P05.07.04 WS2 Validation Report (VALR)

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Abstract

This document provides the Validation Report for Work Stream 2 of Project 5.7.4 related to P-RNAV procedures in complex TMAs using Point Merge. It describes the results of the RTS for both exercises EXE-05.07.04-VP-229 and EXE-05.07.04-VP-228 exploring the feasibility of the Point Merge Concept in complex TMAs-

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Executive summary

This Validation Report (VALR) is for the Operational Focus Area (OFA) "Point Merge in Complex TMA" delivered by Work Stream 2 of Project 05.07.04 "*Full Implementation of P-RNAV in TMA*". It describes the activities conducted to support validation for the Point Merge Concept in London and Milan TMAs.

Real Time Simulation (RTS) Activities, EXE-05.07.04-VP-229, were performed at the NATS Corporate and Technical Centre (CTC) on their V3 validation platform in November 2011 and December 2011. The focus of the simulation was to assess the viability of P-RNAV procedures in complex TMAs using Point Merge. In this instance the airports of Luton (EGGW), Stansted (EGSS) and London City (EGLC) were utilised. In order to allow the assessment of the fitness of the concept then the RTS used the following objectives as the primary assessment method:

- 574Obj_01 - Assess impact to Runway Throughput
- 574Obj_02 - Assess workload impact of procedures for Approach Controllers & Flight Crew
- 574Obj_03 - Assess Human Performance levels (such as Situational awareness, effective communication/teamwork detection/recovery of human error)
- 574Obj_04 – Assess TMA Safety levels
- 574Obj_06 - Assess the impact to Hold Occupancy & Flight Levels
- 574Obj_07 - Assess the impact to Fuel Burn / CO2 Emissions for arrivals and departures
- 574Obj_08 - Assess the impact of Noise pollution to the local Environment for arrivals and departures

Overall, approach controllers using the P-RNAV system reported reduced workload, improved situation awareness and reduced R/T. They issued fewer instructions than in current day operations and the spare capacity this provided improved their capability to deal with a range of non-nominal scenarios.

Aircraft spent less time holding overall and a significant reduction was observed in the level of outer holding in the TMA. A slight increase in the distance flown, and therefore fuel burnt, for arrivals was more than compensated by a greater decrease in the fuel saved by allowing departing aircraft an unrestricted initial climb phase of flight. The noise impact for arrivals was found to be neutral, but an improvement, also due to the unrestricted initial climb, was identified for departures. As a result 574Obj_01, 574Obj_03, 574Obj_07 and 574Obj_08 have been assessed as 'OK' for this validation exercise. Against SESAR KPAs this results in benefits against Environmental Sustainability (ENV1: 2% benefit against fuel burn and CO2) and Airport Capacity (CAP3: 4% increase in runway throughput).

While the results for EGSS and EGLC are almost entirely positive, the assessment of EGGW raises more issues. At least in part, these impacts were due to the introduction of two dedicated holding facilities at EGGW replacing the shared hold at LOREL and are not solely attributable to the Point Merge aspect of the P-RNAV implementation.

As a result, validation objectives 574Obj_02 and 574Obj_06 have been assessed as 'NOK' for this exercise despite the success at the TMA level and for EGSS and EGLC. The project may wish to consider this result an implementation specific issue; rather than a reflection on the concept as a whole. Against the SESAR KPA, a potential improvement in Local Airspace Capacity was indicated (CAP2: 16% decrease in controller workload) for the TMA as a whole. An outstanding analysis is to assess the R/T workload impact of P-RNAV procedures on the cockpit.

A wide variety of non-nominal situations were run during the course of the simulation based on input from the P5.7.4 Safety Assessment. The controllers felt their ability to manage these scenarios was not affected by the introduction of Point Merge. In some cases, such as single aircraft R/T failure, the increased level of systemisation improved the system's response to the scenario. The final assessment of 574Obj_04 at the project level will be documented in the Safety Assessment Report, which will be included in the P5.7.4 OSED [2] as an appendix. The conclusions of this exercise were that 574Obj_04 is assessed as 'OK' subject to the recommendations contained in this report and the safety requirements contained within the Safety Assessment Report of the OSED. Against the SESAR KPAs this indicates a potential benefit against ATM Related Safety Outcome (SAF1).

