departure time spacings applied by the ATCOs between REF, SOL1 and SOL2 in Figure 7-55 shows that there is little difference between them; however, as the concept is designed to ensure a greater consistency in the *distance* spacing delivered between aircraft, this may result in a larger variation in *time* spacings applied compared to current operations since the extended OSD tool accounts for variation in wind and aircraft performance.

Figure 7-56 shows a comparison of the delivered departure time spacing between REF, SOL1 and SOL2 for diverging SID pairs on easterly operations. The number above each box represents the sample size.

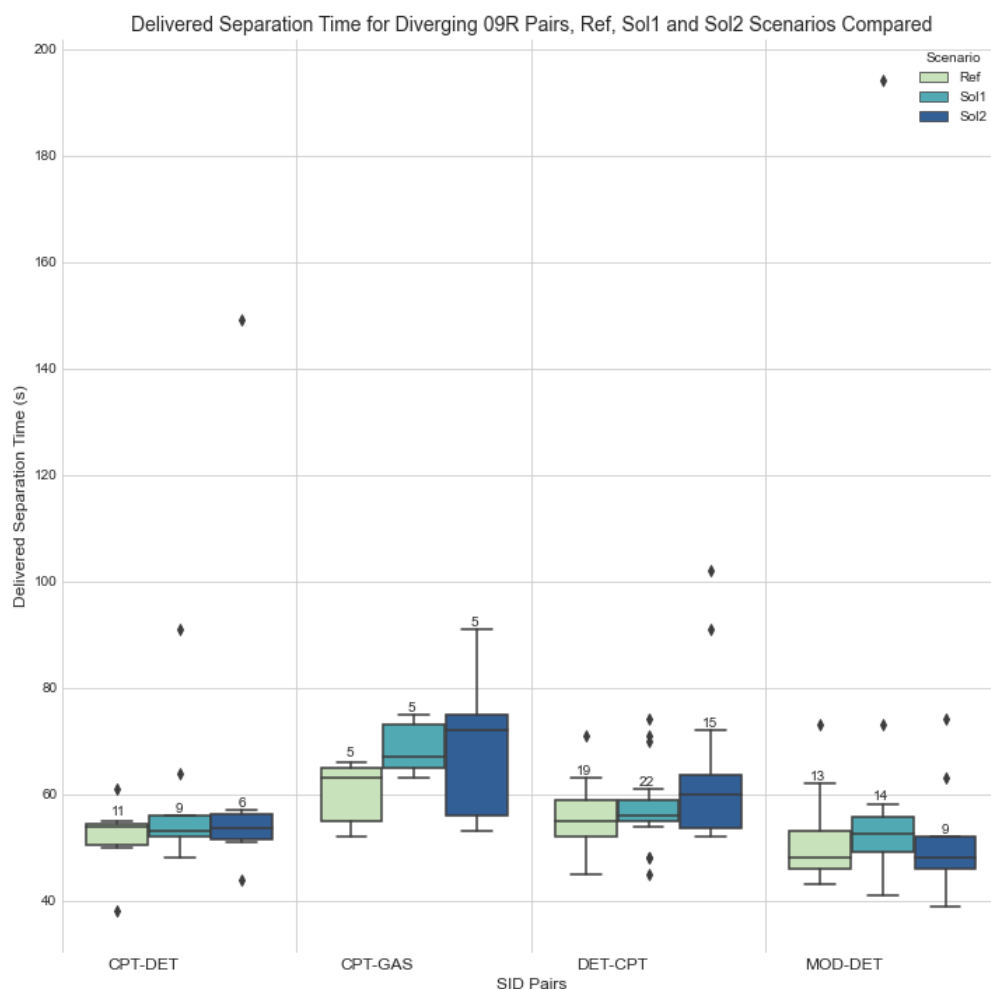


Figure 7-56: Distributions of delivered separation times for diverging SID pairs for easterly operations. Data is only shown for SID pairs flown in the solution runs.

Figure 7-56 shows no clear trend between the departure time spacings delivered for the REF, SOL1 and SOL2 scenarios. However, for all of the SID pairs shown, the ATCOs would generally use RSVA when permitted and were therefore less likely to be following the route countdown timer than for the westerly MAX-CPT SID pair shown in Figure 7-55.

Accuracy of extended OSD tool in delivering target route spacings

Figure 7-57 summarises the results from the end-of-day questionnaire on the accuracy of the extended OSD tool in delivering the target distance spacings.

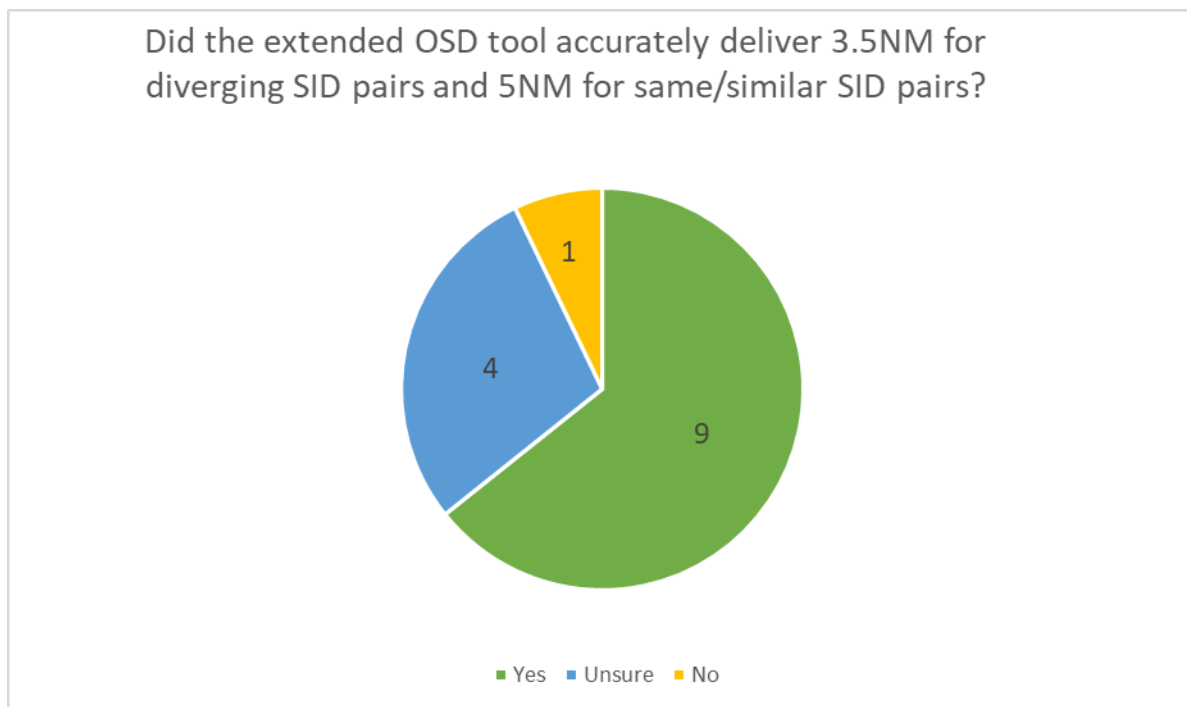


Figure 7-57: Results from end-of-day questionnaire: Accuracy of extended OSD tool in delivering target distance spacings.

Figure 7-57 shows that the majority of participating ATCOs agreed that the extended OSD tool accurately delivered the target distance spacings (3.5NM for diverging SIDs and 5NM for same/similar-SID pairs).

One ATCO commented that the extended OSD tool is more accurate in strong winds compared to the current operation where there is a lot of variation in spacing delivery on departure.

In the questionnaire and debrief feedback, some ATCO participants commented that the tool was overly conservative at times. However, it is not clear whether this related to how accurately the extended OSD tool delivered the target distance spacings or regarding the appropriateness of the target distance spacings themselves.

During the debriefs, some ATCOs commented that the separations felt a bit “tight” in some instances, although monitoring of the ATM radar revealed that the target distance spacing was usually achieved

at the follower aircraft Delivery Point. They felt that this perception may be based on the spacings being applied being smaller than those applied today in some cases.

Analysis of under-spacing events in the DEMO Report Part II (Safety Assessment Report) [18] revealed seven cases in the RTS where less than the target distance spacing was achieved (but the MRS was preserved) and one Loss of Separation (LOS) event. In all eight cases the ATCO applied the time spacing advised by the extended OSD tool (or greater).

It is likely that the accuracy of the extended OSD tool algorithm in predicting the time-to-fly to the Delivery Point for the leader and follower aircraft is influenced by a number of factors, including the accuracy of the wind data (surface and aloft), the aircraft departure speed profiles used by the algorithm, the assumed departure tracks flown by the leader and follower aircraft, and how the algorithm applies a wind correction to the time-to-fly calculation.

Note that in the RTS, the wind profile used by the extended OSD tool was identical to that applied to the aircraft by the simulation, so that should not be a contributing factor to any observed inaccuracies. If the extended OSD tool was implemented in the real operation, however, an accurate source of departure wind aloft data would be required.

This leads to **REC-37-W3-OPF-R1: The extended OSD tool algorithm which calculates the time spacing required to achieve the target distance spacing should be improved by considering the accuracy and appropriateness of the:**

- **Source of wind information aloft used by the extended OSD tool.**
- **Departure tracks used by the extended OSD tool.**
- **Aircraft departure speed profiles used by the extended OSD tool.**
- **Assumptions used by the extended OSD tool about how the time-to-fly of the aircraft is affected by wind.**

During the simulation debrief sessions, the ATCOs commented that there can be a lot of variation in the climb performance of the same aircraft type operated by different airlines (which is not reflected in the simulation environment). This is due to a combination of factors, including the loading of the aircraft (related to the destination), Noise Abatement Departure Procedure flown (1 or 2), and airline-specific Standard Operating Procedures (SOPs) on aircraft settings and management during the departure phase. The extended OSD tool currently uses the observed median departure speed profile per aircraft type as an input and it does not consider the impact of airline. This leads to **REC-37-W3-OPF-R2: The feasibility of including the impact of individual airline behaviour on the time-to-fly calculation should be considered as part of future extended OSD tool development.**

During the post-simulation workshop, there was a discussion about how the extended OSD tool algorithm could be improved by considering the whole geometry of the SID pair rather than just using a single Delivery Point for the time spacing calculations. This would help to mitigate the potential for catch-up in cases where there is a convergence of the leader and follower SIDs after the leader's Delivery Point, e.g., in the case of the MODMI and GASGU SIDs on 09R and MAXIT and DETLING SIDs on 27R. This leads to **REC-37-W3-OPF-R2: The feasibility of considering the whole geometry of the SID pairs rather than single Delivery Points should be considered as part of future extended OSD tool development.**

Appropriateness of target route spacings provided by extended OSD tool

Figure 7-58 summarises the results from the end-of-day questionnaire on the appropriateness of the route spacings provided by the extended OSD tool route countdown timer.

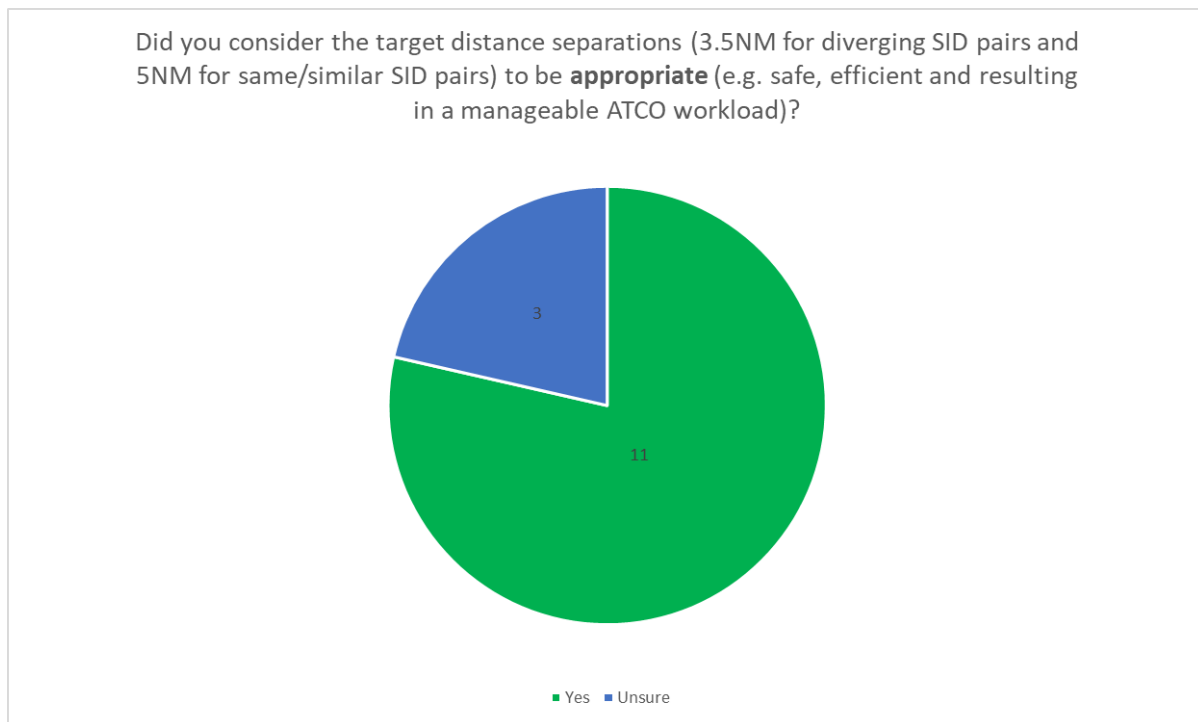


Figure 7-58: Results from end-of-day questionnaire: Appropriateness of route spacings provided by extended OSD tool.

Figure 7-58 shows that the majority of participating ATCOs responded that the target distance spacings (3.5NM for diverging SIDs and 5NM for same and similar SIDs) were appropriate (note that at least one of the 'Unsure' responses was due to the participant having used the OSD (wake support) tool only on that day). This was also confirmed by the TMA Observer; however, they noted that more same and similar SID pairs would be needed to assess this issue ("More 2 min pairs would be good to properly assess this area"). This observation leads to **REC-37-W3-OPF-R4: Future demonstration exercises should use traffic samples which are conducive to same/similar SID pairs being created in the departure sequence, whilst remaining realistic.**

The TMA Observer also noted that "There were no major issues observed with presentation to the TMA.....more focused testing based on objectives for the TMA will be required at some point". This observation was supported by a participating Tower ATCO, who commented "This is fundamentally a TC issue though as to what they can accept". This observation leads to **REC-37-W3-OPF-R5: Future demonstration exercises should test integration of air traffic departing from the aerodrome using the extended OSD tool with wider TMA traffic.**

Finally, there was a consensus amongst the Tower and TMA controllers that although the target distance spacings used in the RTS were appropriate, the Delivery Points may need refining on a SID pair basis in future iterations of the concept once integration with TMA traffic has been tested, i.e., not a blanket application of 3.5NM for all diverging pairs and 5NM for all same and similar-SID pairs. This observation leads to **REC-37-W3-OPF-R6: There should be flexibility to tailor the target distance spacings on a SID pair basis in future demonstration exercises.**

Benefit of extended OSD tool in non-RSVA conditions

Figure 7-59 summarises the results from the end-of-day questionnaire on the perceived benefit of the extended OSD tool route countdown timer in non-RSVA (i.e., non-visual conditions).

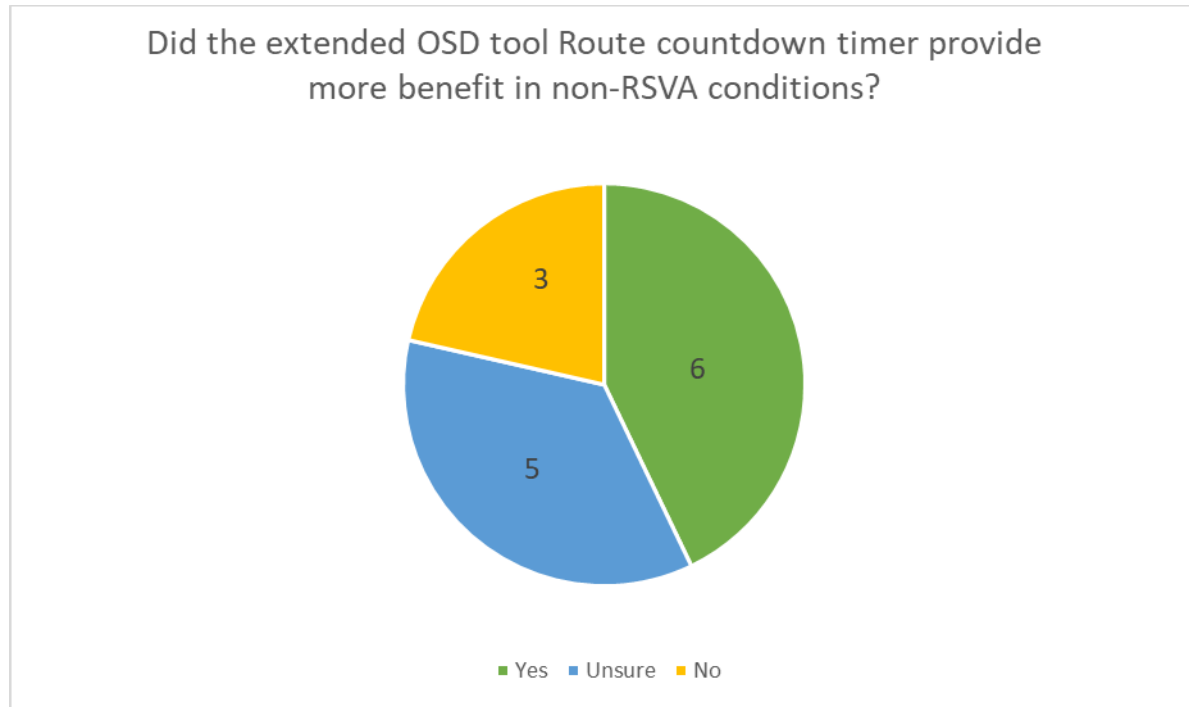


Figure 7-59: Results from end-of-day questionnaire: Benefit of extended OSD tool in non-RSVA conditions.

Figure 7-59 shows that just over half of participating ATCOs responded that the extended OSD tool provided more benefit in non-RSVA conditions. This is because under RSVA conditions, the ATCOs have the option to apply a reduced visual separation (which may be less than MRS), which isn't permitted during low visibility conditions. As a result, in the current operation there is a large variability in the time spacing applied to departures during non-RSVA conditions with some ATCOs building in extra conservatism to ensure the minimum lateral separation is achieved between the leader and follower aircraft. In the debrief discussions and post-simulation workshop, the ATCOs agreed that the extended OSD tool would give these ATCOs the confidence to reduce the departure time spacing with the reassurance that the target spacing would be achieved. One ATCO commented in the end-of-day questionnaire that "You could rely on hitting the required distance" using the extended OSD tool in non-RSVA conditions.

One ATCO responded that they would not use the extended OSD tool when using RSVA and this may have prompted their "No" response; however, this is likely a misinterpretation of the meaning of the question. There were no other comments provided that helped to provide insight on why the remaining two ATCOs would not find the extended OSD tool of more benefit in non-RSVA conditions.

Note that at least one of the "Unsure" responses was due to the participant having used the OSD (wake support) tool only on that day.

During each exercise run, the Air Departures Controller was asked to note when they were applying a reduced form of departure separation, such as RSVA, where they were applying a smaller spacing than

advised by the route countdown timer. Figure 7-60 shows the split between the cases where the controllers followed the tool versus applied a reduced separation on a SID pair basis for 27R departures (left) and 09R departures (right).

Note that Figure 7-60 is not expected to provide a perfect representation of when the extended OSD tool was followed as it was noted there were occasions when the Air Departures Controller forgot to note that they were applying a reduced separation; however, the charts provide an indication of which SID pairs the route countdown timer was most useful for.

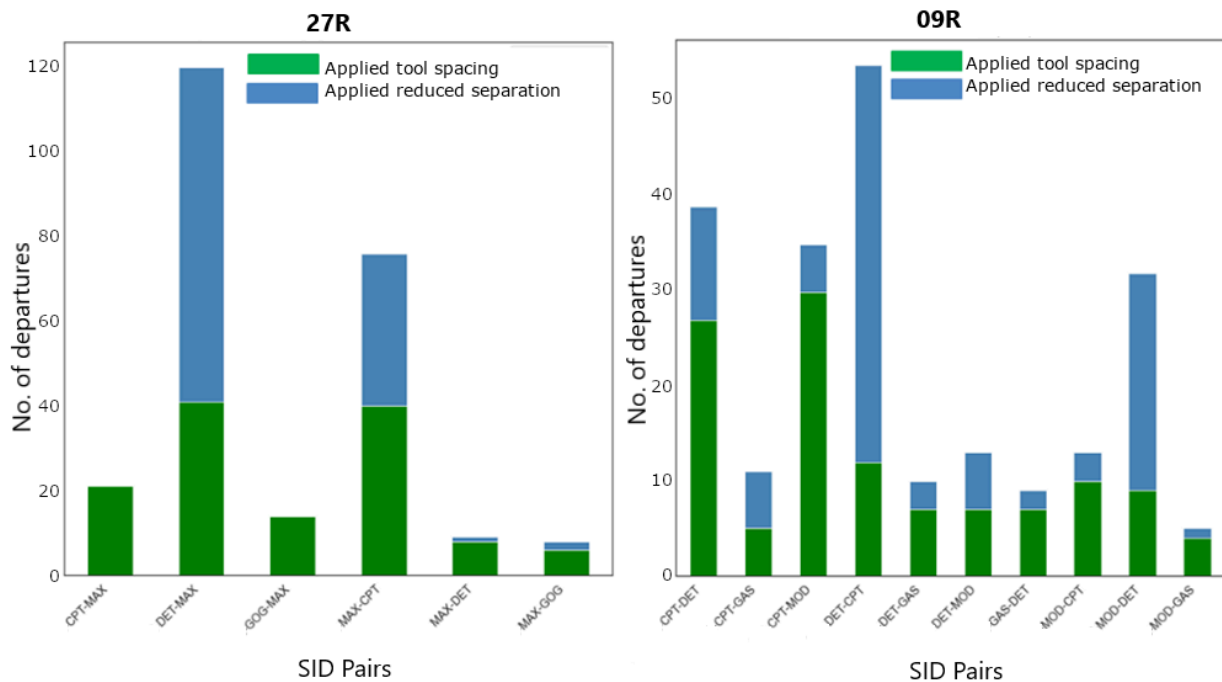


Figure 7-60: Departures where ATCOs reported they used a reduced form of separation during the solution runs for 27R operations (left) and 09R operations (right).

Figure 7-60 reveals that the controllers frequently applied a reduced separation on DET-MAX and MAX-CPT on westerlies and DET-CPT and MOD-DET on easterlies. All of these SID pairings have good divergence and therefore allow the application of RSVA procedures. It is expected, therefore, that the extended OSD tool countdown timer will provide less benefit for these pairs compared with other diverging SID pairings, such as CPT-MAX (westerly) and CPT-MOD (easterly) where the aircraft follow an initial part of the track which is common to both SIDs before diverging. This conclusion aligns with feedback from the controllers who commented in the end-of-day questionnaire that they perceived the extended OSD tool to have more benefit on SIDs such as CPT-MAX and CPT-MOD, which have less opportunities to apply reduced separation.

Inclusion of route flow restrictions in route countdown timer

Figure 7-61 summarises the results from the end-of-day questionnaire on the acceptability of including the route flow restriction into the route countdown timer.

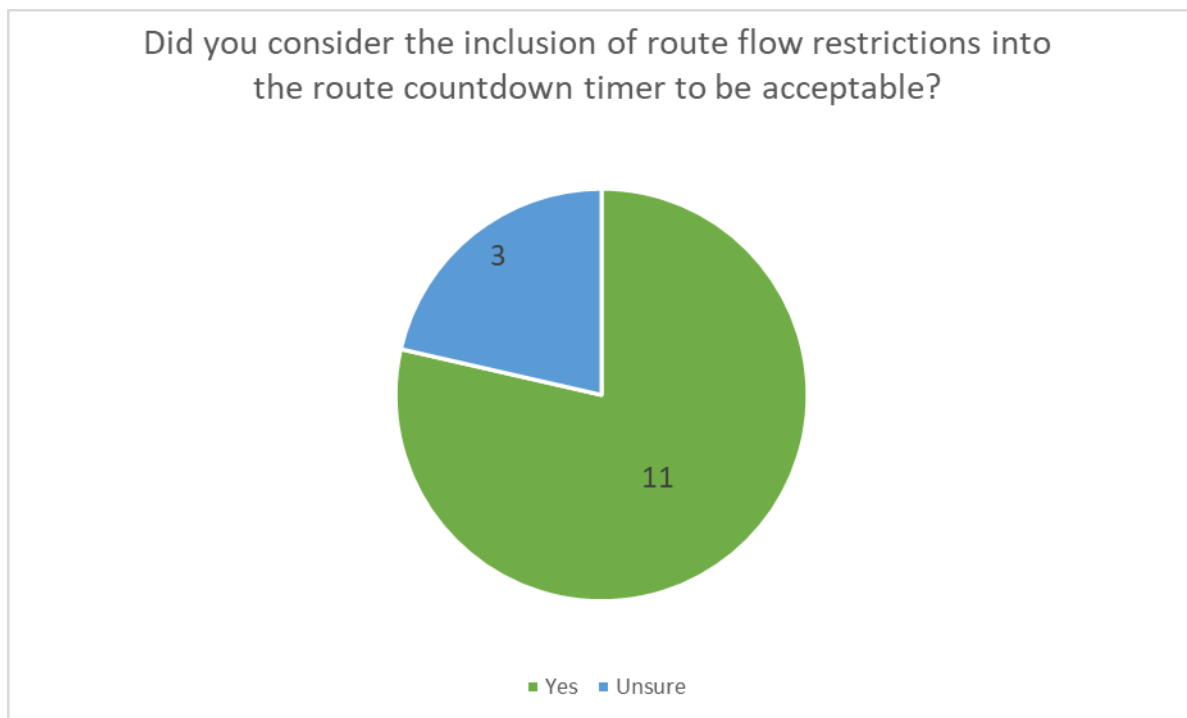


Figure 7-61: Results from end-of-day questionnaire: Inclusion of route flow restrictions into extended OSD tool route countdown timer.

Figure 7-61 shows that the majority of participating ATCOs responded that the inclusion of route flow restrictions into the route countdown timer was acceptable.

The inclusion of the SID flow restrictions into the route countdown timer was considered to be a “great help” by the participating ATCOs. They commented that it reduced their mental workload as this aspect no longer needed to be mentally calculated by the ATCO and the extended OSD tool also allowed more granular flow restrictions to be applied (i.e., not constrained to integer minutes). The ATCOs commented that this would result in a huge benefit to the operation on days where there are several flow restrictions applied due to, e.g., bad weather. One ATCO commented that a non-integer flow restriction, such as the 3m30s restriction emulated in the RTS, would be useful as “3 minutes is not (always) enough for the TMA controllers, but 4 minutes is too restrictive for (efficient) departures”. It was felt that the inclusion of the TMA data-feed would allow for greater flexibility in departure spacing.

Note that at least two of the ‘Unsure’ responses was due to the participant not having used the TMA data-feed element of the extended OSD tool that day (i.e., SOL2).

Reduction in Workload

There was a consensus amongst the ATCOs in the debrief sessions and post-simulation workshop that the extended OSD tool would help to reduce controller workload. One ATCO commented that the timer was helpful because it “reduced the metal arithmetic required when calculating airborne times”. Another ATCO found the tool support “allowed more time for other tasks and provided more opportunities to plan ahead with the departure sequence”.

One ATCO commented in a debrief session that the route countdown timer provides a visual reminder of when action needs to be taken and also how many other tasks can be achieved before issuing a

take-off clearance. They also observed that the tool served to validate the spacing they were going to apply.

A more detailed assessment of the impact of the extended OSD tool on workload can be found in the DEMO Report Part III (Human Performance Assessment Report) [19].

Acceptability of countdown timers

Figure 7-62, Figure 7-63 and Figure 7-64 summarise the results from the end-of-day questionnaire on the acceptability of the countdown timers and associated HMI (use of separate timers, indicator for underlying wake separation and timeliness of information provision on countdown timer, respectively).

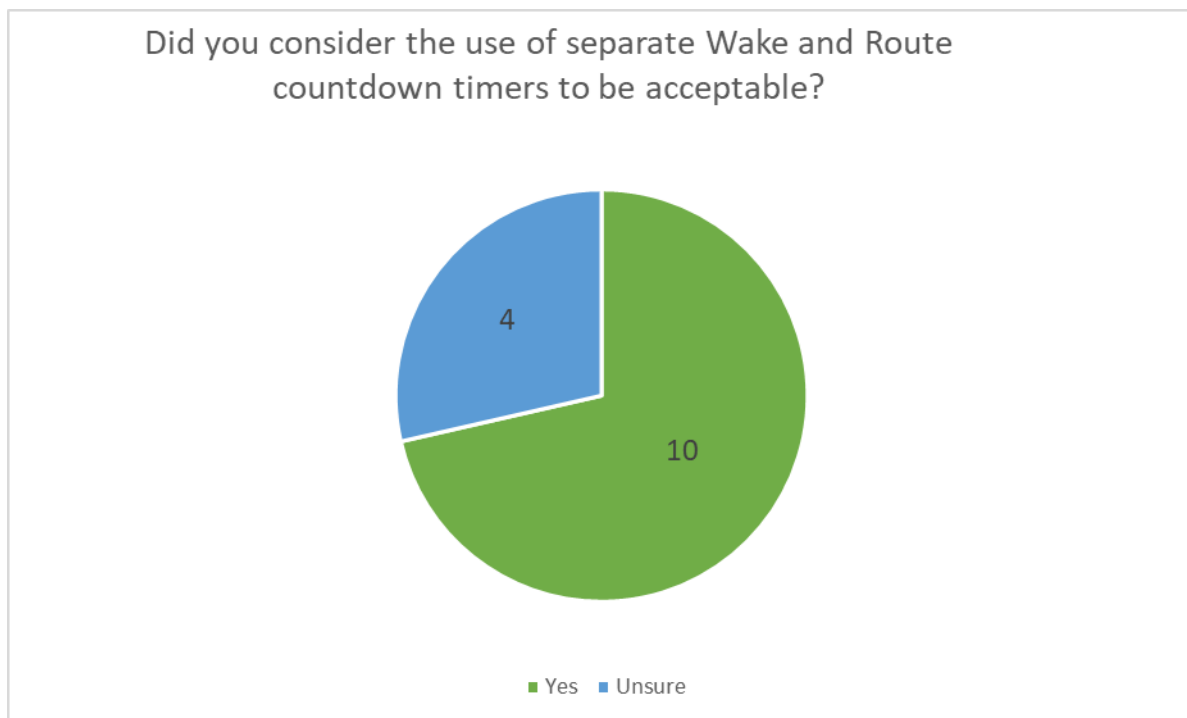


Figure 7-62: Results from end-of-day questionnaire: Acceptability of separate Wake and Route countdown timers.

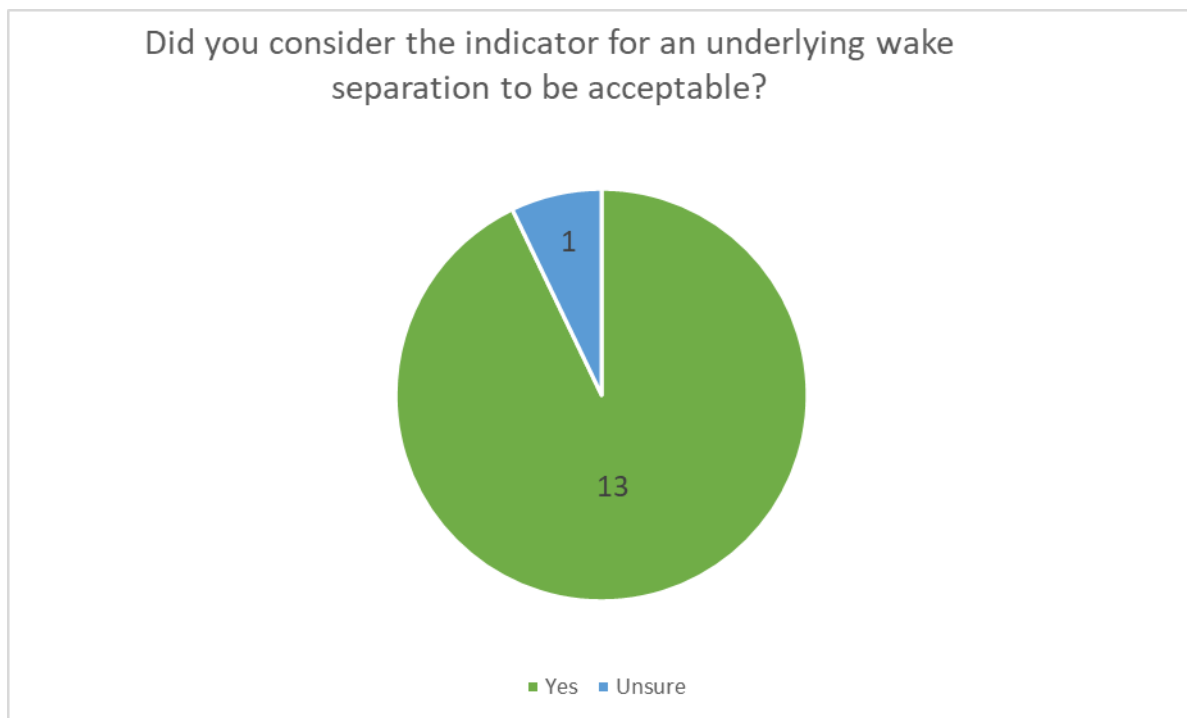


Figure 7-63: Results from end-of-day questionnaire: Acceptability of indicator for underlying wake separation.

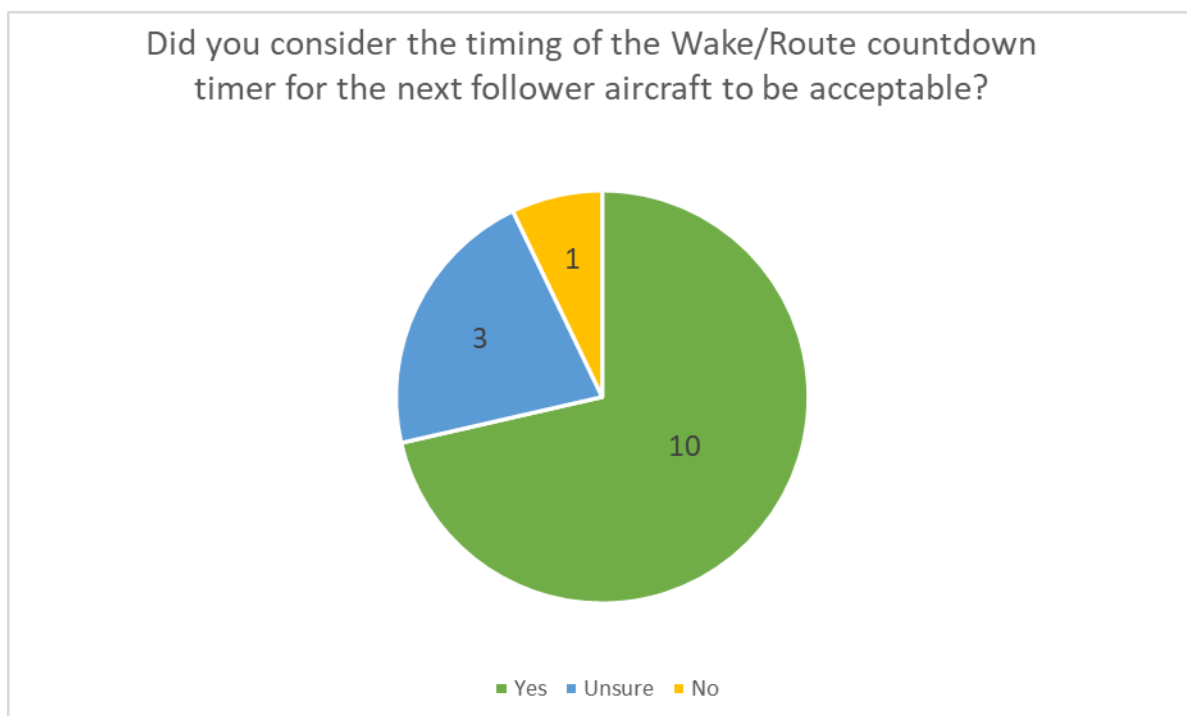


Figure 7-64: Results from end-of-day questionnaire: Acceptability of timing of Wake/Route countdown timer for next follower aircraft.

Figure 7-62 and Figure 7-63 show that the use of separate countdown timers for applying wake separations and route spacings/flow restrictions was considered acceptable to most controllers. In addition, the use of a symbol next to the route countdown timer to indicate an underlying wake separation was also considered useful. The countdown timers were stated to be a useful “visual reminder of the main task in hand”.

During the feedback sessions, the ATCOs provided comments about how the extended OSD tool HMI could be improved, but note that this was in the context of their experience of using the tool in the simulation environment (e.g. HMI only available on ADIS), which they acknowledged would be different to the tool HMI that would go into operation (the intended design is for the countdown timer to be placed on the EFPS).

Several ATCOs commented that they were unable to distinguish from the route countdown timer HMI whether “the route restriction was due to route or MDI” (where the latter is a separation that cannot be reduced) and that they would like to see this included in any future developments of the extended OSD tool. This was considered important to the ATCOs as they need the information to assess whether a reduced separation, e.g., RSVA can be used (which is not permitted if a route flow restriction applies). This leads to **REC-37-W3-OPF-R7: Future versions of the extended OSD tool should differentiate between route spacings and route flow restrictions on the controller’s HMI.**

Additionally, the ATCOs requested that route countdown timer HMI differentiated between a route spacing that applied between a follower aircraft and the leader’s leader (i.e. Aircraft 1 and 3 in the departure sequence) when flying the same or similar routes (and hence requiring 5NM spacing) as opposed to the leader and follower aircraft which may be flying diverging SIDs and hence be eligible for a reduced separation. This leads to **REC-37-W3-OPF-R8: Future versions of the extended OSD tool should differentiate between whether the time on the route countdown timer applies to the current leader-follower pair or the follower and the aircraft ahead of the leader.**

The ATCOs commented in the debriefs and in the end-of-day questionnaires that they would like the countdown timers to be available on the individual electronic flight strips, although some ATCOs also liked it on the ADIS display, so the possibility of having it located on both should be further investigated. This leads to **REC-37-W3-OPF-R9: Future versions of the extended OSD tool should locate the wake and route countdown timers on the electronic flight progress strips, as well as investigate the option to go on ADIS.**

Figure 7-64 shows that some of the ATCOs did not find the timing of the information appearing on the countdown timers to be acceptable. The ATCOs commented in the debriefs that they would find it useful if the countdown timer could reach zero before it refreshed to show the time applicable to the next follower aircraft. This is so that they could measure their performance in estimating the roll time of the follower aircraft.

The refreshing of the countdown timer information was a limitation of not being able to display the countdown timers on the individual flight progress strips in the simulation and being limited to the ADIS. This issue is addressed by REC-37-W3-OPF-R6 above since locating the countdown timers on the electronic flight strips would not require a single timer to refresh every time a new aircraft enters the runway.

A detailed analysis of the acceptability of the extended OSD tool design can be found in the DEMOR Part III (Human Performance Assessment Report) [19].

Future airspace design

During the Post-Simulation Workshop in discussion with ATCOs, the extended OSD tool was predicted to provide a large benefit upon the introduction of new SID structures where the controllers would have less experience and familiarity with the spacing to apply.

2. Analysis of Human Performance Objectives

See tables within Section 4.3 for the high-level results and see the DEMOR Part III (Human Performance Assessment Report) [19] for the detailed analysis and results.

3. Analysis of Capacity Objective

OBJ-37-W3-DEMOP-CAP1-0004

To assess the improvement in airport capacity due to the ITARO Departures Solution versus the Reference Scenario

CRT-37-W3-DEMOP-CAP1-0004

Evidence shows an increase in maximum hourly operational runway throughput for departures in the Solution Scenario versus the Reference Scenario

Departure throughput indicates the number of departures that get airborne in an hour. The departure throughput for each run was calculated by:

$$\text{Throughput} = \frac{\text{Number of Movements} - 1}{\text{Last Airborne Time} - \text{First Airborne Time}}$$

Figure 7-65 shows the departure throughput for each run within a matched set (either a triple or double match). In the graph the different categories are as follows:

REF Runs – The Reference Scenario of either PWS or RECAT-EU with the OSD Tool.

SOL1 Runs – Solution Scenario of either PWS or RECAT-EU with the extended OSD tool, with no TMA Data Feed support.

SOL2 Runs – Solution Scenario of either PWS or RECAT-EU with the extended OSD tool and the support of an emulated TMA Data Feed.

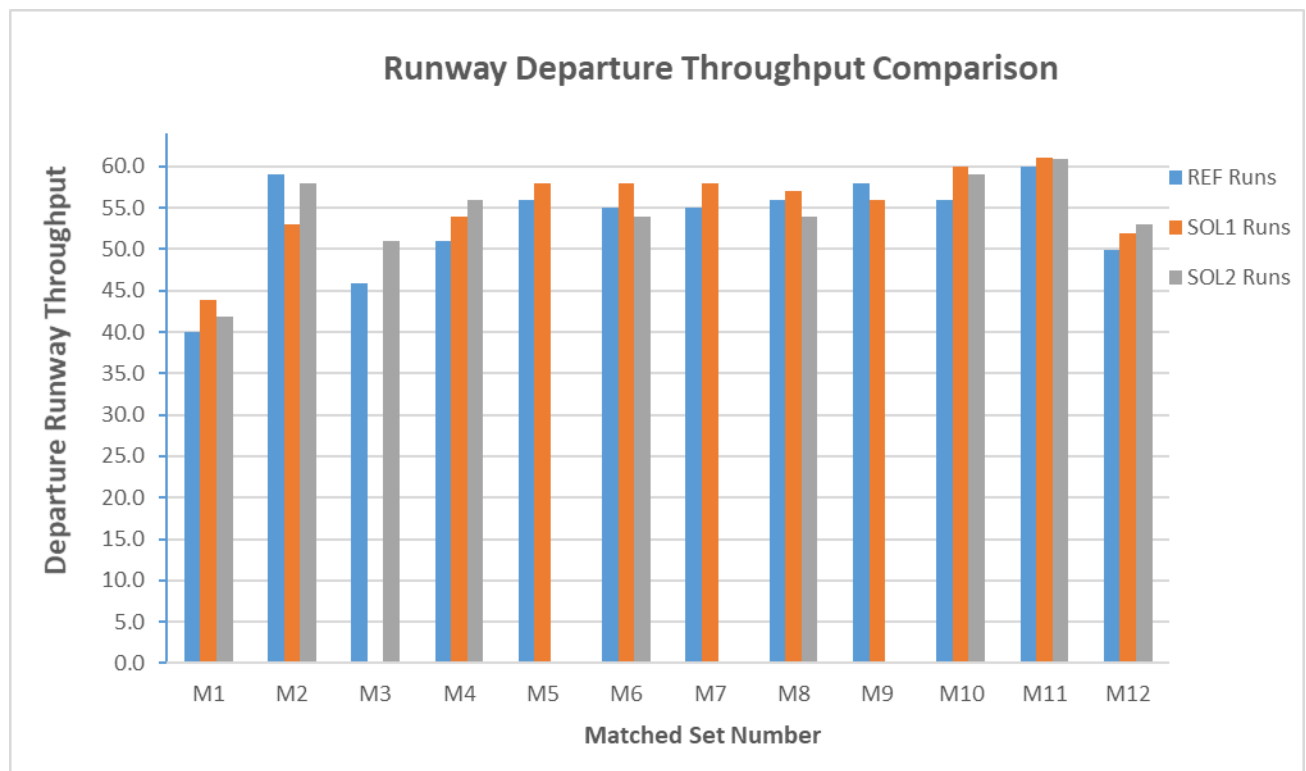


Figure 7-65: Runway Departure Throughput Comparison - All Matched Sets

From examining the Runway Throughput Comparison analysis in Figure 7-65, it shows that SOL1 achieved a higher throughput than the REF in 9 out of 11 matches. SOL2 achieved a higher throughput than the REF in 7 out of 10 matches. SOL2 achieved an equal or higher throughput in SOL1 in 4 out of 8 matches. There is no clear trend observed of an incremental increase in throughput from REF – SOL1 – SOL 2 across the triple matched pairs; however, there is an incremental increase in throughput for REF – SOL1 – SOL2 in 2 out of 9 matches (M5 and M12).