Real Time Simulation exercise EXE-05.07.04-VP228 was performed at Rome ACC premises on their Validation Platform. The main objective of the Simulation was to assess the feasibility of the Point Merge concept for multiairport Milan TMA. The concept was applied to Milan Malpensa airport, considering the interaction and interdependencies with Milan Linate airport,

In order to assess the concept to be validated a series of objectives have been defined as a method of assessment:

- 574Obj_01 - Assess impact to Runway Throughput
- 574Obj_02 - Assess workload impact of procedures for Approach Controllers & Flight Crew
- 574Obj_03 - Assess Human Performance levels (such as Situational awareness, effective communication/teamwork detection/recovery of human error)
- 574Obj_04 – Assess TMA Safety levels
- 574Obj_05 - Assess the impact effectiveness of Arrival and Departure Management
- 574Obj_07 - Assess the impact to Fuel Burn / CO2 Emissions for arrivals and departures

Since the simulator didn't allow the possibility for data recording, the Validation was conducted through a validation team which evaluated the objective verification through qualitative assessment.
All the sessions have been video-recorded.

The results were very encouraging since for all objective there has been a positive feedback.. Unfortunately some of them experience only a partial assessment (e.g. Fuel Burn) due to the lack of log data coming out from the platform.
The Point Merge geometry tested demonstrated to be very efficient in handling traffic for Milan TMA which is characterized by limited airspace availability and requesting very "dynamic" traffic management. In this context the word dynamic refers to the fact that from some directions from the moment when Milan TMA ATCOs accept incoming traffic from surrounding ATC unit (especially foreign ones) there is really a short time for manage traffic properly for arrival sequence, taking into account also potential interactions with departures from surrounding aerodromes and overflying aircraft.

In particular, less ATCO workload was experienced even in high traffic load, with ATCOs being almost unaware on how much aircraft they were handling, if compared to present situation.

1 Introduction

1.1 Purpose and scope of the document

As per Section 2.1.1 of the WP5 Validation Strategy [8], Project 05.07.04 "*Full Implementation of P-RNAV in TMA*" is split into two work streams. Work Stream 1 (WS1) validates the Operational Focus Area (OFA) "*Optimised RNP Structures*". Work Stream 2 (WS2) validates the OFA "Point Merge in Complex TMA".

Work Stream 2 is divided into two test cases: London TMA and Milan TMA.

This Validation Report (VALR) of Work Stream 2 of Project 05.07.04 describes the activities conducted to support validation for the P-RNAV Point Merge Concept in the London TMA and Milan TMA. P-RNAV Point Merge procedures were applied to the airports of Luton, Stansted and London City in London TMA. P-RNAV Point Merge procedures were applied to Milan Malpensa for Milan TMA, assessing interactions and interdependencies with Milan Linate airport.

Work Stream 2 of the project is defined as: 'P-RNAV procedures in complex TMAs using Point Merge'. The key aspects of this work stream are:

- Feasibility of Point Merge in a complex (multi-airport) TMA.
- Optimization of airspace use and traffic management for complex TMAs through the use of Point Merge technique coupled with P-RNAV navigation capability. Airspace designs were iteratively developed and improved through V2 and V3 to optimise the balance between capacity and route efficiency as far as practicable.
- P-RNAV CDAs in high density traffic. The airspace was designed to manage high density traffic; busy traffic periods were simulated for the validation and controllers encouraged to look for profile efficiencies on a tactical basis.
- Continuous Climb Departures enabled by the enhanced horizontal performance of P-RNAV.
- Impact on preferential noise routes upon transition from conventional to P-RNAV procedures, due to the turning performance linked to each respectively.

Key stakeholders contributing to the underlying evidence within this report include the SESAR Validation Team who were involved in the development, execution and analysis of the activities, Safety, Human Factors and Operational Analysis Experts. Additionally significant ATCO operational expertise was included in the development and execution of the activities. All these stakeholders played an active role in the production of this document.

Prior to this activity, and of interest to the results presented here, are the results of Validation Exercise #1 relating to the Fast Time assessment of the London TMA [4], and to V2 preliminary real time simulation for Milan TMA.

1.2 Intended audience

The intended audience for this document are other P.05.07.04 team members and those in corresponding technical project, WP05.06.04. *"Tactical TMA and En-Route Queue Management"*

At a higher project level members of SWP05.07 "*TMA and Trajectory separation Management*" are expected to have an interest in this document.