A lower throughput in M1 compared to the other matches was found. This can be attributed to the ATCO who was sat in the Air Departure seat requiring time to re-familiarise with the more complex and less often used Easterly operations at Heathrow.

For two matches (M2 and M9), the Reference Scenario achieved a higher throughput than the Solution Scenarios. The ATCOs reported that this was due to the impact of learning the traffic sample, as they were exposed to the same traffic sample across a number of consecutive runs during the same day in order to achieve the matched comparison experimental design. This learning effect helped the ATCO to be more efficient, as they knew what was coming up in the traffic sample and therefore could improve if possible on the order in which they departed the aircraft than in the previous run. This can be seen in M2 and M9 where the reference run was conducted after the solution runs. However, the experimental design was such that the order in which the reference and solution runs were conducted were mixed up in an attempt to mitigate against the learning effect. Another factor that must be considered when examining the capacity results is the improvements that are recommended to be made to the algorithm that calculates the required separation between the leader and follower aircraft (refer to previous section 1).

When the ATCOs were asked during the post simulation workshop if they were able to quantify the impact of the learning effect on the Capacity metric, they did not feel that this was possible with a high degree of accuracy. However, when asked for their feedback on whether the concept would bring about an increase in capacity, taking into account improvements made to the algorithm, one ATCO commented that he thought the benefit would be in the region of one to two aircraft an hour, and the other ATCOs concurred.

When examining the average Runway Departure throughput, an increase can be seen between the Reference and Solution 1 and Reference and Solution 2 (see Figure 7-66).

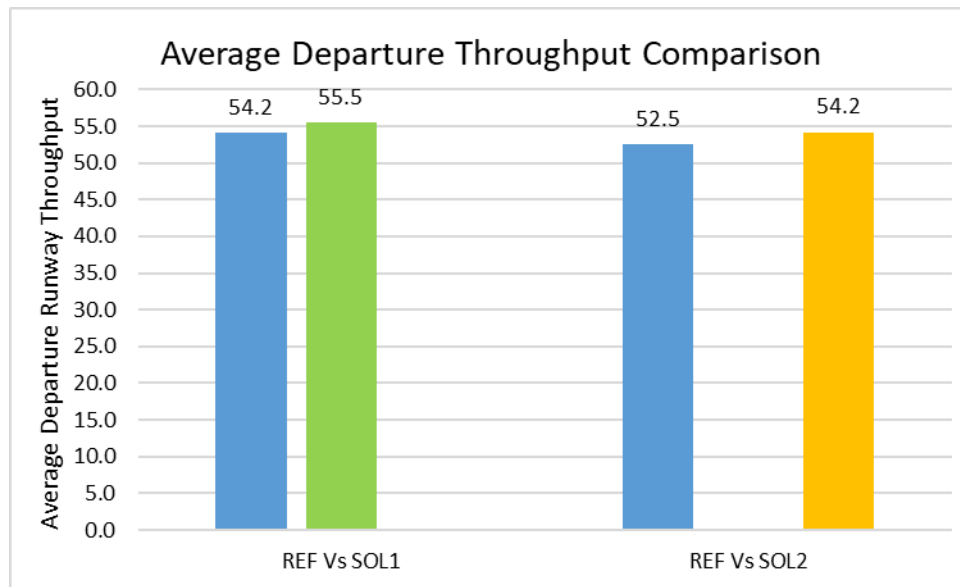


Figure 7-66: Average Departure Throughput Comparison REF V SOL1 and REF V SOL2

When comparing REF with SOL1 an increase of 1.3 movements an hour is seen (2.4%). When comparing REF with SOL2 an increase of 1.7 movements can be seen (3.2%). This correlates with the ATCOs estimate of an increase in movements of 1-2 per hour.

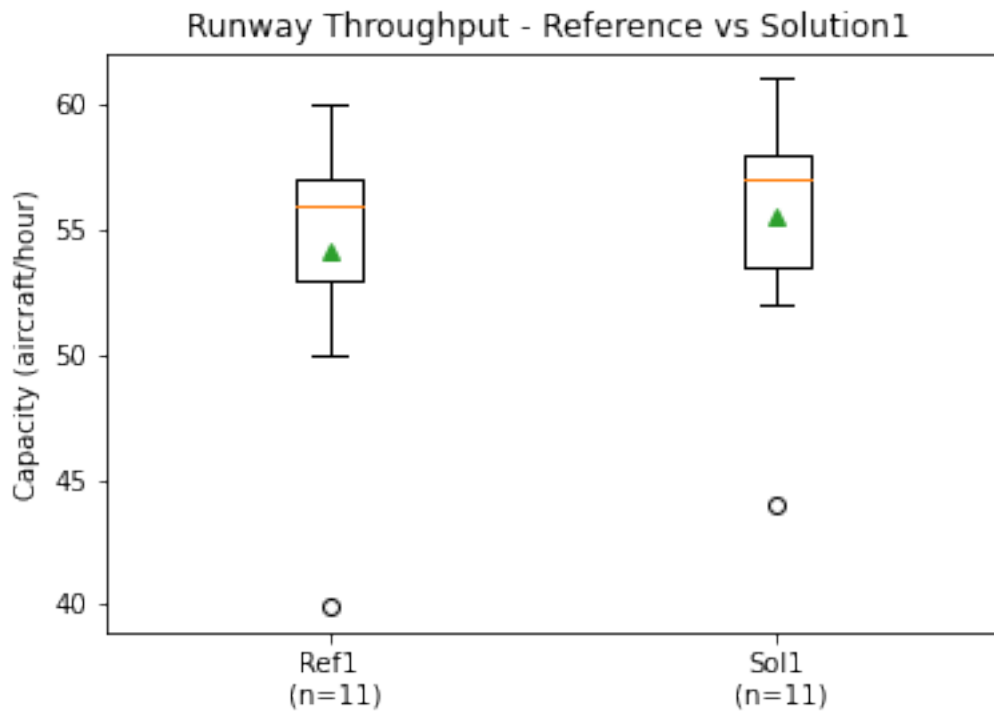


Figure 7-67: Departure Runway Throughput comparison REF Vs Solution 1

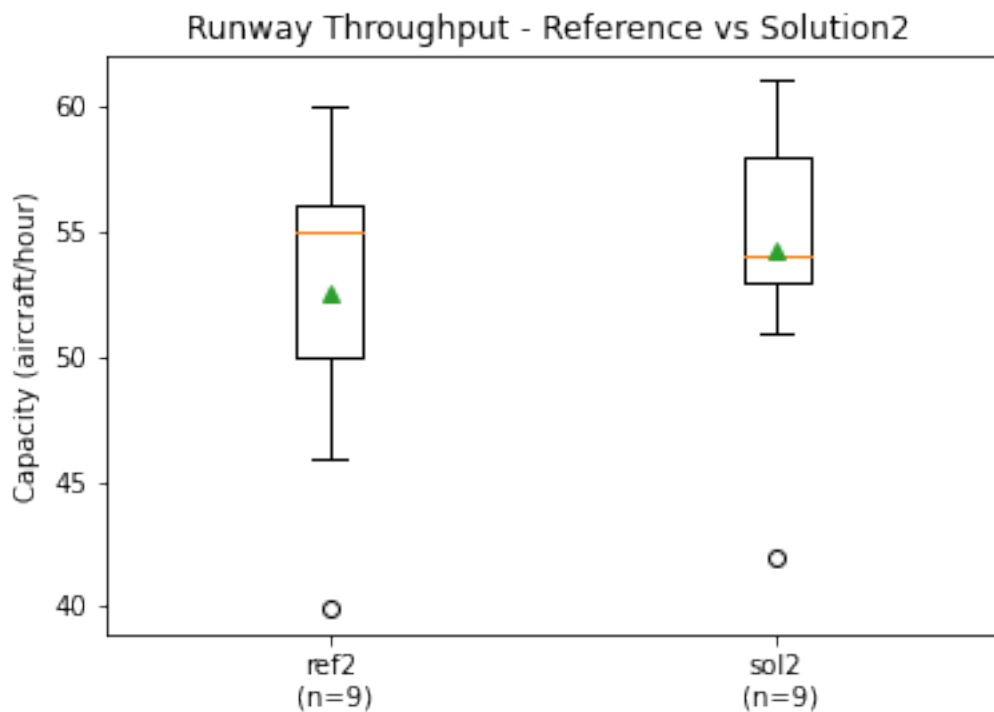


Figure 7-68: Departure Runway Throughput Comparison Reference Vs Solution 2

Figure 7-67 and Figure 7-68 show a more detailed picture of the departure runway throughputs. The orange lines in the boxes are the median values for the average throughput. The median values for Solution 1 is higher than the Reference (57 compared to 56). Although the median value is lower for Solution 2 than the Reference (54 compared to 55), the average value (as depicted by the green triangle) is higher for Solution 2 than the Reference.

The size of the boxes show the range of the throughput for each solution. Again, both figures show the range of throughput was higher than the Reference for both Solution 1 and Solution 2.

The circles denote outliers, and the outlier in the data was due to the lower throughput achieved in Match 1 as explained previously.

Paired t-tests have been carried out on the runway throughput data samples.

The t-test for Solution 1 versus Reference did not provide evidence of a significant difference between the two ($t = -1.52$, $p = 0.16$).

The t-test for Solution 2 versus Reference did provide evidence of a significant difference the two at 90% confidence ($t = -1.90$, $p = 0.09$).

Summary:

The data analysis shows that there is an increase in capacity when comparing the Reference Scenario with Solution 1 and the Reference Scenario with Solution 2, which is corroborated with feedback from the ATCOs that they would expect to see an increase of around 1-2 aircraft per hour. The results of the statistical test show that the difference between Solution 1 and Reference is not significant, whereas the difference between Solution 2 and Reference is significant.

Although the ATCOs reported a learning effect from being exposed to the same traffic sample numerous times, this was mitigated as much as possible by mixing up the order of the runs in which the Reference, Solution 1 and Solution 2 were conducted. Feedback from the ATCOs indicated that even given the limitations of the simulation they believed that the concept (with recommended algorithm improvements) would bring about an increase of capacity.

RECAT and Pairwise Split

Although both RECAT and Pairwise Wake Turbulence schemes were used in this demonstration exercise, analysis has not focussed on the comparison between the two, as this evaluation was conducted in RTS5 in Wave 1 [12] However, for completeness, the results of the split between RECAT and Pairwise and both Solution 1 and Solution 2 have been provided below:

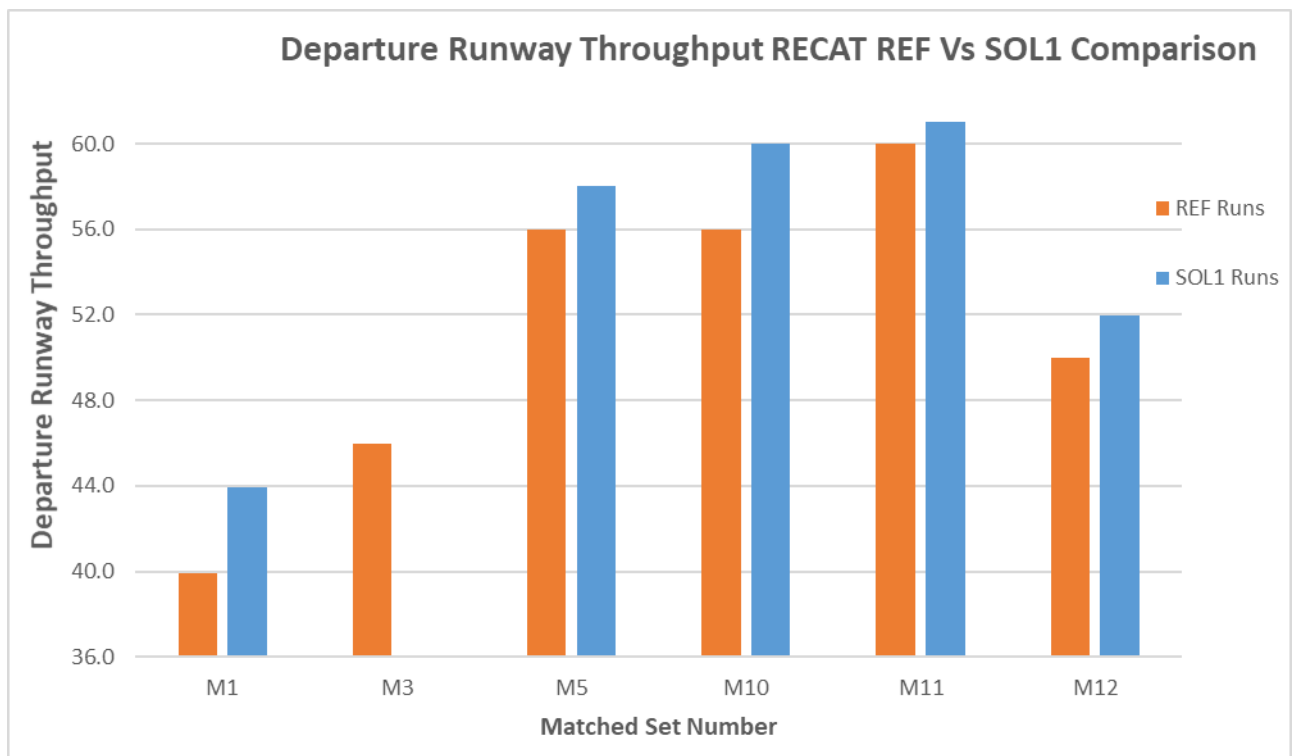


Figure 7-69: Departure Runway Throughput RECAT REF Vs SOL1 Comparison

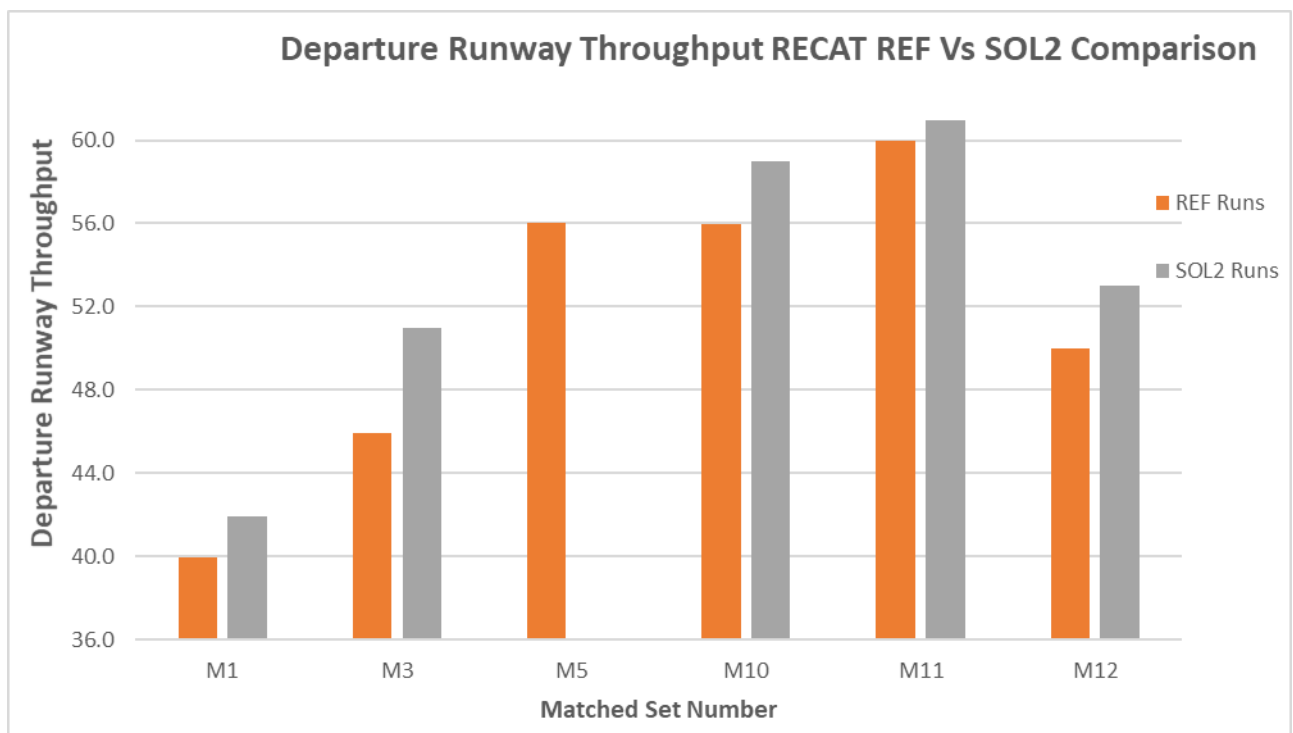


Figure 7-70: Departure Runway Throughput RECAT REF Vs SOL2 Comparison

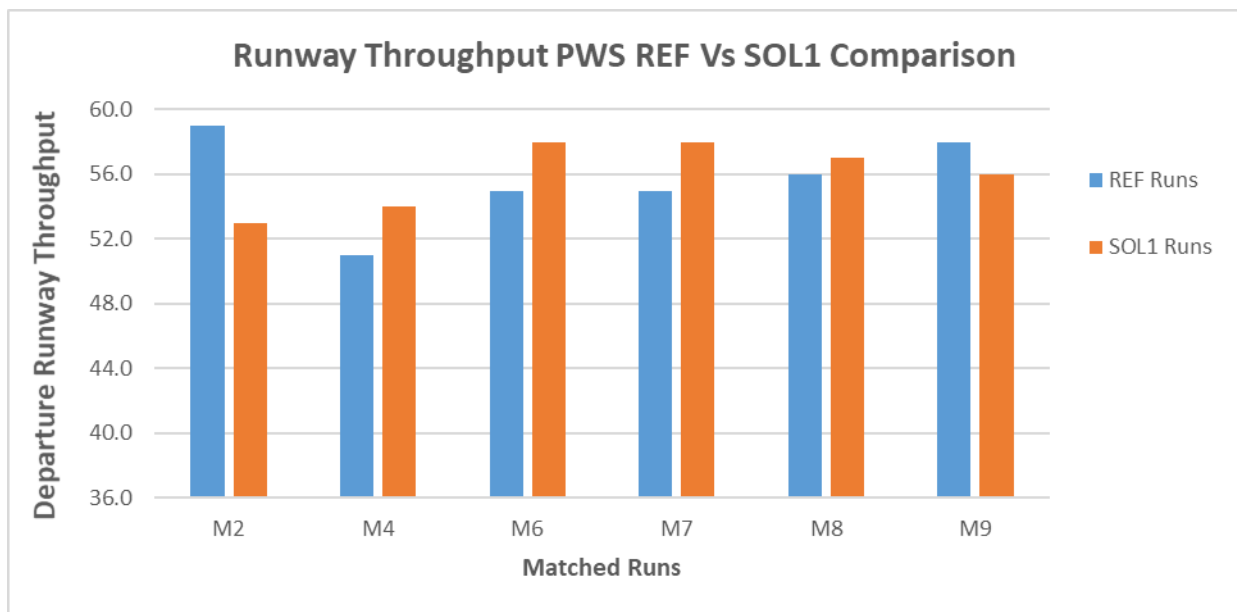


Figure 7-71: Departure Runway Throughput PWS REF Vs SOL1 Comparison

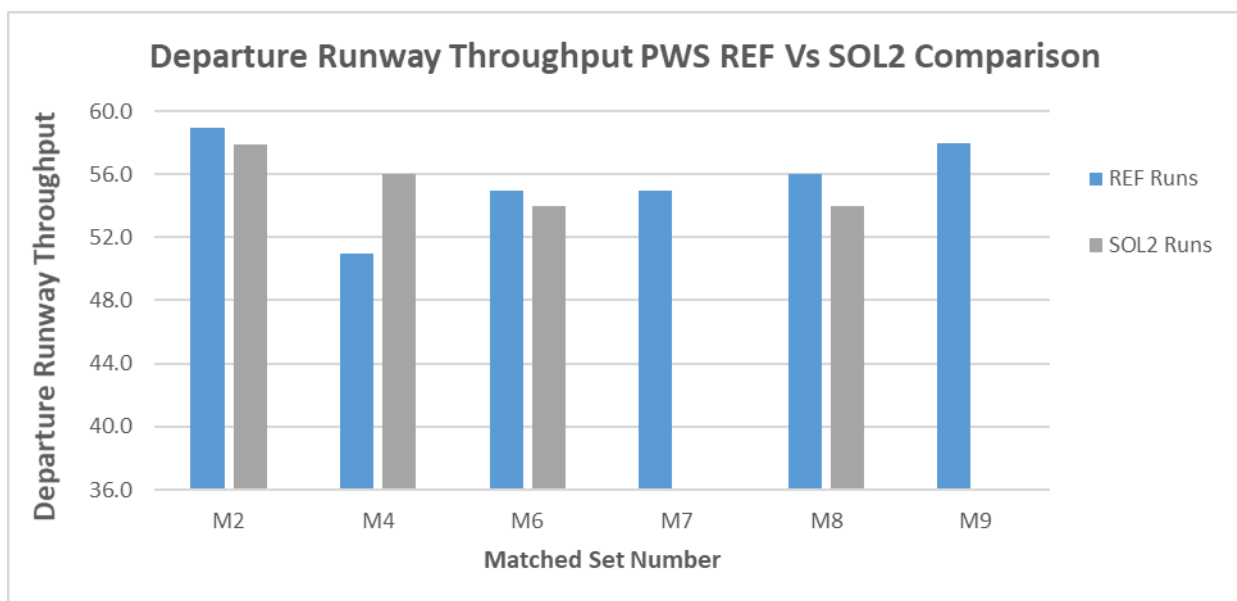


Figure 7-72: Departure Runway Throughput PWS REF Vs SOL2 Comparison

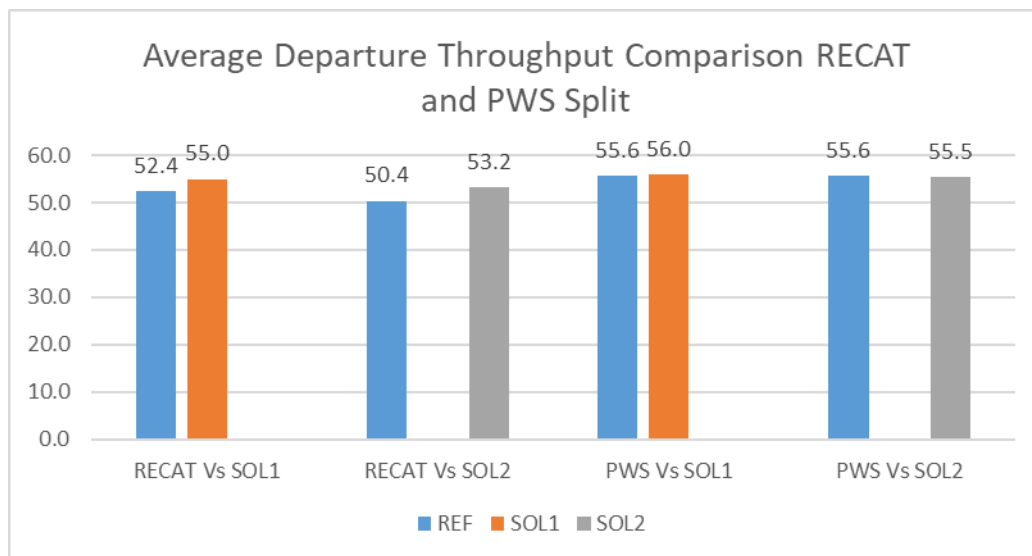


Figure 7-73: Average Departure Throughput Comparison RECAT and PWS Split

Figure 7-69 to Figure 7-72 above show each Solution compared against RECAT and Pairwise Wake Turbulence schemes that were in use during each of the matched sets and Figure 7-73 compares the average departure throughput across all matched sets for each Wake Turbulence scheme and Solution.