External to the SESAR project, other stakeholders are to be found among:

- Appropriate ANS;
- ANS providers;
- Airport owners/providers;
- Affected employee unions;
- Airspace users

1.3 Structure of the document

The structure of the document is as follows:

- **Section 1** (this section) describes the purpose and scope of the document, the intended audience, and gives an explanation of the abbreviations and acronyms used throughout the document.
- **Section 2** describes the scope of the validation and a summary of the validation exercise
- **Section 3** describes the conduct of validation exercise including the preparation, execution and deviations away from the planned activities.
- **Section 4** describes the validation exercise results. It includes a detailed analysis of the results including a description of the confidence in results.
- **Section 5** states all the conclusions and recommendations from the validation exercise.
- **Section 6** lists all the applicable and reference documents.

1.4 Acronyms and Terminology

Term	Definition
AC	Area Control
ACE	ACE simulator software and system
ACPO	Aircraft Position Operator
ADD	Architecture Definition Document
AMAN	Arrival Management
ANS	Air Navigation Services
APS	Air Traffic Project Specialist
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATSA	Air Traffic Services Assistant
CARS	Controller Acceptance Rating Scale
CDA	Continuous Descent Approach
CFMU	Central Flow Management Unit (Eurocontrol)
CTC	Corporate and Technical Centre
DOD	Detailed Operational Description
E-ATMS	European Air Traffic Management System
EFD	European Flight Data
EGGW	London Luton Airport
EGLC	London City Airport
EGSS	London Stansted Airport
E-OCVM	European Operational Concept Validation Methodology

FIN	Final Director (Controller)
INTEROP	Interoperability Requirements
IAS	Indicated Air Speed
ILS	Instrument Landing System
ISA	Instantaneous Self Assessment
IRS	Interface Requirements Specification
KERMIT	Kerosene Emissions Research Model In the TMA
LAC	London Area Control
LAMP	London Airspace Management Programme
LTC	London Terminal Control
LTMA	London Terminal Manoeuvring Area
MOps	Method of Operations
NATS	National Air Traffic Services Ltd
nm	Nautical miles
OA	Operational Analysis
OFA	Operational Focus Areas
OSED	Operational Services Environment Description
OSED	Operational Service and Environment Definition
P-RNAV	Precision Area Navigation
R&D	Research & Development
R/T	Radio Telephony
SAR	System Analysis Recording
SEC	Scenario Execution and Control
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SID	Standard Instrument Departure
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SPR	Safety and Performance Requirements
SPT	Support (Controller)
SSS	Simulator Support Specialist
STAR	Standard (Instrument) Arrival Route
SUT	System Under Test
TAD	Technical Architecture Description

TC	Terminal Control
TDB	Track Data Block
TMA	Terminal Manoeuvring Area
TMS	Thames (Approach Controller)
TRUCE	Training in Unusual Circumstances and Emergencies
TS	Technical Specification
UKFDB	UK Flight Database
VALP	Validation Plan
VALR	Validation Report
VALS	Validation Strategy
VCS	Voice Communications System
VP	Verification Plan
VR	Verification Report
VS	Verification Strategy
WP	Work Package

2 Context of the Validation

In the context of WS2 of P05.07.04 ("Full P-RNAV Implementation in the TMA"), this document provides the Validation Report for the aspects relevant to London TMA and Milan TMA. Specifically, WS2 deals with "P-RNAV procedures in complex TMAs using Point Merge" and the key aspects are:

I. Feasibility of Point Merge in a complex (multi-airport) TMA;

II. Optimization of airspace use and traffic management for complex TMAs through the use of Point Merge technique coupled with P-RNAV navigation capability;

III. Integration of Point Merge with Arrival Management;

IV. Maximum capacity of P-RNAV Arrivals/Transitions/SIDs/STARs;

V. P-RNAV Continuous Descent Approaches (CDAs) in high density traffic;

VI. Continuous Climb Departures (CCDs) enabled by the enhanced horizontal performance of P-RNAV;

VII. Impact on preferential noise routes upon transition from conventional to P-RNAV procedures, due to the turning performance linked to each, respectively;

VIII. Route spacing for P-RNAV operations.

The key aspects, defined above, were firstly validated to E-OCVM V2 level of maturity and then to E-OCVM V3 level of maturity, as defined by the System Engineering Management Plan (SEMP) [1].

The V2 level of maturity was attained through a combination of Fast-Time and Real-Time Simulations (FTSs and RTSs). V2 validation assessed the feasibility of the concept, tested the human-in-the-loop and verified that certain benefits in terms of workload, capacity and performance can be achieved prior to transit to V3 validation.

The V3 level of maturity is that attained through high-fidelity RTSs, i.e. that reported within this document. Specifically, V3 validation should assess the benefits of practical implementation by testing the concept under realistic scenarios.