The biggest improvement in capacity can be seen in the comparison between RECAT and SOL1 and RECAT and SOL2 with an average increase shown of 2.6 and 2.8 movements per hour, respectively. Pairwise compared to SOL1 shows an increase of 0.4 movements per hour whereas Pairwise compared to SOL2 shows a decrease by 0.1 movement per hour.

As the same wake schemes were used in both the Reference and Solution scenarios (i.e., RECAT-EU or PWS), it is unlikely that the wake scheme in use made a significant difference to the observed capacity benefits and that the observed discrepancies between RECAT-EU and PWS are more likely to be a result of the small number of data points available when the results are split by the wake scheme in use. Therefore, the results presented at an aggregated wake scheme level in Figure 7-65 to Figure 7-68 and can be considered as more meaningful.

4. Analysis of Predictability Objectives

OBJ-37-W3-DEMOP-PRD1-0002

To assess the improvement in predictability per flight for the Aerodrome due to the ITARO Departures Solution versus the Reference Scenario.

CRT-37-W3-DEMOP-PRD1-0002

Evidence shows a decrease in taxi out variability for departing aircraft in the Solution Scenario versus the Reference Scenario.

The average taxi-out time was calculated for each scenario within a matched set as the difference between aircraft simulation start-up time and take-off roll time. As aircraft do not start-up at their gates but on the taxiways, taxi-times presented in this section are shorter than the taxi-time recorded in operational data. However, because these start-up locations were kept constant across scenarios,

this comparison is acceptable. Figure 7-74 shows a comparison of the average taxi-out time in minutes per scenario between REF and SOL1, and Figure 7-75 shows a comparison between REF and SOL2.

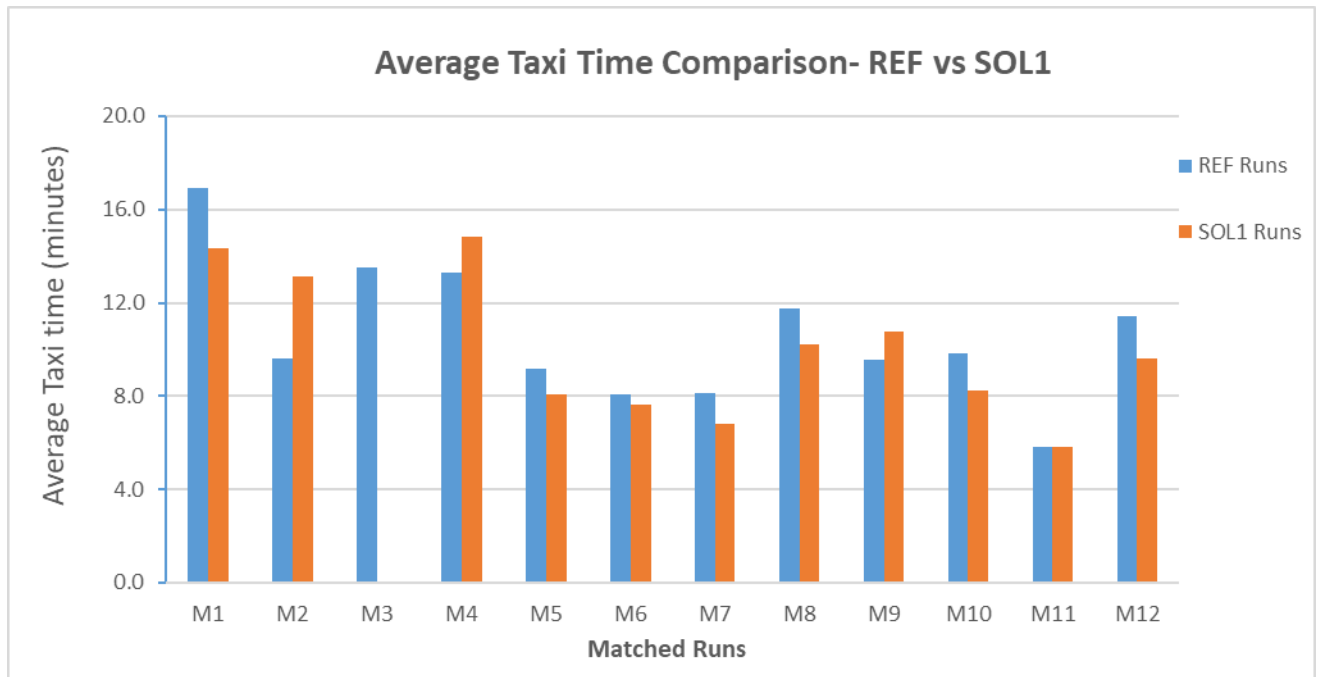


Figure 7-74: Average Taxi-out times in minutes per scenario per match – REF vs SOL1.

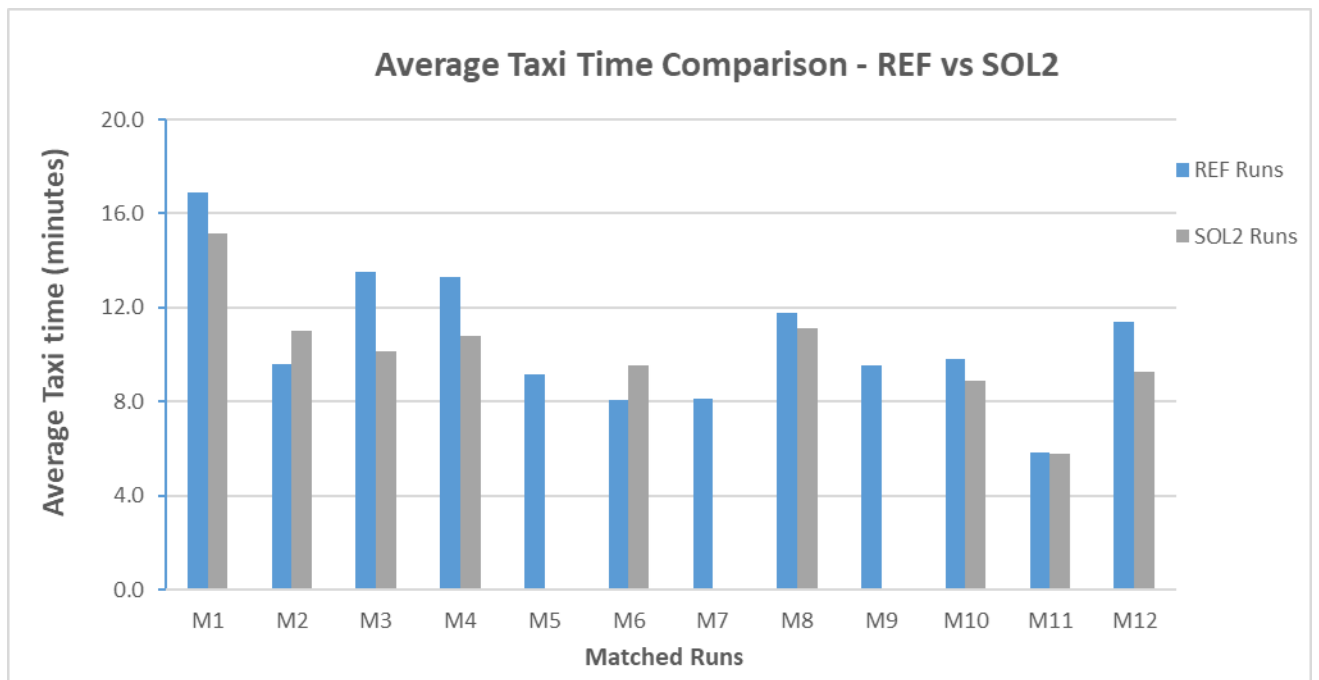


Figure 7-75: Average Taxi-out times in minutes per scenario per match – REF v's SOL2.

When comparing REF to SOL1, the average taxi time was higher in REF than for SOL1 in 8 out of 11 matches.

When comparing REF to SOL2, the average taxi time was higher in REF than for SOL2 in 7 out of 9 matches.

For the majority of matches, the REF average taxi times were higher than for either SOL1 or SOL2.

An average was taken of all matches of the average taxi-out time and the delta between each solution and reference calculated. See Table 7-51 below:

	SOL1 Comparison			SOL2 Comparison		
	REF	SOL1	Delta	REF	SOL2	Delta
Average taxi-out time across all matches (minutes)	10.3	9.9	0.4	11.1	10.2	0.9

Table 7-51: Average Taxi-out time across all matches (minutes)

As can be seen, the average taxi-out time for SOL1 compared to REF is reduced by 0.4 minutes. A reduction is also seen between SOL2 and REF with a reduction of 0.9 minutes.

As well as a reduction in the mean taxi-out time, Table 7-52 below compares the standard deviation in taxi-out time for the Solution Scenario runs against the matched Reference Scenario runs. The standard deviation is a measure of variability and can be considered as an indicator of the predictability. A reduction in variability indicates more consistent taxi-out times and therefore improved predictability. The results show a minor reduction in standard deviation in SOL1 runs compared to the matched Reference Scenario runs of -0.10 minutes. A similar result is found for SOL2 compared with the matched Reference Scenario runs with a reduction of standard deviation by -0.40 minutes.

	SOL1 Comparison			SOL2 Comparison		
	REF	SOL1	Delta	REF	SOL2	Delta
Standard Deviation in Taxi-Out Time (Minutes)	5.33	5.23	-0.10	5.33	4.93	-0.40

Table 7-52: Standard Deviation in Taxi-Out time Comparison between REF Vs SOL1 and REF Vs SOL2

A second indicator of predictability is Runway Hold Area (RHA) delay. RHA delay is a measure of the time departures spent stationary in the runway hold area positions next to the runway, whilst waiting to depart. Figure 7-76 shows the mean RHA delay comparison:

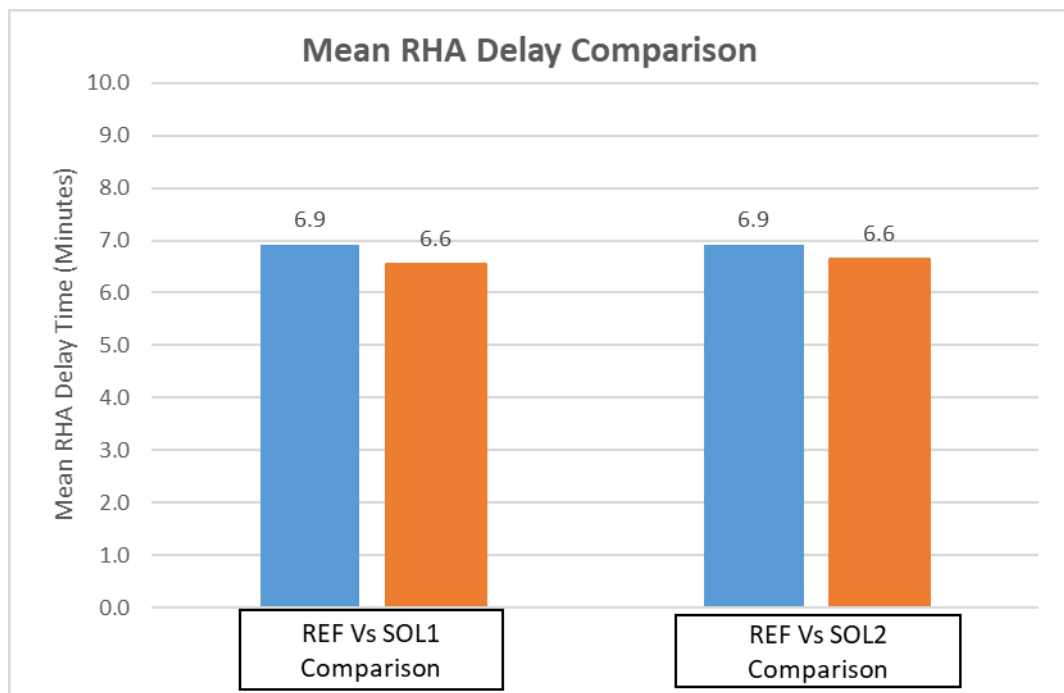


Figure 7-76: Mean RHA Delay Comparison between the Solution Scenario Runs and the Matched Reference Scenario Runs.

As can be seen from Figure 7-76, there was a reduction in mean RHA delay of 0.3 minutes when comparing REF with SOL1 and REF with SOL2.

The following table shows that the standard deviation in RHA delay in the SOL1 and SOL2 Scenario runs was reduced compared to the matched reference scenario runs.

SOL1 Comparison				SOL2 Comparison		
	REF	SOL1	Delta	REF	SOL2	Delta
Standard Deviation in RHA Delay (Minutes)	4.8	4.7	-0.1	4.8	4.5	-0.3

Table 7-53: Standard Deviation in RHA Delay Comparison between REF Vs SOL1 and REF Vs SOL2

These results indicate slightly improved predictability through the reduced standard deviation in RHA delay in the Solution Scenario runs compared to the matched Reference Scenario runs.

The findings from the Taxi-out and RHA Delay analysis correlates with the Capacity findings for the matches where the departure runway throughput was higher in the SOL scenarios. This is to be expected because if the departure throughput is higher, as a consequence, the less time the aircraft spends taxiing and waiting to depart. As discussed in the capacity objective results (see Section D.3.2.3), although there were some limitations of the runway throughput results (learning effect of traffic sample and improvements required to the algorithm), the ATCOs opinion was that improvement in capacity and therefore an improvement in predictability would be seen.

Summary:

The data analysis for average taxi-out times across all matches shows that for both Solutions there is a reduction in average taxi-time in the solution compared to the reference. The results also show that there is less variability in the taxi-out times when compared to the reference scenario, and hence increased predictability. Solution 2 has improved predictability over both the Reference Scenario and Solution 1, which is in line with expectations that the ATCOs were able to use the countdown timer rather than mental arithmetic to apply a flow restriction, therefore helping them to be more efficient.

The data analysis for the RHA Delay shows that for both solutions, there is a reduction in the average runway hold area delay when compared to the reference scenario of 0.3 minutes, and when looking at the standard deviation, SOL2 had an improvement over SOL1, which correlates with the findings for the taxi-out times and therefore adding further evidence for improved predictability, for both solutions, but for Solution 2 in particular.

RECAT and Pairwise Split

As discussed in 3 Analysis of Capacity, the analysis for this KPI has not focussed on the split between RECAT and Pairwise Wake Turbulence as an assessment was conducted in Wave 1. However, for completeness, the results of the split between RECAT and Pairwise for both Solution 1 and Solution 2 for the average Taxi-out times has been provided in Figure 7-77 below:

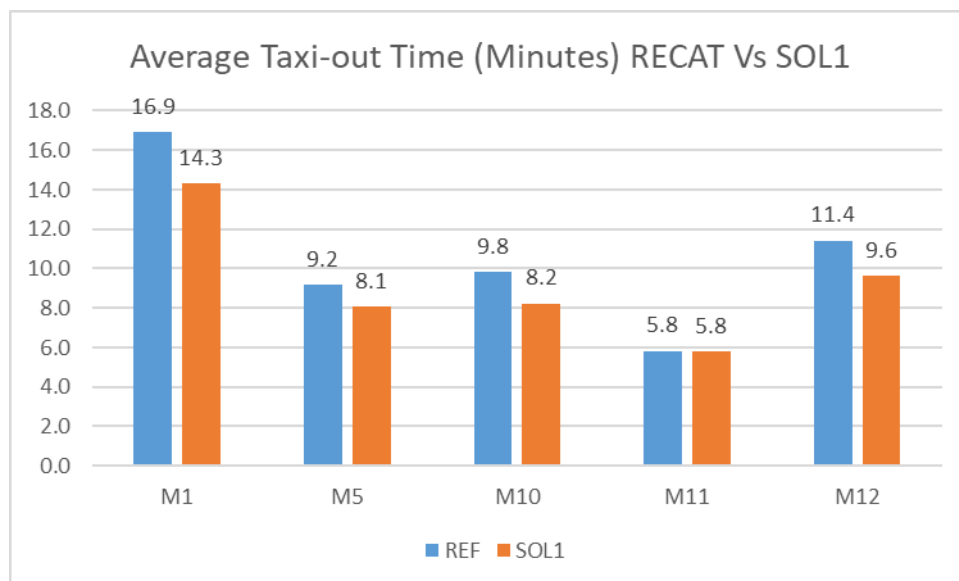


Figure 7-77: Average Taxi-out Time (Minutes) RECAT Vs SOL1.

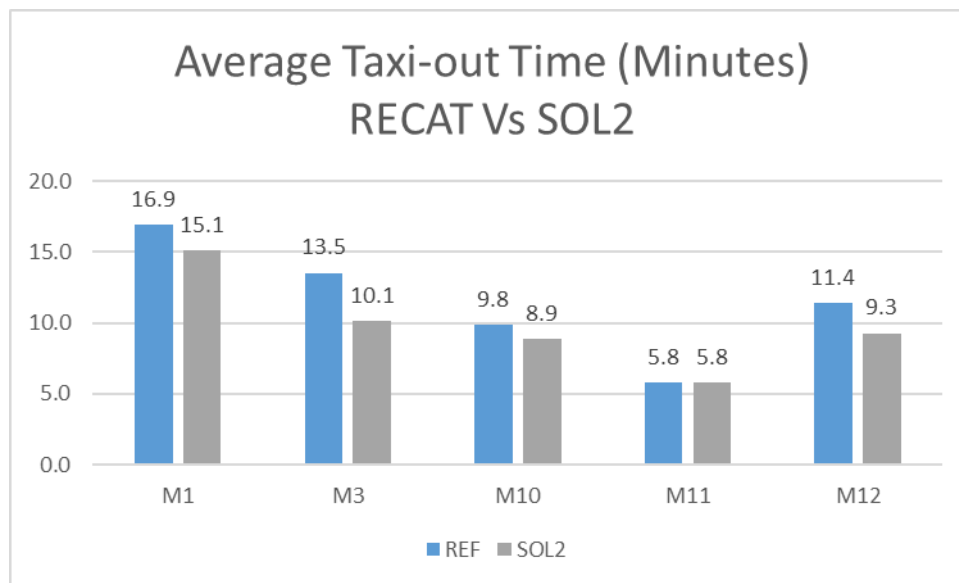


Figure 7-78: Average Taxi-out Time (Minutes) RECAT Vs SOL2

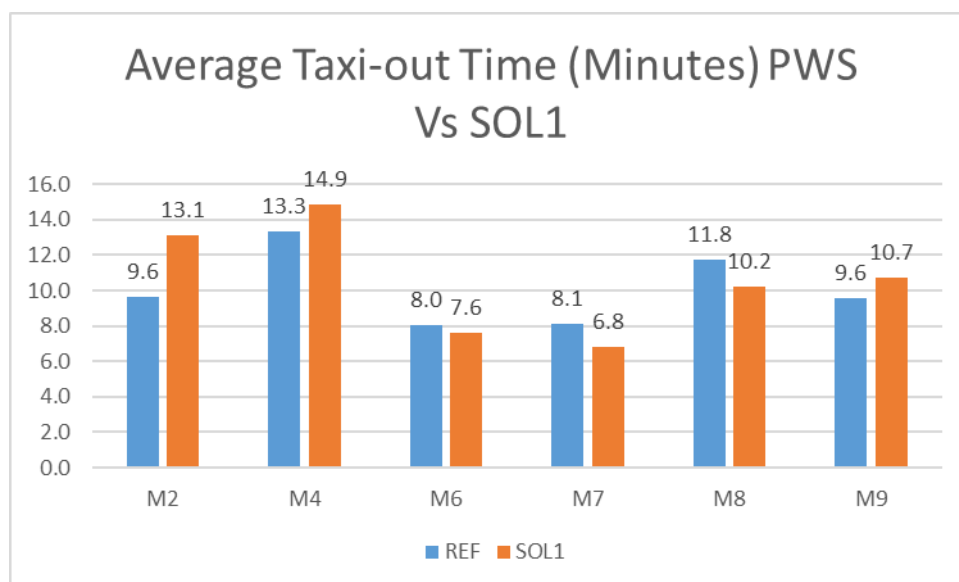


Figure 7-79: Average Taxi-out Time (Minutes) PWS Vs SOL1

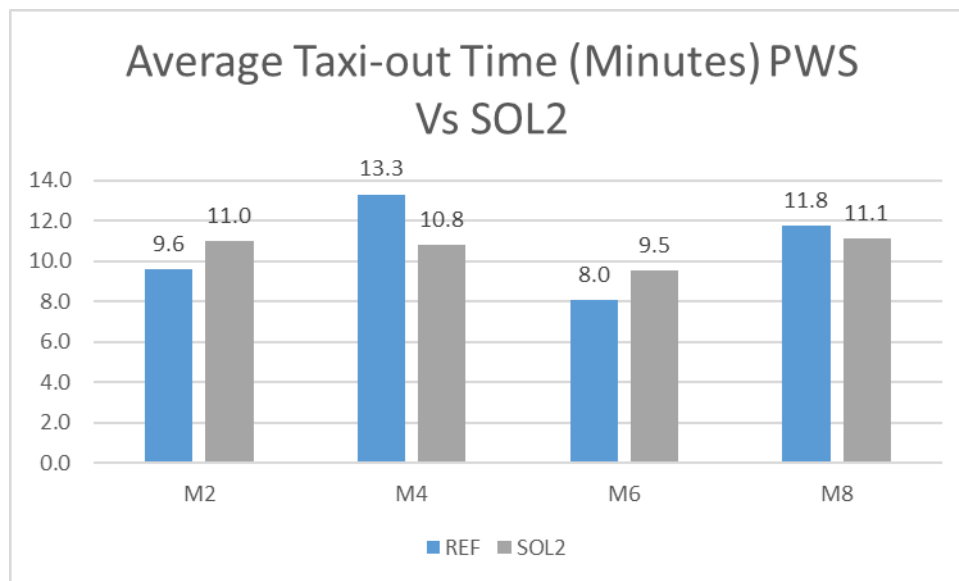


Figure 7-80: Average Taxi-out Time (Minutes) PWS Vs SOL2

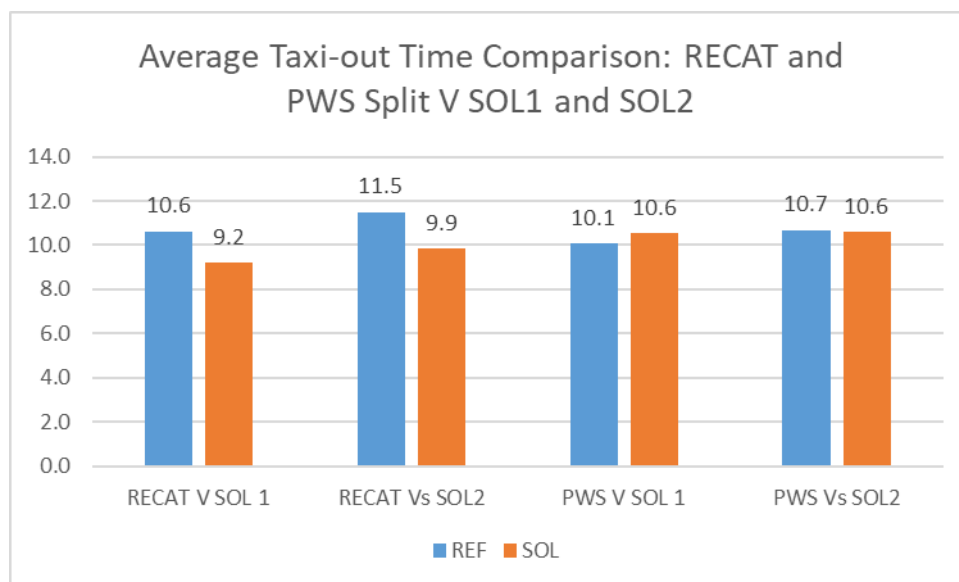


Figure 7-81: Average Taxi-out Time Comparison: RECAT and PWS Split V SOL1 and SOL2