With reference to Section 2.1 of the Validation Plan [5] this Validation Report:

(a) Covers SESAR Concept Step 1 only.

(b) Covers the London TMA operational scenarios of WS2 (defined in the PIR [9]), EXE-05.07.04-VP-229.

(c) Covers the Milan TMA operational scenarios of WS2, EXE-05.07.04-VP-228.

(d) Does not cover the validation of WS1, which will be undertaken by AENA using the Madrid TMA as the test case, EXE-05.07.04-VP-142.

The output of the Validation Report will inform the final OSED for the OFA, which will incorporate all aspects of WS2. Using the final OSEDs from P05.07.04, an Integrated Operational Scenario will be developed with P05.06.04; this will be used for a Real-Time Simulation undertaken within SWP5.3 (integrating P05.07.04 with P05.06.04).

V3 Validation for the London TMA will be represented by the 3 major commercial airports where Point Merge is expected to be most effective: London Stansted, London Luton and London City as confirmed during V2 Validation [4]. This provides a multi-airport TMA, with real-life restrictions and considerations. The operations of other airfields in the London TMA (LTMA) must not be significantly impaired, so the impact to them must be considered for any subsequent implementation at London TMA. However, the routes to/from these other airfields will not be validated as part of P05.07.04 R&D.

The three selected airports are geographically co-located, thereby providing a sound test case for the multi-airport TMA concept. The V2 validation [4] showed that the concept was feasible for London Heathrow. However, it was not possible to secure the operational resource needed to mature the detailed design to the level required for V3 real time simulations.

The validation context in operational terms is such that the P-RNAV Point Merge system was utilised for the airports of London City, Luton and Stansted, and it is only these that shall be covered within this report. Further reference to the validation context can be gained from the corresponding validation plan, “SESAR P 5.07.04 – WS2 Validation Plan”, or via the SESAR OSED, “OSED for Point Merge in Complex TMA - London & Milan”.

V3 Validation for Milan TMA will focus on handling traffic for Milan Malpensa and Milan Linate airport, establishing a Point Merge structure to handle Milan Malpensa arrivals, since at the moment it has been found not significant investigate it for Linate. In particular the geometry tested arises from the results obtained during the preliminary RTS for V2 Validation performed in May 2011, driving for a change of it.

V3 Validation scenarios allow for real operational conditions and restrictions representing with high fidelity the daily way of working of Air Traffic Controllers in Milan Area.

The preliminary V2 RTS confirmed the feasibility of the concept from the point of view of Human performance (R/T communications, coordination, workload), while finding some issues that needed to be improved in order to have a more efficient geometry for the traffic to be managed.

2.1 Concept Overview

Terminal Control (TC) Approach operations currently employ “Open-loop” techniques to sequence and space the arrival traffic. This entails the use of tactical vectors: heading, speed and vertical altitude intervention, to merge traffic onto the line of the Final Approach ILS.

Point Merge is an innovative method developed by the EUROCONTROL Experimental Centre (EEC) for merging arrival flows with existing technology including Precision Area Navigation (P-RNAV). Under a Point Merge System, the aircraft are merged to a point using “Closed-loop” techniques.

A Point Merge System may be defined as an RNAV STAR, transition or initial approach procedure, or a portion thereof, and is characterised by the following features:

A single point – denoted ‘merge point’, is used for traffic integration;

Pre-defined P-RNAV legs – denoted ‘sequencing legs’, isodistant and equidistant from the merge point, are dedicated to path stretching/shortening for each inbound flow. These legs shall be separated by design vertically, laterally or both.

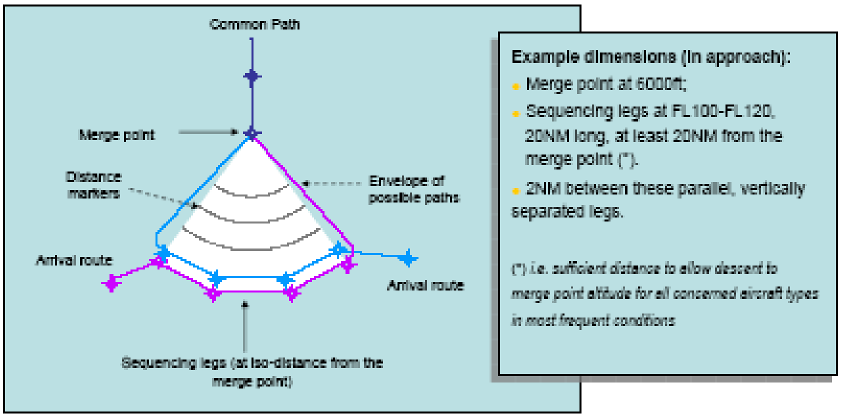


Figure 1. Example Point Merge route structure

This Real Time Simulation is part of SESAR Project 5.7.4 “Full Implementation of P-RNAV in TMA”