Figure 7-77 to Figure 7-80 show each solution compared against RECAT and Pairwise Wake Turbulence schemes that were in use during each of the matched sets, and Figure 7-81 compares the combined average of all matches within a comparison. As can be seen from Figure 7-81, the average taxi-times for the Reference scenarios was higher in the RECAT comparison compared to SOL1 and SOL2 of 1.4 and 1.7 minutes respectively. However, the benefits are not so clear when comparing PWS with each solution as the average taxi-time shows an increase of 0.5 minutes for SOL1 and a decrease of 0.1 minute for SOL2.

As the same wake schemes were used in both the Reference and Solution scenarios (i.e., RECAT-EU or PWS), it is unlikely that the wake scheme in use made a significant difference to the observed predictability benefits and that the observed discrepancies between RECAT-EU and PWS are more

likely to be a result of the small number of data points available when the results are split by the wake scheme in use. Therefore, the results presented at an aggregated wake scheme level in Figure 7-74 to Figure 7-76 and Table 7-51 to Table 7-53 can be considered as more meaningful.

OBJ-37-W3-DEMOP-PRD1-0003

To assess the predictability per flight for the TMA due to the ITARO Departures Solution versus the Reference Scenario.

CRT-37-W3-DEMOP-PRD1-0003

Evidence shows a more consistent delivery of aircraft into the TMA in the Solution Scenario versus the Reference Scenario.

SESAR typically measures Predictability as a function of delay and defines the measurement of the KPI as variances in differences of actual and the flight plan. As this simulation was a Tower focussed simulation with no measured TMA sector, the data is not available to measure this KPI.

However, one way of looking at predictability into the TMA is by assessing the consistency of delivery into the TMA. In current operations the distance between aircraft pairs delivered into the TMA can be inconsistent and therefore unpredictable as the ATCO is using mental calculations to clear the aircraft for take-off and there can be variations either side of the required separation distance achieved. However, the extended OSD tool should help to reduce the variation, by taking away the mental calculation task for the ATCO and therefore increase predictability. As described in the Operational Feasibility objective analysis section, it was agreed amongst the ATCOs that the extended OSD tool would help to provide a more consistent flow of traffic into the TMA. However, without fully simulating the TMA environment it was difficult for this to be assessed in any meaningful way, and therefore it would be recommended for any future activities to include a greater focus on the benefits for the TMA (REC-37-W3-OPF-R5 as listed in D.3.61).

5. Analysis of Environment Objective

OBJ-37-W3-DEMOP-ENV1-0002

To assess the impact of the ITARO Departures Solution on the average fuel burn per flight versus the Reference Scenario.

CRT-37-W3-DEMOP-ENV1-0002

There is evidence to show there is a reduction in the average fuel burn per flight, and therefore average CO₂ emissions per flight in the Solution Scenario versus the Reference Scenario.

Only flights that were airborne in one of the Solution Scenarios and the corresponding Reference Scenario were included in the environmental analysis. As a result, the total sample size was reduced by 60% from 2,694 flights down to 1,071 flights for comparison.

Table 7-54 shows that the generally the extended OSD tool with or without the TMA data-feed would decrease the average departure separation times compared to the Reference OSD tool⁹, therefore reducing ground holding (i.e., taxi time) durations and potentially decrease the amount of fuel burnt and CO₂ emitted. Scenario 1 presented the most efficient departure separation times resulting in lower average taxi time durations compared to Scenario 2 however, there is a risk of overloading the TMA sectors by not using a TMA data-feed.

Scenario	Average Departure Separation Time	Average Taxi Time Duration
Reference Scenario: OSD	1m 7s	11m 18s ¹⁰
Scenario 1: extended OSD without TMA data-feed	1m 4s	10m 29s
Scenario 2: extended OSD with TMA data-feed	1m 5s	10m 42s

Table 7-54: Average departure separation time and taxi time durations per airborne flight in the Scenarios

To perform the fuel burn analysis the taxi time durations¹¹ were calculated in each scenario. For each aircraft type, the BADA 4.2 taxi fuel burn rate was applied to the taxi time durations. The resulting taxi time fuel burns were then compared against its ground holding fuel burn in the corresponding Reference Scenario to calculate the fuel burn and CO₂ emissions differences¹² for each flight. The average fuel burn and CO₂ emissions differences per flight from the Reference Scenarios are shown in Table 7-55.

Solution Scenario	Average Difference Per Flight from Reference Scenario	
	Fuel Burn Difference	CO ₂ Emissions Difference
Scenario 1: extended OSD without TMA data-feed	-7 kg	-23 kg
Scenario 2: extended OSD with TMA data-feed	-18 kg	-57 kg

Table 7-55: Average fuel burn and CO₂ emissions difference per flight compared to the Reference Scenario

Scenario 2 resulted in the lowest average environmental savings of 18 kg fuel burn reduction and 57 kg reduced CO₂ emissions per flight compared to the Reference Scenario. Although Scenario 1 had more efficient departures and lower taxi time durations, it had smaller average environmental savings with reduced fuel burn of 7 kg and CO₂ emissions of 23 kg per flight compared to the Reference

⁹ Not all aircraft were airborne in the RTS; those that were airborne are classified as flights in this report.

¹⁰ Average across all airborne flights in the Reference Scenario for info. This value is different when only flights airborne in both the Reference and the corresponding Solution Scenario are compared – see detailed results contained in Appendix A in the DEMO Report Part IV (ENVAR) [21].

¹¹ The ground holding duration is calculated as the time from the aircraft starting up its engine (which is consistent across all scenarios) to its airborne time in each of the scenarios.

¹² Using the direct link between fuel burn and the amount of CO₂ produced (3.15 times the mass of fuel burnt).

Scenario. This was due to more aircraft types with high taxi fuel burn rates holding for longer durations in Scenario 1 compared to Scenario 2 and also the small sample sizes likely to have an effect on the results.

The analysis indicates that extended OSD with a TMA data-feed would be more beneficial in environmental savings than extended OSD without a TMA data-feed. Furthermore, using a TMA data-feed may prevent excessive demand on the TMA sectors by dynamically adjusting the departure flow rate into the TMA. The participating ATCOs in the RTS expected to see more benefits for the solution **with** the TMA data-feed as it helps them to apply flow restrictions more accurately as well as allowing more granular flow restrictions to be applied (e.g., 3m 30s instead of 4m). However, without fully simulating the TMA environment it was difficult for this to be assessed in any meaningful way, and therefore it would be recommended for any future activities to include a greater focus on the benefits for the TMA (REC-37-W3-OPF-R5 as listed in D.3.61).

RECAT and Pairwise Split

It is interesting to see the environmental benefits of the ITARO Departures solution track PJ.37-W3-01B based on the wake schemes (i.e. RECAT-EU or PWS-D) and with or without the TMA data feed (Solution Scenarios). So a comparative assessment is conducted against two Reference Scenarios and presented in this Appendix. There are two Reference Scenarios:

1. RECAT-EU 6-CAT wake time separations with OSD tool organisation (no route spacing tool support).
2. PWS-D solution organisation based on 103x103 PWS and 20-CAT PWS wake time separations with OSD tool support (no route spacing tool support).

There are four Solution Scenarios:

1. Time-Based RECAT-EU with extended OSD (extended OSD) tool support without a TMA data-feed.
2. Time-Based RECAT-EU with extended OSD (extended OSD) tool support with an emulated TMA data-feed.
3. Time-Based PWS-D with extended OSD tool support without a TMA data-feed.
4. Time-Based PWS-D with extended OSD tool support with an emulated TMA data-feed.

Note in Table 45 and 46 the reference to a TMA data-feed was through an emulation of TMA data. Only flights that were airborne in one of the Solution Scenarios and also the corresponding Reference Scenario were included in the environmental analysis. As a result, the sample size was reduced by 60% from 2,694 flights down to 1,071 flights for comparison. Table 7-56 below shows that the generally the extended OSD tool with or without the TMA data-feed would decrease the average departure separation times compared to the RECAT-EU or PWS-D OSD tool¹³. Average taxi time durations for Scenarios 1 and 2 decreased compared to its Reference Scenario 1. However, for Scenarios 3 and 4 the

¹³ Not all aircraft were airborne in the RTS; those that were airborne are classified as flights in this report.

taxi time durations increased even though the average departure separation times fell by 1 second compared to its Reference Scenario 2.

Scenario	Average Departure Separation Time	Average Taxi Time Duration
Ref 1: RECAT-EU OSD	1m 9s	11m 50s
Sc1: RECAT-EU extended OSD without TMA data-feed	1m 5s	9m 30s
Sc2: RECAT-EU extended OSD with TMA data-feed	1m 6s	10m 5s
Ref 2: PWS-D OSD	1m 5s	10m 46s
Sc3: PWS-D extended OSD without TMA data-feed	1m 4s	11m 17s
Sc4: PWS-D extended OSD with TMA data-feed	1m 4s	11m 25s

Table 7-56: Average departure separation time and taxi time durations per flight in the Scenarios by Wake Scheme

To perform the fuel burn analysis the ground holding durations¹⁴ were calculated in each scenario. For each aircraft type, the BADA 4.2 taxi fuel burn rate was applied to the ground holding durations. The resulting ground holding (or taxi) fuel burns were then compared against its ground holding fuel burn in the corresponding Reference Scenario to calculate the fuel burn and CO₂ emissions differences¹⁵ for each flight. The average fuel burn and CO₂ emissions differences from the Reference Scenarios are shown in Table 7-57.

Solution Scenario	Average Difference Per Flight from Reference Scenario	
	Fuel Burn Difference	CO ₂ Emissions Difference
Sc1: RECAT-EU extended OSD without a TMA data-feed	-27 kg	-86 kg
Sc2: RECAT-EU extended OSD with a TMA data-feed	-33 kg	-104 kg
Sc3: PWS-D extended OSD without a TMA data-feed	+9 kg	+29 kg
Sc4: PWS-D extended OSD with a TMA data-feed	-1 kg	-4 kg

Table 7-57: Average Ground Holding Fuel Burn and CO₂ Emissions Difference per Flight Compared to the Reference Scenario by Wake Scheme

¹⁴ The ground holding duration is calculated as the time from the aircraft starting up its engine (which is consistent across all scenarios) to its airborne time in each of the scenarios.

¹⁵ Using the direct link between fuel burn and the amount of CO₂ produced (3.15 times the mass of fuel burnt).

Solution Scenario 2 resulted in a reduced average departure separation time of 1m 6s between flights and average fuel burn savings of 33 kg and 104 kg of reduced CO₂ emissions per flight compared to the Reference Scenario 1. Scenario 1 had, on average, a lower departure separation time of 1m 5s compared to the Reference Scenario 1 at 1m 9s, and on average reduced fuel burn of 27 kg and CO₂ emissions of 86 kg per flight. Both Scenarios 1 and 2 indicated more efficient departures with lower taxi time durations compared to the Reference Scenario 1.

The analysis indicates that RECAT-EU extended OSD with a TMA data-feed would be more beneficial in environmental savings than RECAT-EU extended OSD with a TMA data-feed. The TMA data-feed will also prevent excessive demand on the TMA sectors by dynamically adjusting the departure flow rate into the TMA, allowing for more granular flow restrictions, e.g., 3m 30s instead of 4m.

Table 7-56 shows that Solution Scenario 4, on average, a lower departure separation times of 1m 4s compared to the Reference Scenario 2 at 1m 4s, and on average reduced fuel burn of 1 kg and CO₂ emissions of 4 kg per flight. However, Scenario 3 increased the average fuel burn by 9 kg per flight and CO₂ emissions by 29 kg per flight compared to Reference Scenario 2 even though the average departures separation time was lower by 1s. This was due to more aircraft types with higher taxi fuel burn rates holding for longer durations compared to Reference Scenario 2 in the RTS and the small sample size likely to have an effect on the results. Furthermore, both Scenarios 3 and 4 both indicated less efficient departures overall compared to the Reference Scenario 2 with higher taxi time durations offsetting the reduced departure separation times.

For PWS-D, the analysis indicates that using extended OSD and a TMA data-feed is likely to provide environment savings as well as preventing excessive demand onto the TMA sectors. However, not using a TMA data-feed risks causing excessive demand onto the TMA sectors by not dynamically adjusting the departure flow rate into the TMA and therefore can increase average fuel burn and CO₂ emissions per flight. Therefore, without fully simulating the TMA environment it was difficult for this to be assessed in any meaningful way, and therefore it would be recommended for any future activities to include a greater focus on the benefits for the TMA (REC-37-W3-OPF-R5 as listed in D.3.61).

6. Analysis of Punctuality Objective

OBJ-37-W3-DEMOP-PUN1-0001

To assess the impact on ANSP-attributed holding delay at the Aerodrome as a result of the ITARO Departures Solution versus the Reference Scenario.

CRT-37-W3-DEMOP-PUN1-0001

There is evidence to show that the ANSP-attributable delay at the Aerodrome is reduced in the Solution scenario versus the reference scenario.

Punctuality as defined by SESAR is departure delay in minutes of flights departing within +/- 3 minutes of SOBT (Scheduled Off-blocks Time), which is measured by taking the difference between AOBT (Actual Off-blocks time) and the SOBT. The data from the RTS is not available to measure this objective, as the aircraft in the traffic samples generated at holding points from the runway, rather than at the stand. However, a qualitative argument can be made for an improvement in punctuality which links to the PRD001 and CAP results. If the solution reduces the variability in the taxi-out time, time spent waiting to depart at the RHA, and increases the runway throughput, it can therefore be argued that the queue of aircraft waiting to depart is reduced and the GMC may be more able to push aircraft back

sooner. In addition, in periods of disruption (i.e., adverse weather) the increase in runway throughput allows the runway throughput to recover faster than before.

7. Analysis of Aerodrome Cost Efficiency Objective

OBJ-37-W3-DEMOP-CEF1-0001

To assess the increase to Aerodrome ATCO productivity in terms of flights handled per unit time in the ITARO Departures Solution versus the Reference Scenario.

CRT-37-W3-DEMOP-CEF1-0001

Evidence shows an increase in the number of flights handled by an Aerodrome ATCO per hour in the Solution Scenario versus the Reference Scenario.

To assess Aerodrome Cost Efficiency, the productivity of the ATCO was calculated by measuring the number of flights handled per hour in the solution scenarios compared to the reference scenarios. The same data that was used to calculate the metrics for the Capacity KPI was used, however with the addition of including any arrivals and crossing aircraft (which were excluded from the Capacity analysis).

Figure 7-82 below shows a comparison of the number of flights handled per run across all matched sets between reference and solution scenarios.

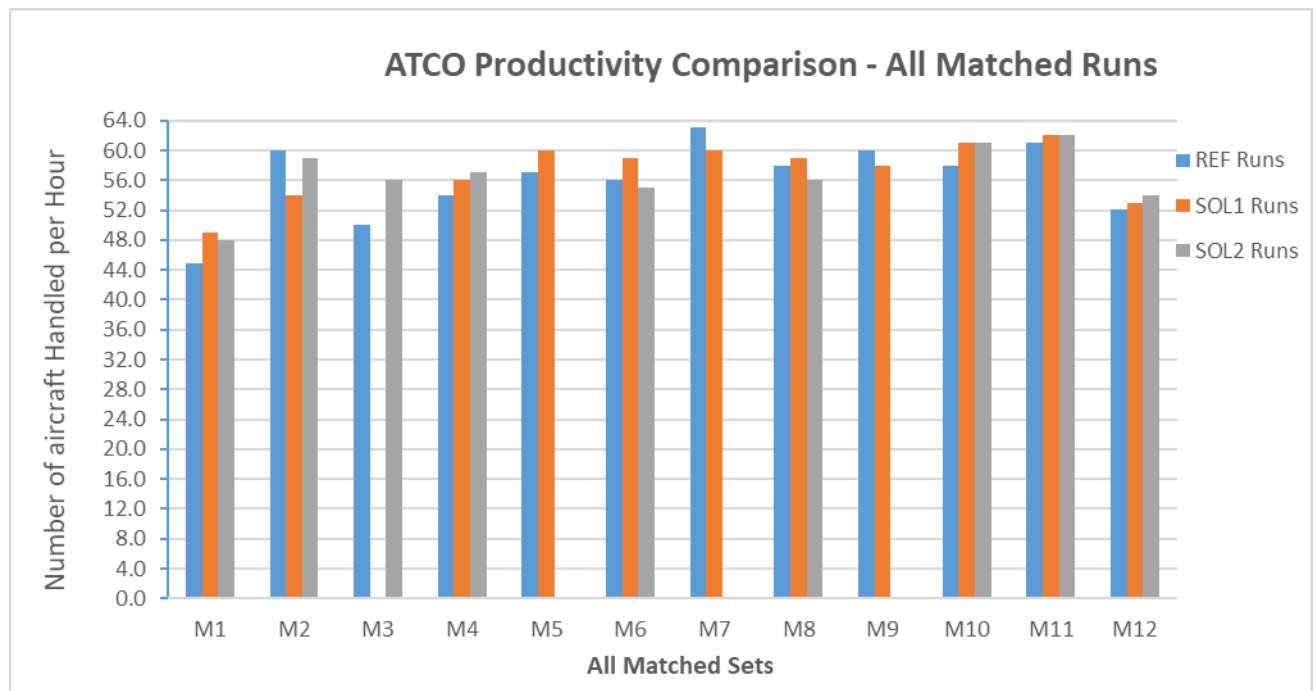


Figure 7-82: ATCO Productivity Comparison- Number of flights handled per hour across all matched runs

From examining the number of aircraft handled per hour (each exercise was run for exactly 1 hour, by 1 Departure Controller), it shows that SOL1 achieved a higher number of aircraft handled than the REF in 8 out of 11 matches. SOL2 achieved a higher number of aircraft handled than the REF in 6 out of 10 matches.

A lower ATCO productivity can be observed in M1 compared to the other matches was found. This can be attributed to the ATCO who was sat in the Air Departure seat requiring time to re-familiarise with the more complex and less often used Easterly operations at Heathrow.

In some of the matches the ATCO handled more flights in the REF scenario than either SOL1 or SOL2 or both. As explained in the Capacity results discussion, this could have been attributed to a learning effect of the traffic sample as they were exposed to the same traffic sample across a number of consecutive runs during the same day in order to achieve the matched comparison experimental design. However, the experimental design was such that the order in which the reference and solution runs were conducted were mixed up in an attempt to mitigate against the learning effect.

Figure 7-83 below shows the average number of aircraft handled per hour across all reference runs and all solution runs, and an increase can be seen for both solution scenarios, showing that on average the number of flights handled by the ATCO is increased.

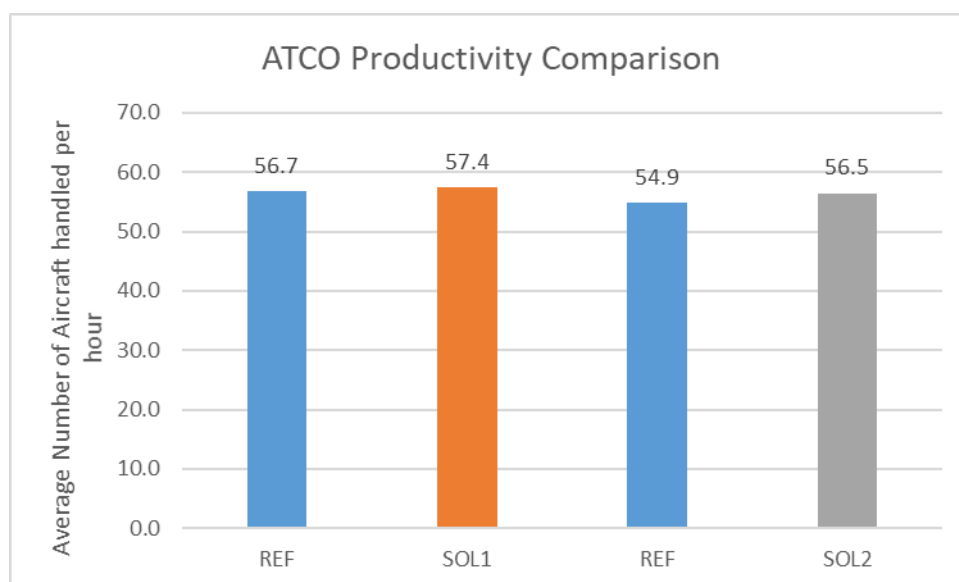


Figure 7-83: Average Number of Flights Handled per hour comparison REF V SOL1 and REF V SOL2

When comparing REF with SOL1 an increase in number of flights handled per hour of 0.6 movements is seen (1.1%). When comparing REF with SOL2 an increase of 1.6 movements can be seen (2.9%).

As discussed in the discussion of assessment results for the Capacity findings (see Appendix 3), the ATCOs when questioned in the post-simulation workshop felt that the concept would bring about an increase in capacity which therefore will enable them to handle a greater number of aircraft per hour. The ATCOs also fed back during the simulation debriefs and the post-simulation workshop that they believe the extended OSD tool will enable those ATCOs who are less experienced and less efficient to have the confidence to apply reduced route spacings compared with their delivery performance today, therefore implying that this will increase their productivity. This feedback is also discussed under the Operational Feasibility objective OBJ-37-W3-DEMOP-OPF1-0001 (see Section 1).

RECAT and Pairwise Split

The results above are a combined results of all runs conducted using the Pairwise and RECAT-EU wake separation schemes, however a split between the two is provided below (see Figure 7-84 to Figure 7-86).

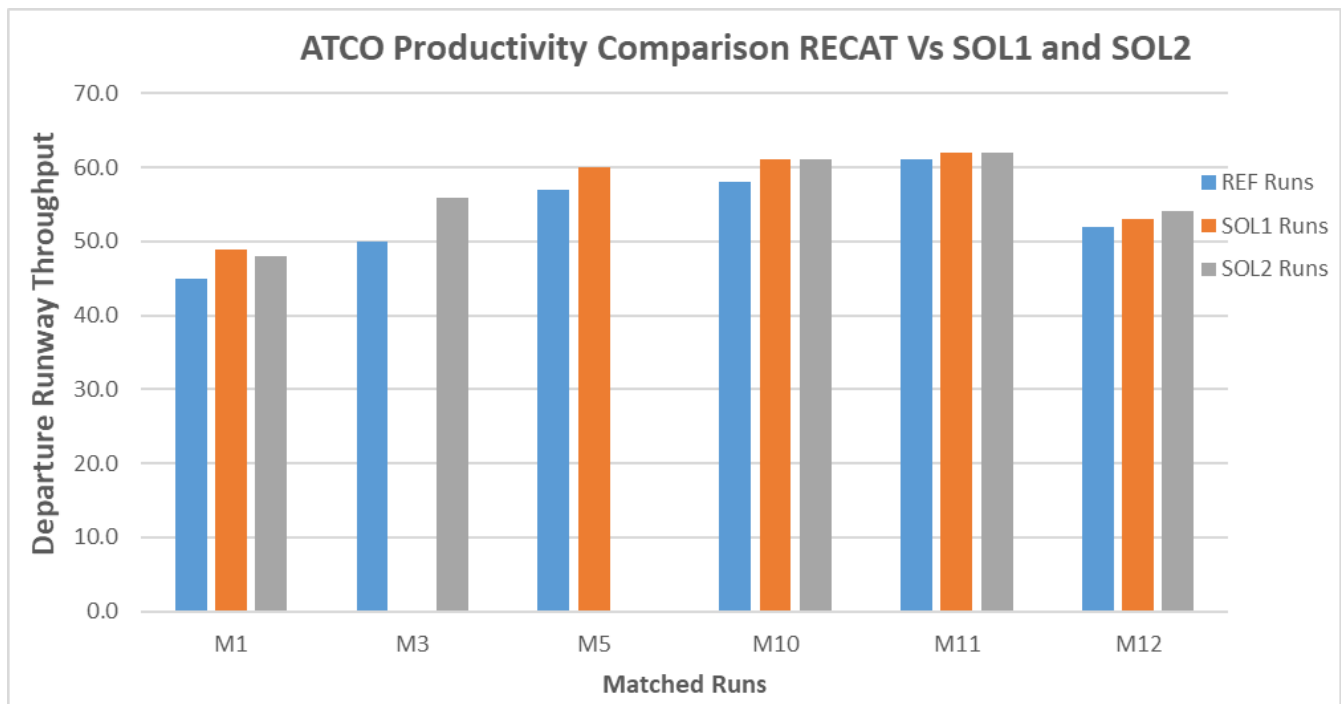


Figure 7-84: ATCO Productivity Comparison RECAT Vs SOL1 and SOL2

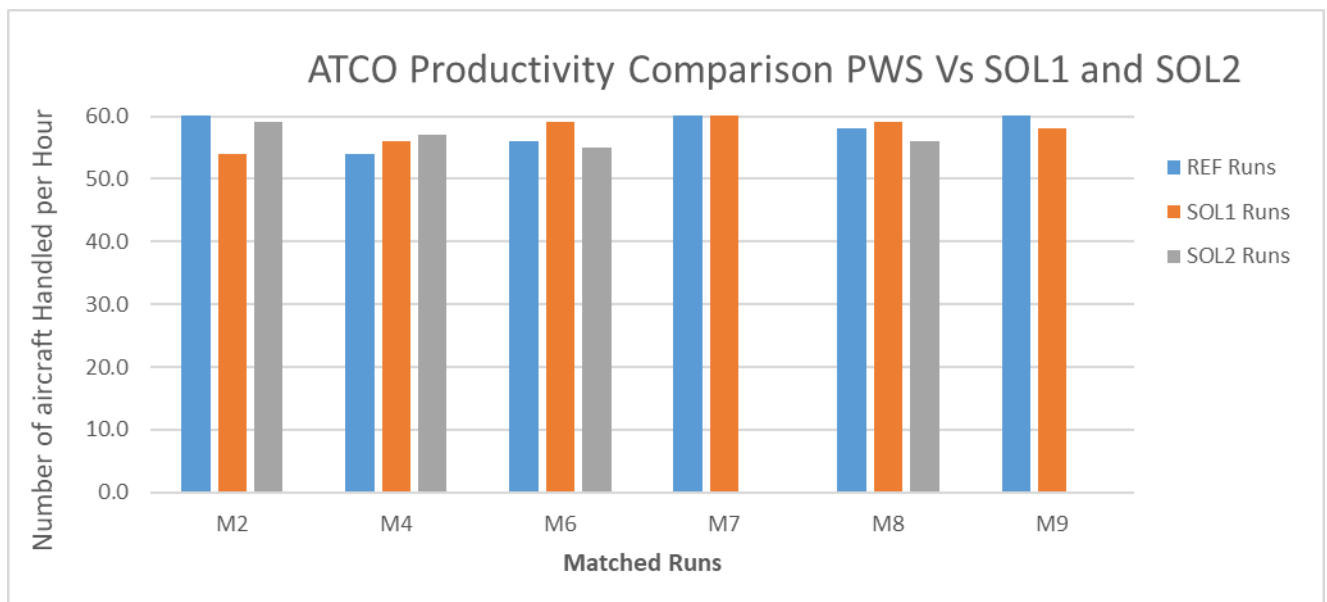


Figure 7-85: ATCO Productivity Comparison PWS Vs SOL1 and SOL

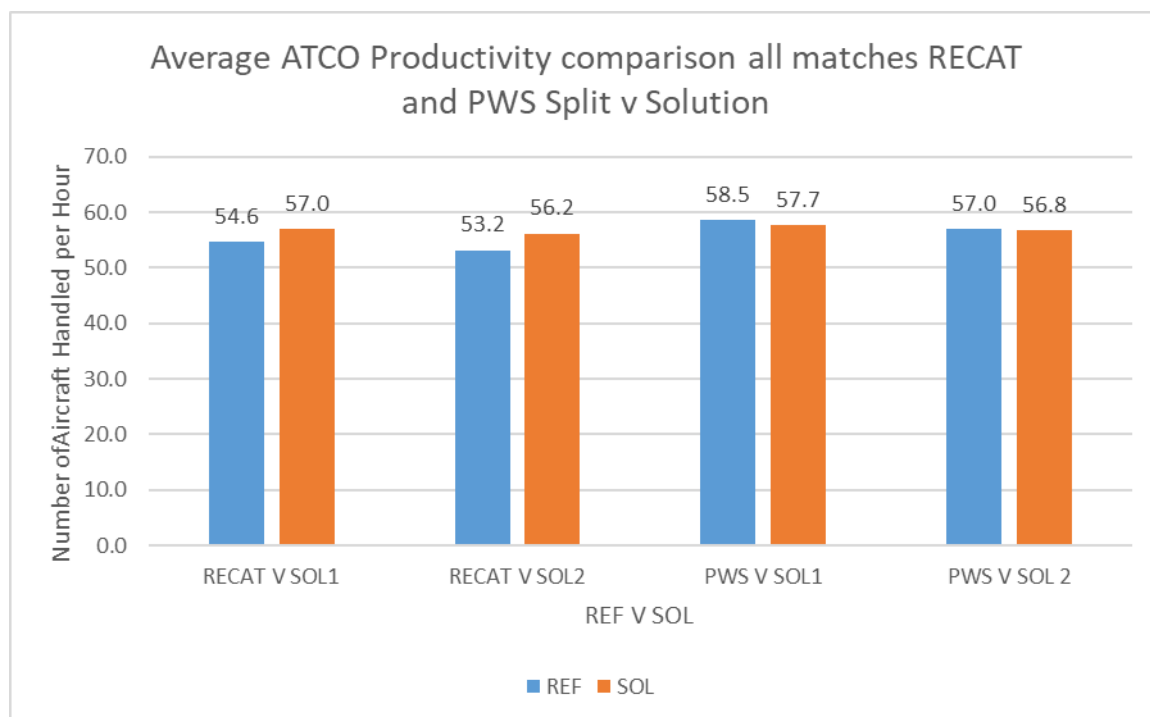


Figure 7-86: Average ATCO Productivity comparison all matches RECAT and PWS Split v Solution

Figure 7-84 and Figure 7-85 above show each Solution compared against RECAT and Pairwise Wake Turbulence schemes that were in use during each of the matched sets and Figure 7-86 compares the average number of aircraft handled per hour across all matched sets for each Wake Turbulence scheme and Solution.

As for the Capacity findings, the biggest improvement in ATCO productivity can be seen in the comparison between RECAT and SOL1 and RECAT and SOL2 with an average increase shown of 2.4 and 3 movements per hour respectively. Whereas Pairwise compared to SOL1 shows a decrease of 0.8 movements per hour and a decrease of 0.2 with SOL2.

As described for both the Capacity and Productivity findings, as the same wake schemes were used in both the Reference and Solution scenarios (i.e., RECAT-EU or PWS), it is unlikely that the wake scheme in use made a significant difference to the observed capacity benefits and that the observed discrepancies between RECAT-EU and PWS are more likely to be a result of the small number of data points available when the results are split by the wake scheme in use. Therefore, the results presented at an aggregated wake scheme level in Figure 7-82 and Figure 7-83 can be considered as more meaningful.

8. Analysis of Safety Objectives

See tables within Section 4.4.7 for the high-level results and see the DEMO Report Part II [18] for the detailed analysis and results.

D.3.3 Unexpected Behaviours/Results

The following unexpected behaviours/results were found during the simulation execution:

- On two occasions the ATCOs realised at the end of the run that they had been applying the flow restriction to the wrong SID. This had the impact of those runs being excluded from analysis (meaning that the matched set was reduced from a triple to a double matched set) and also required the runs to be repeated, meaning that other runs had to be rectified.
- Several technical issues arose during the simulation such as the 'out of the window view' screens freezing on a number of occasions, and the ATCOs reporting that the RT was crackling. However, these issues are not believed to have impacted the quality of the results.
- During the simulation there were several instances where the tool displayed unexpected information to the ATCO – the countdown timer gave a route separation of 2:00 minutes, whereas it was expected to have displayed 'N/A'. After investigation it was discovered that there was an issue with the tool giving a route separation between aircraft A and C where the sequence is aircraft A-B-C. However, when the issue was detected, it was agreed that the issue would not have a significant impact to warrant it being amended for the rest of the simulation.
- Feedback from the ATCOs indicated that on several occasions the behaviour of certain aircraft did not perform as per real world operations (e.g., GLF4, callsign N383LS. The aircraft turned earlier than it would in the real world and the speed profile was not realistic). For future RTS activities any anomalies such as this should be addressed.
- There were several occasions whereby a member of the Demonstration team was required to cover the GMC position due to unavailability of the second ATCO. This did not have an impact on the data collection as the GMC was not a measured position. However, at the times the measured AIR DEPS ATCO had to help the step-in GMC to ensure the strips were handed over in the correct order. The ATCOs did not feel this will have had a significant impact on the efficiency of the impacted runs.

D.3.4 Confidence in Results of Demonstration Exercise EXE-PJ.37-W3-004

1. Level of significance/limitations of Demonstration Exercise EXE-PJ.37-W3-004 Results

The results presented in this exercise report are considered to be sufficiently representative of the operational environment simulated in this exercise.

As has been described in several of the KPI analysis results, the ATCOs commented that they experienced a learning effect from being exposed to the same traffic sample several times during the same day. This was due to a limitation of ATCO resourcing and having to conduct matched sets on the same day of the simulation. Because the ATCOs had learned which aircraft were coming up in the traffic sample, and based on their knowledge of what occurred in the previous run, they could therefore be more efficient each time around. However, to mitigate this as much as possible the timetable design was such that the order in which the reference and solution scenarios were conducted was varied every day. Although it is difficult to say in definite terms the impact on capacity that the learning effect had, the ATCO feedback indicated that the concept would bring about improvements in capacity in the operation.

There are limitations in extrapolating the quantitative results to a higher level to apply in other operating environments. This is because the departure throughput results and those metrics influenced by the departure throughput (i.e. predictability and fuel efficiency) are only applicable for operating environments with a similar runway and taxiway layout, traffic mix and separation requirements (in terms of wake mix, SID mix and separations). Changing the traffic mix or separation requirements will likely change the benefits in departure throughput from each of the solution scenarios assessed.

The taxi-out time and associated fuel burn results presented in this report are not fully representative of the operational environment because the measurement of taxi-out time started when the aircraft first loaded on the taxiway, rather than from pushback from stand. As this was kept constant across all scenarios, a comparative assessment could be made for these metrics that is sufficient for this demonstration exercise.

The results are limited in that only a small sample of responses to questions and ATCO opinions could be collected as only six ATCOs participated in EXE-PJ.37-W3-004.

2. Quality of Demonstration Exercises EXE-PJ.37-W3-004 Results

Apart from the limitations as described in section D.3.3 and D.3.4 paragraph 1, the quality of the demonstration exercise results for EXE-PJ.37-W3-004 are acceptable due to the following:

- Experienced NATS Heathrow TWR controllers were used.
- The simulation platform and IBP tool worked as required.
- Variables were kept the same between matched sets, and so a fair comparison could be made between each of the scenarios. As described in D.3.4.2 the order in which the reference and solution scenarios were conducted was varied to mitigate as much as possible against the learning effect of the traffic samples.

3. Significance of Demonstration Exercise EXE-PJ.37-W3-004 Results

A total of 12 matches set totalling 32 runs were conducted, thus a comprehensive set of results has been obtained.

Statistical analysis was performed on the Capacity metric, as this was the main objective to assess, and other KPI results are linked to this. Paired T-tests were conducted on the runway throughput data samples.

The t-test for Solution 1 versus Reference did not provide evidence of a significant difference between the two ($t = -1.52$, $p = 0.16$), whereas the t-test for Solution 2 versus Reference did provide evidence of a significant difference the two at 90% confidence ($t = -1.90$, $p = 0.09$).

D.3.5 Conclusions

1. Conclusions on concept clarification

The results show that the PJ.37-W3-01B Departures Solution is operationally feasible and acceptable. The extended OSD tool enables the ATCOs to provide more efficient and granular route spacings, particularly in the case of same/similar SID pairs where they can reduce the two-minute procedural time separation applied in current operations to the time equivalent of 5NM. In the case of diverging

SIDs, the extended OSD tool allows the ATCOs to provide more consistent route spacings, particularly when reduced visual separations cannot be applied. It was also agreed amongst the ATCOs that the extended OSD tool would help to provide a more consistent flow of traffic into the TMA.

The inclusion of the TMA data-feed is considered to be beneficial as it allows the ATCOs to apply more efficient non-integer flow restrictions and allows for greater flexibility in departure spacing. This has the potential to provide significant benefits to the operation on days where there are several flow restrictions applied due to, e.g., bad weather.

The extended OSD tool support reduces the workload of the ATCO, providing them with additional thinking time to perform other tasks, such as planning ahead with the departure sequence. The route countdown timer also provides a visual reminder to the ATCO that action needs to be taken and also how many other tasks can be achieved before issuing take-off clearance.

The target distance spacings used in the RTS were considered to be appropriate, but the concept needs flexibility to refine the Delivery Points on a SID pair basis in future iterations once integration with TMA traffic has been tested. In addition, further research is needed into replacing single Delivery Points in the TMA with consideration of the whole SID geometries.

Finally, there was a consensus amongst the Tower and TMA controllers that although the target distance spacings used in the RTS were appropriate, the Delivery Points may need refining on a SID pair basis in future iterations of the concept once integration with TMA traffic has been tested, i.e., not a blanket application of 3.5NM for all diverging pairs and 5NM for all same and similar-SID pairs.

Departure throughput benefits were brought about from the optimised route spacings in the ITARO Departures solution track PJ.37-W3-01B and the increase was found to be statistically significant in SOL2 (extended OSD tool with the emulated TMA data-feed). However, some of the observed increase is likely to be a result of the learning effect of the traffic samples, although the order in which the reference and solution scenarios were conducted were varied in an attempt to mitigate against this as much as possible. The capacity benefits also corroborate with the ATCOs expert opinion.

Further work is needed to address the potential for human error from the risk of over-reliance on the extended OSD tool leading to de-skilling of the ATCOs

2. Conclusions on Technical Feasibility

The extended OSD tool was found to be technically feasible for the application of the ITARO Departures Solution Scenario¹⁶.

The extended OSD tool was found to accurately deliver the target distance spacings (3.5NM for diverging SIDs and 5NM for same/similar-SID pairs) in the majority of cases, although the tool was assessed as being overly conservative at times and resulting in slight under-spacings in other cases. Further work is therefore needed to refine the algorithm which converts the target distance into a departure time spacing. This will need to consider the appropriateness and accuracy of the aircraft

¹⁶ Note that Technical Feasibility of the extended OSD tool was considered within the Operational Feasibility assessment as there was no dedicated Technical Feasibility demonstration objective for the PJ.37-W3-01B Departures Solution.

departure speed profiles and wind information used by the tool, the assumed departure tracks flown by the leader and follower aircraft, and how the algorithm applies a wind correction to the time-to-fly calculation.

The use of separate countdown timers for wake separations and route spacings was found to be acceptable; however, improvements to the extended OSD tool HMI are required in future versions of the tool, including better indication of tool failure, locating the countdown timers on the EFPS display and indicating whether the time value displayed on the route countdown timer applies to a route spacing or a TMA flow restriction.

Despite the issues noted above, the ATCOs said they had a high user confidence in the system in the ITARO Departures Solution Scenarios, enabling them to perform their task in an accurate, timely and efficient manner.

3. Conclusions on performance assessments

Data Analysis was performed on the following Performance KPIs, and in conclusion all have achieved 'OK' status whilst taking into the account the quality and limitations of the demonstration results as described in D.3.4.

CAPACITY

The data analysis show that the SOL1 (extended OSD Tool without TMA Data Feed) achieved a higher throughput than the REF in 9 out of 11 matches. SOL2 achieved a higher throughput than the REF in 7 out of 10 matches, although there was no clear trend SOL2 observed of an incremental increase in throughput from REF – SOL1 – SOL 2. When comparing REF with SOL1 an average increase of 1.3 movements an hour is seen (2.4%). When comparing REF with SOL2 an average increase of 1.7 movements can be seen (3.2%). Paired t-tests have been carried out on the runway throughput data samples. Whilst the t-test for Solution 1 versus Reference did not provide evidence of a significant difference between the two ($t = -1.52$, $p = 0.16$), the t-test for Solution 2 versus Reference did provide evidence of a significant difference the two at 90% confidence ($t = -1.90$, $p = 0.09$).

Although the ATCOs reported a learning effect from being exposed to the same traffic sample numerous times, this was mitigated as much as possible by mixing up the order of the runs in which the reference, solution 1 and solution 2 were conducted. Feedback from the ATCOs indicated that even given the limitations of the simulation they believed that the concept (with recommended algorithm improvements) would bring about an increase of capacity.

PREDICTABILITY:

The data analysis for PRD001 tells a similar story to the Capacity results, as any increase in runway throughput will therefore assume that aircraft are not spending as much time in the taxi-out phase and waiting at the Runway Hold area for as long to take off. The average taxi-out time was calculated for each scenario within a matched set as the difference between aircraft simulation start-up time and take-off roll time. When comparing REF to SOL1, the average taxi time was higher in REF than for SOL1 in 8 out of 11 matches (a reduction in SOL1 of 0.4 minutes). When comparing REF to SOL2, the average taxi time was higher in REF than for SOL2 in 7 out of 9 matches (a reduction in SOL2 of 0.9 minutes).

The standard deviation in taxi-out time for the Solution Scenario runs was compared against the matched Reference scenarios. The results show a reduction in Standard Deviation for SOL1 runs compared to the matched Reference Scenario runs of -0.10 minutes. A similar result is found for SOL2

compared with the matched Reference Scenario runs with a reduction of standard deviation by -0.40 minutes.

A second measure of predictability is Runway Hold Area (RHA) delay. The data analysis shows that there was a reduction in mean RHA delay of 0.3 minutes when comparing REF with SOL1 and REF with SOL2.

The standard deviation in RHA delay in the SOL1 and SOL2 Scenario runs was reduced compared to the matched reference scenario runs, which indicates slightly improved predictability.

This result is to be expected, as the RHA delay is attributable to the runway throughput – the more aircraft that are departed within a set time will therefore reduce the amount of time the aircraft is waiting to depart at the runway hold area.

As discussed in the capacity objective results D.3.2.3, although there were some limitations of the runway throughput results (learning effect of traffic sample and improvements required to the algorithm) the ATCOs opinion was that improvement in capacity and therefore an improvement in predictability would be seen.

ENVIRONMENT:

The environmental analysis assumes that the more efficient departure separations created by the ITARO Departures solution track PJ.37-W3-01B could be directly translated into a reduced ground holding durations, therefore decreasing the amount of fuel consumed whilst the engines of aircraft are idle and pilots waiting to be issued with take-off clearance.

Analysis on the RTS data has indicated that the extended OSD tool with an emulated TMA data-feed would give fuel burn savings of 18 kg and CO₂ emission savings of 57 kg per flight on average compared to the OSD tool. These savings are due to more efficient departure separation times between aircraft, therefore reducing ground holding (i.e., taxi time) durations and the amount of fuel burnt and CO₂ emitted compared to OSD.

However, the extended OSD tool without a TMA data-feed presented the most efficient departure separation times and lowest ground holding durations but resulted in smaller average environmental savings of 7kg fuel burn and 23 kg CO₂ emissions per flight respectively compared to the OSD tool. This was due to more aircraft types with higher taxi fuel burn rates holding for longer durations and also likely the small sample sizes likely to have an effect on the results.

As expected, the participating ATCOs in the RTS expected to see more benefits for the solution with the TMA data-feed as it helps them to apply flow restrictions more accurately as well as allowing more granular flow restrictions to be applied (e.g., 3m 30s instead of 4m). However, as these results are based on a very small RTS sample, they are highly dependent on the traffic samples and the ATCOs involved in the RTS. Furthermore, the RTS are focused on the London Heathrow operation only and considerations should be made on departure sequencing behaviours that are not necessarily universal at other airports. Other limitations include the simplified RTS environment (such as no other airport traffic simulated) and aircraft fleet mix which was used to determine these environmental benefits. The results should therefore be considered as indicative and further investigations could be carried out using more sophisticated methods such as Fast-Time Simulations with larger traffic samples.

ATC PRODUCTIVITY:

The analysis findings for the Capacity objective OBJ-37-W3-DEMOP-CAP1-0004 can also be used to assess the ATC Productivity objective as the departure runway throughput is directly related to the number of aircraft that the ATCO has handled in an hour. Therefore, the benefit in terms of ACTO productivity for the departures RWY position operating in segregated mode, excluding RWY crossers or towing aircraft, is exactly the same as for the overall increase in capacity: 2.4% for Solution 1, or 3.2% for Solution 2. Refer to section D.3.2.3 for the data analysis.

D.3.6 Recommendations

1. Concept and Tool Recommendations

The following recommendations have been formulated to improve the operational feasibility of the extended OSD tool:

REC-37-W3-OPF-R1: The extended OSD tool algorithm which calculates the time spacing required to achieve the target distance spacing should be improved by considering the accuracy and appropriateness of the:

- Source of wind information aloft used by the extended OSD tool.
- Departure tracks used by the extended OSD tool.
- Aircraft departure speed profiles used by the extended OSD tool.
- Assumptions used by the extended OSD tool about how the time-to-fly of the aircraft is affected by wind.

REC-37-W3-OPF-R2: The feasibility of including the impact of individual airline behaviour on the time-to-fly calculation should be considered as part of future extended OSD tool development.

REC-37-W3-OPF-R3: The feasibility of considering the whole geometry of the SID pairs rather than single Delivery Points should be considered as part of future extended OSD tool development.

REC-37-W3-OPF-R4: Future demonstration exercises should use traffic samples which are conducive to same/similar SID pairs being created in the departure sequence, whilst remaining realistic.

REC-37-W3-OPF-R5: Future demonstration exercises should test integration of air traffic departing from the aerodrome using the extended OSD tool with wider TMA traffic.

REC-37-W3-OPF-R6: There should be flexibility to tailor the target distance spacings on a SID pair basis in future demonstration exercises.

REC-37-W3-OPF-R7: Future versions of the extended OSD tool should differentiate between route spacings and route flow restrictions on the controller's HMI.

REC-37-W3-OPF-R8: Future versions of the extended OSD tool should differentiate between whether the time on the route countdown timer applies to the current leader-follower pair or the follower and the aircraft ahead of the leader.

REC-37-W3-OPF-R9: Future versions of the extended OSD tool should locate the wake and route countdown timers on the electronic flight progress strips, as well as investigate the option to go on ADIS.

2. Safety Recommendations

The following recommendations have been formulated to improve the safety of the extended OSD tool (for details, see Appendix A.1 of DEMO Report Part II [18]):

REC-37-W3-SAF-R1.1: During future testing of this solution in future projects, more robust procedures should be created to ensure all forms of Reduced Separation that ATCOs apply are recorded accurately and correctly in the simulation environment.

REC-37-W3-SAF-R1.2: For future iterations of the extended OSD algorithm, refinements are required to ensure accuracy of the input values to the extended OSD tool describing the SID profiles flown by aircraft.

REC-37-W3-SAF-R1.3: Further investigation should be undertaken regarding the MET conditions used in simulations and its interaction with the algorithm in order to refine the calculation of the route time spacing required.

REC-37-W3-SAF-R1.4: Further investigation should be undertaken in future projects to ensure realistic departure speed profiles are used as an input in the simulation environment (note this aligns with REC-37-W3-OPF-R1).

REC-37-W3-SAF-R1.5: Further investigations should be undertaken in future projects to examine the use of 'safety buffers' on certain route pairings.

REC-37-W3-SAF-R1.6: A larger sample size of differing aircraft types should be utilised in future projects to deduce whether improved departure speed profiles are required and if there are any issues with specific aircraft speed data.

REC-37-W3-SAF-R1.7: Additional simulations should be undertaken to explore the interactions of Heathrow departures with all traffic movements both through the TMA and into and out of the major airports in the London TMA, with a consideration to include unfavourable wind profiles at all levels.

REC-37-W3-SAF-R1.8: Further investigation should be undertaken in future projects to ascertain whether other significant parameters need to be included in the Solution (e.g., Airline, destination, and air pressure.)

REC-37-W3-SAF-R1.9: Further investigations should be undertaken in future projects regarding same SID pair departures, catch-ups and potential wake encounters above the Controlled Traffic Region.

REC-37-W3-SAF-R1.10: The HMI needs to clearly display when there is wake separation.

REC-37-W3-SAF-R1.11: Further investigations should be undertaken to assess the impact of the extended OSD tool on catch-up occurring in the TMA and if the defined spacing delivery points for the leader and follower aircraft are appropriate on a SID pair basis.

REC-37-W3-SAF-R1.12: Further investigations should be undertaken to assess whether the target distance spacings assigned to SID pair combinations are sufficient.

REC-37-W3-SAF-R1.13: An investigation into whether a destination reference table should be an input to the extended OSD tool should be carried out.

REC-37-W3-SAF-R2.1: A toggle switch should be provided to enable ATCO personalisation of the timer. (See also REQ-37-W3-HP-6).

REC-37-W3-SAF-R2.2: An HMI workshop should be held to discuss suitable placement of the extended OSD tool output. (See also REQ-37-W3-HP-7).

REC-37-W3-SAF-R2.3: An HMI workshop should be held to discuss the suitable placement of the MDI and TMA data feed information.

REC-37-W3-SAF-R2.4: During the next wave of this solution, more scenarios and tasks that ATCOs experience daily should be incorporated into the simulated exercises.

REC-37-W3-SAF-R2.5: A simple to follow separations matrix and immediate action procedures should be produced to enable safe operations to continue.

REC-37-W3-SAF-R2.6: HF, Safety and ATCOs should fully investigate the required procedures, tasks and possible ATCO training requirements in the event of tool failure.

REC-37-W3-SAF-R2.7: All ATC procedures which will be affected by the deployment of the tool should be highlighted early in future projects to assess for any major safety issues.

REC-37-W3-SAF-R2.8: Further investigations are required to fully understand the content and duration and frequency of training required for ATCOs to sufficiently maintain currency and skills to manually apply accurate and efficient separations.

REC-37-W3-SAF-R3.1: A visual only alert (not audible) of the status of the equipment is required to allow maximum time for controllers to identify the failure and then to quickly revert to the alternate procedures.

REC-37-W3-SAF-R3.2: Further investigations are undertaken regarding possible interaction between other ATC systems and the extended OSD tool system and the utilisation of any back up servers already in use in the Air Traffic Control tower.

REC-37-W3-SAF-R3.3: A function should be introduced to allow the Supervisor only to switch off the system (either in certain elements or the whole extended OSD tool) in situations where there was any doubt about the integrity of the information being presented to the controller. (See also REQ-37-W3-HP-3)

REC-37-W3-SAF-R3.4: Further investigation into the issue of corrupt but believable data and its impact to the system should be undertaken in future projects.

REC-37-W3-SAF-R3.5: Further examination should be made into the assigning of the correct software assurance level to the system in association with compliance of ED153.

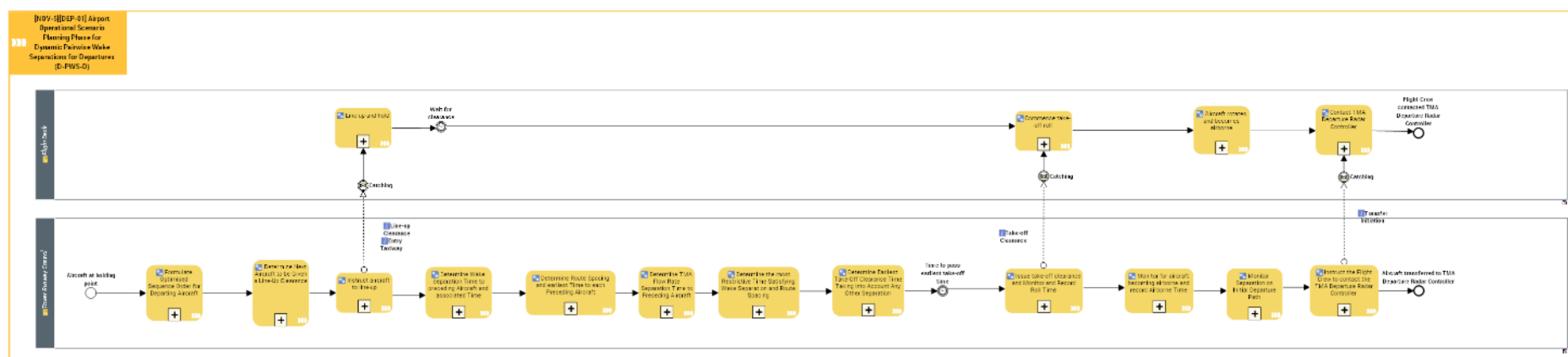
3. Human Factors Recommendations

The Human Performance recommendations can be found in Appendix D of the PJ.37-W3-01B DEMO Report Part III (HPAR) [19].

Appendix E EATMA modelling to support PJ.37-W3-01B – Departure Operations

1. NOV-5 Activity View for determining separation to be delivered (derived from PJ.02-01-02)

Diagram



Description

This NOV-5 is based on the work performed within the PJ.02-01-02 framework. PJ.37-W3-01B aims at extending one of the concepts encompassed by Solution PJ.02-01-02, specifically the one proposed by AO-0329 (OSD tool), by optimising current route separations and adding a flow rate measures consideration when computing the separation required during the departure phase. The relevant flows from PJ.02-01-02 have been taken and enriched appropriately. For PJ.37-W3-01B, only the time-based approach has been considered, although PJ.02-01-02 contained a dedicated flow for the distance-based indicator concept. The distance-based concept can be observed in the diagrams associated with that specific project (currently in [NOV-5][DEP-01] Airport Operational Scenario Execution Phase for D-PWS-D based on Differentiated Airborne Position and Climb Profiles (D/AP&CP) within PJ.02-W2-14.9b folder). It is to be noted that the choice of the implementation option (time-based or distance-based indicators) is to be made by each local ANSP.

This Use Case describes the process to determine and deliver the appropriate separation between aircraft pairs in the departure phase, taking into account the different factors which restrict the separation, such as wake turbulence, SIDs, Minimum Radar Separation and flow rate measures, which may be in place. The separation time required is equivalent to the Target Distance Spacing, which is translated into time in order to facilitate the delivery by the ATCO.

The Use Case starts when the aircraft is at the holding point awaiting departure.

General Conditions (Scope and Summary)

This Use Case describes in detail the steps involved for determining and delivering the separation required between departing aircraft pairs.

Pre-Conditions

The extended OSD tool developed within PJ.37-W3-01B is operational and available for supporting determining time-based separation.

Wind information is provided for consideration when the required separations are determined.

TWR is aware of the applicable flow rate measures (if existing).

Post Conditions

The appropriate spacing is delivered to all departing aircraft, which satisfies all applicable separation constraints.

Actors

Tower Runway Controller, Flight Crew.

Trigger

Aircraft is ready for departure.

Activities

Name	Primary text
Aircraft rotates and becomes airborne	Nominal The aircraft executes a normal take-off roll, and rotates and becomes airborne at the anticipated position for the prevailing operating conditions. Non-Nominal The Flight Crew abort the take-off roll, either due to a problem, or as a result of being instructed by the Tower Runway Controller.
Commence take-off roll	Nominal On receiving the clearance to take-off, the Flight Crew commence the take-off roll. Non-Nominal On receiving the clearance to take-off, the Flight Crew may delay the start of the take-off roll, or may query the Tower Runway Controller on the separation to the preceding departure aircraft when unsure whether sufficient wake separation is being provided.
Contact TMA Departure Radar Controller	As instructed by the Tower Runway Controller, the Flight Crew contact the TMA Departure Radar Controller.
Determine Earliest Take-Off Time Taking into Account Any Other Separation	The Tower Runway Controller determines the earliest take-off clearance time. (S)he is informed by the extended OSD tool about the earliest take-off clearance time considering wake separation, route separation and TMA flow rate if applicable. The route separation time is an advisory/guidance and the Controller may choose to reduce this separation further using another acceptable means, such as Reduced Separation in the Vicinity of the Aerodrome (i.e. RSVA visual separation). This will be at the controller's discretion.

Name	Primary text
Determine next aircraft to be given a line-up clearance	When it is time to line-up the next departure aircraft the Tower Runway Controller uses the formulated optimised departure sequence order to determine the next departure aircraft to line-up.
Determine Route Spacing Time to each preceding aircraft	Nominal The extended OSD tool determines the Route Spacing time (taking into account the applicable SID pair, aircraft performance and wind conditions) that applies to each relevant preceding aircraft. In the case of applying a “Not Before Airborne Time”, once the “airborne time” is provided for the preceding aircraft, the “Not Before Airborne Time” is determined for each relevant route spacing. The usage of "Not Before Take-Off Time" could be chosen as a local implementation, although this option has not been considered as part of the developments within the project. Failure In the event of the extended OSD tool becoming unavailable, the Tower Runway Controller shall revert to manually applying procedural Route separation rules.
Determine the most restrictive Time satisfying Wake Separation and Route Spacing	Nominal The extended OSD tool determines the most restrictive Wake Separation or Route Spacing time that is required to be applied.

Name	Primary text
Determine TMA Flow Rate Separation Time to Preceding Aircraft	The time separation required to the preceding aircraft, based on the applicable TMA flow rate measures (if any), is determined and considered. This will ensure that the workload does not become too high for TMA controllers during busy periods as a result of the refined departure Route Spacings applied by the solution.
Determine Wake Separation Time to preceding aircraft	Nominal When the departure aircraft is the next aircraft in the runway departure sequence to be given a take-off clearance, the Tower Runway Controller determines the Wake Separation time to apply. When PWS-D is being applied, the Tower Runway Controller is unable to mentally apply the PWS-D pairwise 103 x 103 matrix, and the wake category 20-CAT matrix, and so is supported by the extended OSD tool, which determines and presents the Wake Separation time to apply. When RECAT-EU or ICAO wake separations are being applied, the Tower Runway Controller is able to self-determine the required Wake Separation time without the aid of the extended OSD tool, although may optionally be supported by the extended OSD tool. In the case of applying a “Not Before Airborne Time”, once the “airborne time” is provided for the preceding aircraft, the “Not Before Airborne Time” is determined, with the aid of the extended OSD tool in the case of applying the PWS-D wake separations respectively, and optionally with the aid of the extended OSD tool in the case of applying the RECAT-EU or ICAO wake separations. Non-Nominal When follower aircraft lines-up at an intermediate position in relation to the preceding aircraft line-up position, the Tower

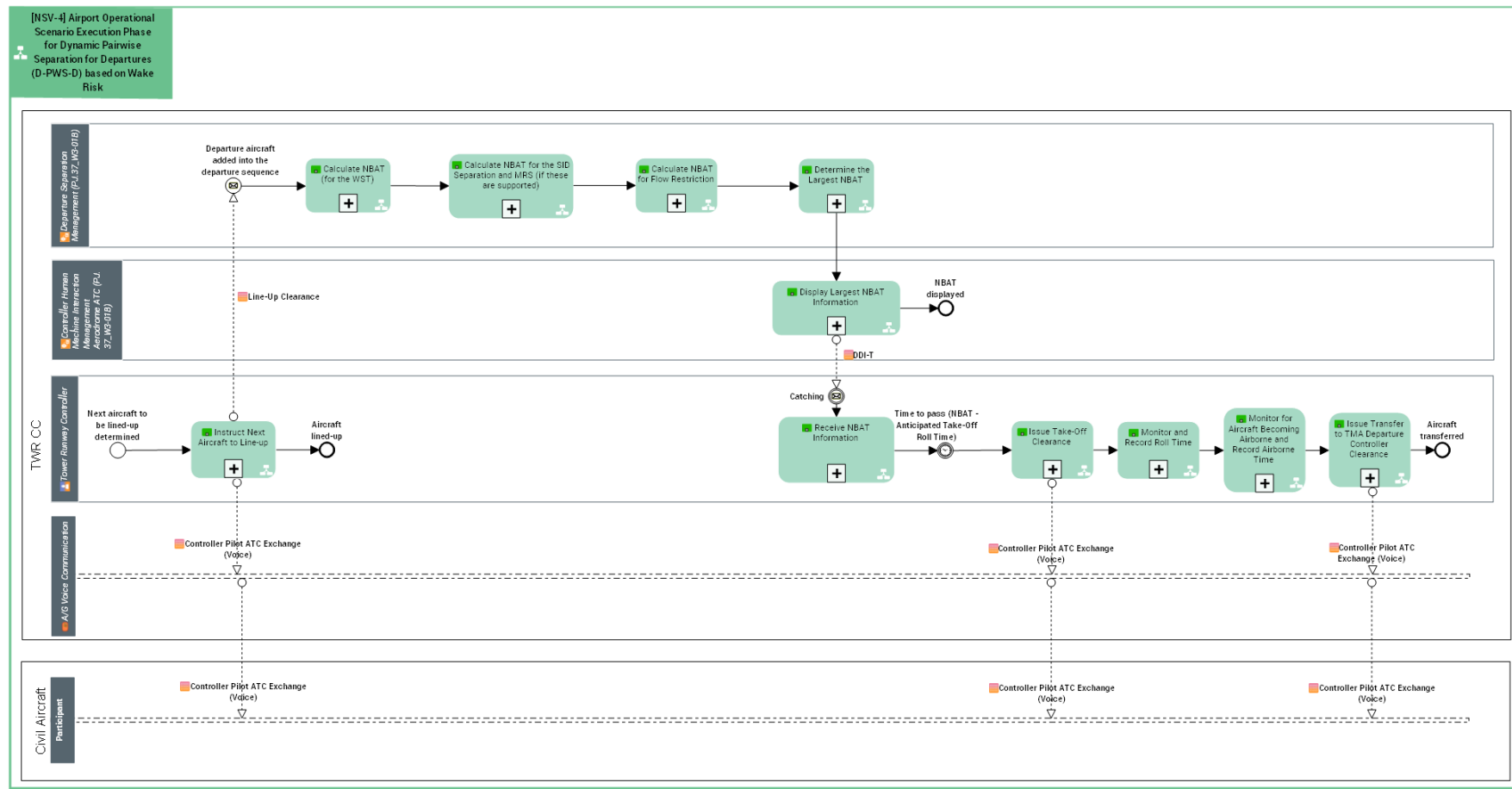
Name	Primary text
	Runway Controller and extended OSD tool are required to apply the wake separation rules for taking-off from an intermediate position. These rules require that an additional 60s is to be added to the Wake Separation time. The Flight Crew may inform the Tower Runway Controller that they want the RECAT-EU or ICAO wake separation to be applied to the preceding departure aircraft, rather than the PWS-D wake separation. The Tower Runway Controller acknowledges the request, and applies the requested wake separation time, with the optional support of the extended OSD tool. Failure In the event of the extended OSD tool becoming unavailable the Tower Runway Controller shall revert to manually applying ICAO or RECAT-EU TB wake separations with an optional aide memoire table of the ICAO or RECAT-EU wake separation rules.
Formulate optimised sequence order for departing aircraft	Nominal For departure aircraft at or approaching the runway holding points, the Tower Runway Controller formulates the optimised sequence order for the next few departure aircraft, optimising the amount of wake separation and Route /spacing and MDI/ADI and speed group constraints required while meeting any CTOT requirements. This may be with the aid of an automatically optimised departure sequence order or may be self-determined without any automated system support. When self-determining the optimised sequence order the Tower Runway Controller may take into account the RECAT-EU (or ICAO) wake category-based wake separations using an aide-memoire table rather than the pairwise and 20-CAT matrices of the PWS-D wake separations. The Tower Runway Controller may reflect the formulated optimised sequence order in the electronic environment runway holding bay. Non-Nominal The Flight Crew may inform the Tower Runway Controller that they are not ready to be given a line-up clearance due for example not having completed the authorisation steps with their airline operations centre. In such cases the Tower Runway Controller requests the reasons for not being ready for line-up, and the estimated time for when the aircraft will be ready for line-up. This may result in the need to change the optimised sequence order.

Name	Primary text
	Once ready the Flight Crew inform the Tower Runway Controller that they are ready to be given a line-up clearance so that the departure aircraft can be re-considered for including in the optimised sequence order.
Instruct aircraft to line-up	Nominal The Tower Runway Controller instructs the departure aircraft to line-up which may include informing the Flight Crew of the entry taxiway with the associated line-up position. In an electronic environment the Flight Data Entry (FDE) or Flight Progress Strip (FPS) is moved from the holding bay to the runway bay and the entry taxiway with the associated line-up position entered on the FDE or FPS. Non-Nominal In segregated mode operations more than one departure aircraft at a time may be instructed to line-up, and the line-up instructions and order the aircraft are moved from the holding bay to the runway bay may be out-of-order. Departure aircraft may be instructed to line-up at an intermediate position with the associated line-up position entered on the FDE or FPS.
Instruct the Flight Crew to contact the TMA Departure Radar Controller	Once the appropriate separation has been set up for the TMA Departure Controller, the Tower Runway Controller instructs the Flight Crew to contact the TMA Departure Controller.
Issue take-off clearance and Monitor and Record Roll Time	Nominal The Tower Runway Controller issues the take-off clearance provided the runway is clear. The Tower Runway Controller may be assisted in detecting the take-off of the leader by automatic tools which monitor the airborne position conformance of the departing aircraft and update the EFPS when the aircraft has been detected to be airborne.

Name	Primary text
	Non-Nominal The take-off clearance may be issued before the follower aircraft is lined-up and waiting at the line-up position. In these cases there is a need to wait until the follower aircraft has passed the normal line-up and wait position before recording the “start of take-off roll time”.
Line up and hold	The Flight Crew lines up the aircraft, using the entry taxiway and associated holding position instructed by the Tower Runway Controller.
Monitor for aircraft becoming airborne and record Airborne Time	Nominal The Tower Runway Controller monitors the take-off roll of the departure aircraft, and the departure aircraft rotating and becoming airborne (back wheels airborne). The Tower Runway Controller may be assisted in detecting the take-off of the leader by automatic tools which monitor the airborne position conformance of the departing aircraft and update the EFPS when the aircraft has been detected to be airborne. Non-Nominal The Flight Crew may be instructed to, or may self-determine, to abort the take-off roll and to not take-off. The Tower Runway Controller instructs the aircraft to vacate the runway, and removes the aircraft from the runway bay in the electronic environment.
Monitor separation on initial departure path	Nominal The Tower Runway Controller monitors the separation on the initial departure path, to ensure that the appropriate separation is being delivered to the TMA Departure Controller.

2. NSV-4 System Function View for determining separation to be delivered (derived from PJ.02-01-02)

Diagram



Description

This NSV-4 describes the system process for the Use Case presented in [NOV-5][DEP-01] Airport Operational Scenario Execution Phase for extended Optimised Separation Delivery for Dynamic Pairwise Separation for Departures (D-PWS-D). This Use Case summarises the calculation of the separation time to be delivered in the departure phase, where this separation time is equivalent to the Target Distance Spacing calculated by the system.

For the deployment of this concept, two approaches may be followed, either working with NBAT (Not Before Airborne Time) or NBTOT (Not Before Take-Off Time). In the PJ.37-W3-01B framework, the NBAT approach will be followed, thus only the parts of the Functions description related to NBAT should be considered. Also, WDS-D functionality is out of the scope of PJ.37-W3-01B, hence everything related to the application of this concept should be disregarded.

It is assumed that for determining the required time spacing, the system is fed with the wind information and aircraft performance data. Besides, the system is aware of the applicable flow rate measures for any moment, which are determined and fed into the extended OSD tool as shown in [NSV-4] Optimise Departure Flows within the TMA by means of Flow Rate Measures.

Concerning the presentation of the separation time by means of a countdown timer, two different implementation options can be considered:

- Two independent countdown timers, one for the Wake separation, and another one for the Route and TMA flow rate measures (if applicable); or,
- One single countdown timer presenting the most restrictive separation time.

Also, it is to be noted that as a result of the latest developments in PWS-D pairwise concept, the 96x96 matrix has been extended to 103x103, which will be used for this Use Case.

Note: This NSV-4 is based on the work performed within PJ.02-01-02 framework, extending it by refining the Route Separations (more granular than the previously used integer minutes). PJ.37-W3-01B aims at extending the concept by adding the flow rate measures consideration when computing the separation required during the departure phase. The relevant flows from PJ.02-01-02 have been taken and updated appropriately. PJ.02-01-02 contained a dedicated flow for the distance-based indicator concept, which can be observed in the diagrams associated to that specific project. It is to be noted that the choice of the implementation option (time-based or distance-based indicators) is to be made by each local ANSP.

Functions

Name	Primary text
Calculate NBAT for Flow Restriction	The NBAT for satisfying the applicable flow restrictions measures (if in place) is calculated.
Calculate NBAT (for the WST)	The extended OSD tool calculates the NBAT (Not Before Airborne Time) for the Wake Separation Time (WST) for take-off time based separation procedure. NBTOT is calculated considering the aircraft types and the procedure that is being followed. When the departure aircraft is the next aircraft in the runway departure sequence to be given a take-off clearance, the Tower Runway Controller determines the Wake Separation Time to apply. When PWS-D is being applied, the Tower Runway Controller is unable to mentally apply the PWS-D pairwise 96 x 96 matrix, and the wake category 20-CAT matrix, and so is supported by the OSD tool, which determines and presents the Wake Separation Time to apply. When WDS-D is being applied in the context of PWS-D, the Tower Runway Controller is unable to mentally determine the Wake Separation Time, and so is supported by the Enhanced OSD tool, which determines and presents the Wake Separation Time to apply, taking into account when the WDS-D reduced wake separation has been authorised to be applied, and in the case of the D-TB-WDS-Xw concept, that the follower departure aircraft planned SID path is upwind of the preceding departure aircraft planned SID path beyond the straight-out initial common departure path. When a D-TB-WDS-Xw reduced wake separation is being applied the Enhanced OSD tool is to clearly inform the Tower Runway Controller this is the case. When RECAT-EU or ICAO wake separations are being applied, the Tower Runway Controller is able to self-determine the required Wake Separation Time without the aid of the OSD or Enhanced OSD tool, although may optionally be supported by the OSD or Enhanced OSD tool.

Name	Primary text
	In the case of applying a “Not Before Airborne Time”, once the “airborne time” is provided for the preceding aircraft, the “Not Before Airborne Time” is determined, with the aid of the OSD or Enhanced OSD tool in the case of applying the PWS-D and WDS-D wake separations respectively, and optionally with the aid of the OSD or Enhanced OSD tool in the case of applying the RECAT-EU or ICAO wake separations.
Calculate NBAT for the SID Separation and MRS (if these are supported)	For the “Not Before Airborne Time”, once the “airborne time” is provided for the preceding aircraft, the “Not Before Airborne Time” is determined by the OSD or Enhanced OSD tool for each relevant SID separation.
Determine the Largest NBAT	The OSD tool determines the most restrictive Wake Separation Time or SID Separation Time that is required to be applied. This is the most restrictive NBAT.
Display Largest NBAT Information	The most constraining out of the Wake Separation Time and SID spacing/Flow restriction information is displayed in the form of an NBAT (Not Before Airborne Time). This will be shown as the earliest time for the aircraft to become airborne. The time to issue the take-off clearance may be supported with a countdown timer in the HMI, based on the information aforementioned. The countdown time shall be displayed differentiating between MRS and SID spacing support and WT support. The countdown timer shall automatically start ticking at adequate time, and shall distinguish a passive status (ticking has not started yet) from an active status (ticking has started).
Instruct Next Aircraft to Line-up	The Tower Runway Controller instructs the departure aircraft to line-up. In an electronic environment the Flight Data Entry (FDE) or Flight Progress Strip (FPS) is moved from the holding bay to the runway bay and the entry taxiway with the associated line-up position entered on the FDE or FPS.

Name	Primary text
Issue Take-Off Clearance	The Tower Runway Controller issues the take-off clearance if the runway is clear.
Issue Transfer to TMA Departure Controller Clearance	Once the appropriate separation has been set up for the TMA Departure Radar Controller, the Tower Runway Controller instructs the Flight Crew to contact the TMA Departure Radar Controller.
Monitor and Record Roll Time	In the case of applying a “Not Before Take-Off Time”, there is a need to monitor and record the “start of take-off roll time”, which may be through a manual interaction in the electronic environment of the Tower Runway Controller, or in a non-electronic environment or an electronic environment may be through automatic surveillance based monitoring support. In the case of applying a “Not Before Airborne Time”, the notification of the “start of take-off roll” may be used as a trigger event to calculate the required Wake Separation time to the next follower aircraft.
Monitor for Aircraft Becoming Airborne and Record Airborne Time	The Tower Runway Controller monitors the take-off roll of the departure aircraft, and the departure aircraft rotating and becoming airborne (back wheels airborne). In the case of applying a “Not Before Airborne Time”, there is a need to monitor and record the “airborne time” which is usually through a manual interaction in the electronic environment of the Tower Runway Controller, with the FDE or FPS being moved from the runway bay to the airborne bay, and the timing of this manual interaction being automatically recorded as the “airborne time” of the departure aircraft. There may be automatic surveillance based monitoring support for determining and recording the “airborne time” of each departure aircraft; however there appear to be significant feasibility issues associated with the consistency of such an approach. This is because the Mode S airborne indicator is indicating the aircraft is airborne while the aircraft is still rolling on the runway for many aircraft types.



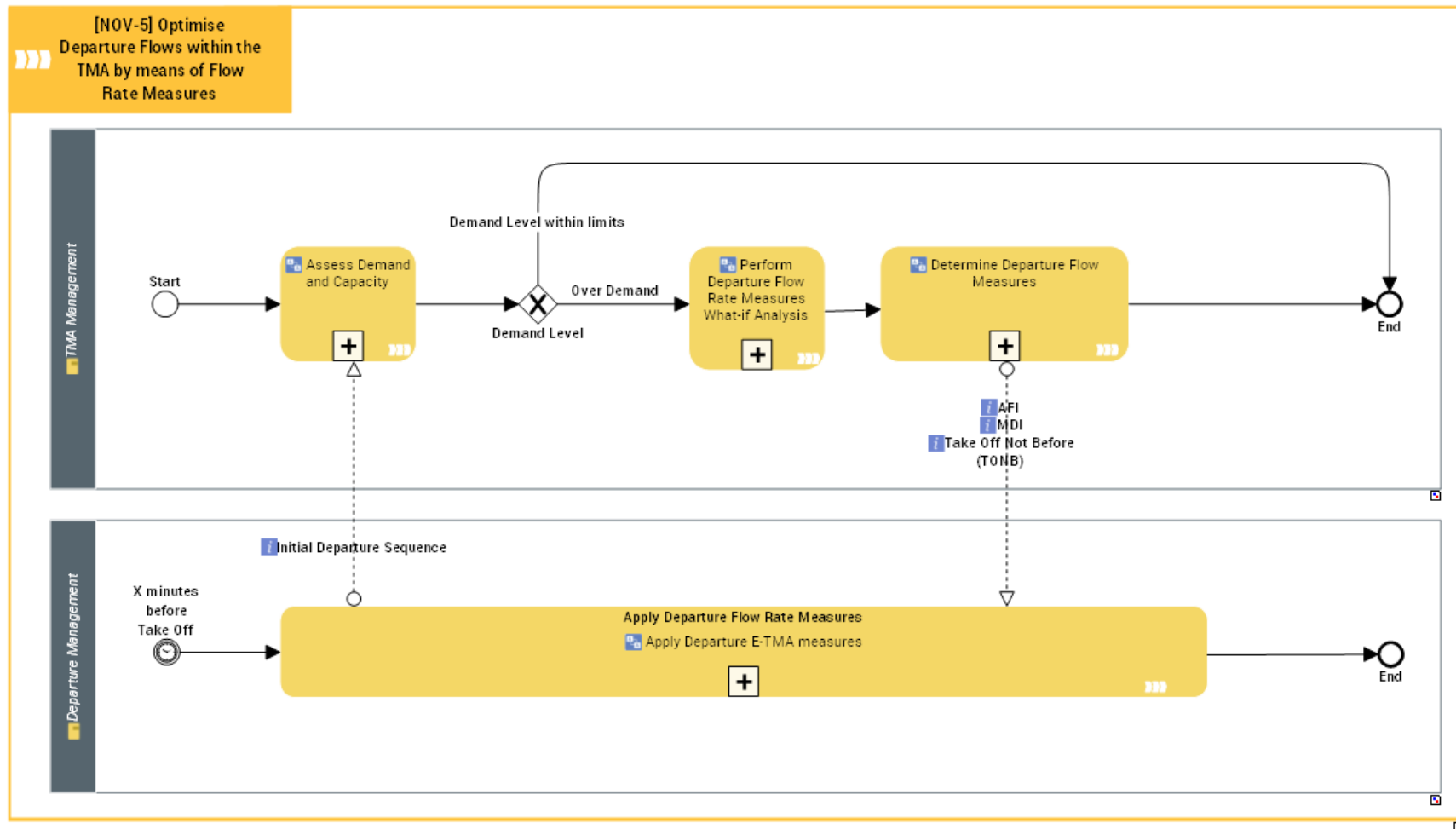
Name	Primary text
Receive NBAT/NBTOT Information	The Tower Runway Controller is informed about the NBAT/NBTOT information displayed in the HMI for the departing aircraft.

(*) In yellow: newly created Function as part of PJ37-W3-ITARO activities. The rest of the Functions are already part of the Common Libraries, so they cannot be further modified.



3. NOV-5 Activity View for determining Flow Rate Measures (derived from PJ.01-W2-08B4)

Diagram



Description

This Activity view summarises the procedure for determining and applying departure flow rate measures in order to keep the controllers' workload within acceptable limits, by preventing demand levels from going above the manageable thresholds.

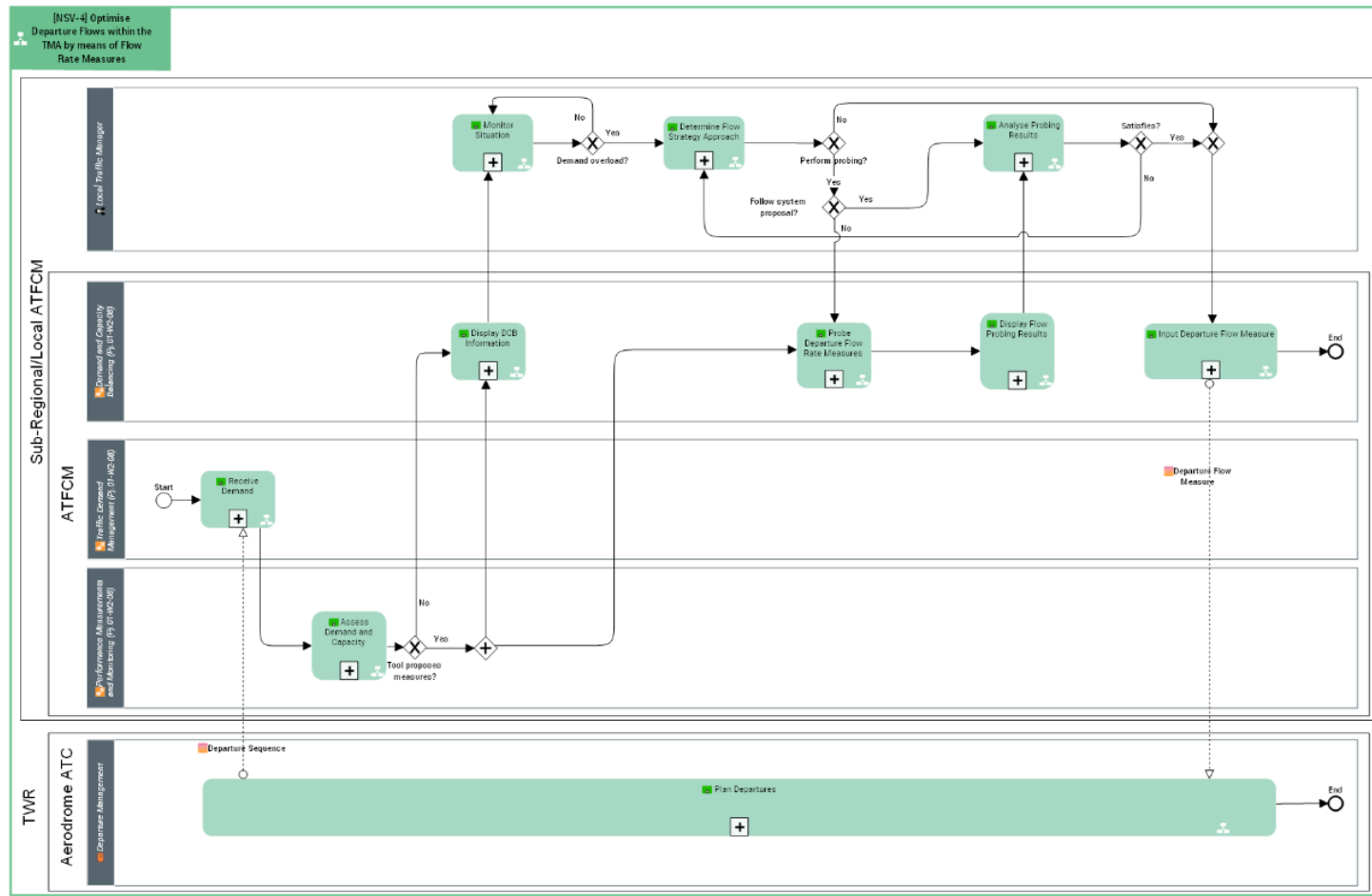
Note: The NOV-5 is an adaptation of the relevant flow coming from PJ.01-W2-08B4.

Activities

Name	Primary text
Apply Departure E-TMA measures	The Flow Rate measures that have been determined for departures are applied, in order to keep demand level within the acceptable limits.
Assess Demand	Predicted flow rates and complexity levels for defined points or sectors are monitored, identifying if the demand is predicted to exceed specified limits.
Determine Departure Flow Measures	In the case of Departure Flow over-demand, flow limits are proposed using either MDIs (Minimum Departure Intervals) or TONB (Take-Off Not Before) constraints to particular aircraft in order to solve the over-demand.
Perform Departure Flow Rate Measures What-If Analysis	When over-demand has been identified, measures are assessed which will bring the demand within limits and propose Departure constraints as appropriate.

4. NSV-4 System Function View for determining Flow Rate Measures (derived from PJ.01-W2-08B4)

Diagram



Description

This Function view summarises the system's procedure for applying departure flow rate measures in order to keep the controllers' workload in the TMA within acceptable limits, by preventing demand levels from going above the manageable thresholds.

Note: The NSV-4 is an adaptation of the relevant flow coming from PJ.01-W2-08B4.

Functions

Name	Primary text
Analyse Probing Results	The E-TMA Management Tool Operator checks the results of the performed Probing (either manual or automatic) and decides if the situation with the probed measures is satisfactory enough. If it is not, more probing and analysis can be performed. This function is contextual, added for diagram clarity and coherency. It is considered that it does not modify the functions already performed by the Local Traffic Manager Role. No requirement traces to this function.
Assess Demand and Capacity	The E-TMA Management tool continuously monitors and assesses the predicted flow rates and complexity levels for defined flows, routes, points or sectors, identifying if the demand is predicted to exceed specified limits. This assessment can be influenced by configuration parameters set by the user (time interval, time window)
Determine Flow Strategy Approach	The Local Traffic Manager determines to follow a Flow Strategy Approach, where time constraints will be applied to solve the over-demand.
Display DCB Information	The E-TMA Management Tool shows all the relevant information on the HMI. This includes the presentation of the Capacity Thresholds, the Demand, the periods and places where an overdemand is predicted, the alerts associated to that overdemand and any other related display of information.

Name	Primary text
Display Flow Probing Results	The system shows the results of Flow Probing Measures. This result can be a consequence of a manual probing by the Operator, or the Measures suggested automatically by the Tool.
Input Departure Flow Measure	In the case of Departure Flow over-demand, the user can input constraints to the flow or to particular aircraft in order to solve the over-demand. The decision of which aircraft have to be acted upon can be taken by the User or following the system suggestions.
Monitor Situation	The E-TMA Management Tool Operator observes the HMI and decides if any action is needed. This function is contextual, added for diagram clarity and coherency. It is considered that it does not modify the functions already performed by the Local Traffic Manager Role. No requirement traces to this function.
Plan Departures	Each airport creates a sequence of departures. A-CDM and DMAN create the sequence at large airports, while controllers organise the sequence manually at small airports. In both cases the sequence respects information from the E-TMA Management tool.
Probe Departure Flow Rate Measures	This function covers the possibility to assess the impact of a Flow Modification, either manually or automatically. The E-TMA Management Tool allows the manual introduction of a hypothetical Flow Measure by the Operator. The tool assesses the impact of that Measure, indicating the consequences to the user. And also automatically, when over-demand has been identified, the E-TMA Management tool will assess which Flow measures will bring the demand within limits and propose Departure constraints as appropriate



Name	Primary text
Receive Demand	The E-TMA Management tool receives the demand information from diverse Sources: FDP Flight Plans/Trajectories, EFTMS, AMAN/DMAN Sequences.



Appendix F Security

F.1.1 Security Requirements

The security requirements for PJ.37-W3-01B are based on requirements identified during SESAR Wave 1 PJ.02-01 and SESAR Wave 2 PJ.01-W2-08B, since both solutions form the starting point of PJ37. The requirements have been reviewed and remain relevant.

The security topics covered are:

Security Policy

Organization of Information Security

Human Resources Security

Asset Management

Access Control

Physical and Environmental Security

Operations Security

Communications Security

System Acquisition, Development and Maintenance

Information Security Incident Management

Information Security aspects of Business Continuity Management

Compliance