SESAR project 5.7.4 is tasked with assessing the feasibility of using a Point-Merge centric P-RNAV route structure for complex (multi-airport) TMAs. The proposed RTS activity will seek to make this assessment using a cut-down version of the London TMA as a test case; this test case will encompass the arrival and departure routes for c.3 major commercial airports within the LTMA. This RTS activity also performs part of the Feasibility & Options (F&O) Phase for LAMP.

The London TMA test case is classed as Very High Capacity (VHC) needs. The TMA is ‘Airspace Constrained’ with ‘Airfield Interaction’ constraints. To address this, an invariant Point Merge design is used, i.e. the Point Merge Systems and STARs do not change whether Easterly or Westerly runways are in use, only the Transitions to runway (Approach Via) change. Downstream 'trombone' transition areas are also used for long transitions.

The Milan TMA test case is classed as Very High Capacity (VHC) needs. Also Milan TMA presents airspace constraints since there's quite a short airspace availability due to vertical constraints represented by the Alps, moreover often ATCOs have short time between taking charge of the inbound traffic and solve all potential interactions between surrounding airports flows (especially departures from Linate, in case of Malpensa). This results in a tactical management to allow for arrival descent and departures climb. In order to improve this management a new of STARs and SIDs has been designed.

The OI Steps assessed under this validation are as identified in Table 1. The concept under test was developed to address, or partially address, these OI Steps to maturity level V3. Note that AO-0703 (IP1) is identified in addition to that given in Section 2.1.1 of the WP5 Validation Strategy [8] but was included in the original project PIR.

Validation Exercise ID and Title	*EXE-05.07.04-VP-229* London TMA Real-Time Simulation #2 Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
Leading organization	NATS
Validation exercise objectives	Assess the benefits of using a Point-Merge centric P-RNAV route structure for complex (multi-airport) TMAs.
Rationale	To improve the operation of the London TMA.
Supporting DOD / Operational Scenario / Use Case	Operational Service and Environment Definition (OSED) for Point Merge in Complex TMA, Edition 00.00.05, 21st October 2011;
OI steps addressed	AOM-0601 "Terminal Airspace Organisation Adapted through Use of Best Practice, PRNAV and FUA Where Suitable" (V3 partial, subject to WS1) AOM-0602 "Enhanced Terminal Airspace with Curved/Segmented Approaches, Steep Approaches and RNAV Approaches Where Suitable" (V3 partial, subject to WS1) AOM-0603 "Enhanced Terminal Airspace for RNP-based Operations" (V3 partial, subject to WS1) AO-0703 "Aircraft Noise Management and Mitigation at and around Airports" (V3 partial, subject to WS1)
Applicable Operational Context	Complex TMAs
Expected results per KPA	No detriment to Safety (SAF1) Improvement to Environmental Sustainability (ENV1) Improvement to Local Airspace Capacity (CAP2) No detriment to Airport Capacity (CAP3) Improvement to ATM Cost Effectiveness (CEF1)
Validation Technique	Real Time Simulation
Dependent Validation Exercises	*SWP5.3*

Table 1: Concept Overview – London TMA

Validation Exercise ID and Title	*EXE-05.07.04-VP-228* Milan TMA Real-Time Simulation Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
Leading organization	ENAV
Validation exercise objectives	Assess the benefits of using a Point-Merge centric P-RNAV route structure for complex (multi-airport) TMAs.
Rationale	To improve the operation of Milan TMA and in particular of Milan Malpensa airport and its dependencies with Milan Linate.
Supporting DOD / Operational Scenario / Use Case	Operational Service and Environment Definition (OSED) for Point Merge in Complex TMA, Edition 00.00.05, 21st October 2011;
OI steps addressed	AOM-0601 "Terminal Airspace Organisation Adapted through Use of Best Practice, PRNAV and FUA Where Suitable" (V3 partial, subject to WS1) AOM-0602 "Enhanced Terminal Airspace with Curved/Segmented Approaches, Steep Approaches and RNAV Approaches Where Suitable" (V3 partial, subject to WS1) AOM-0603 "Enhanced Terminal Airspace for RNP-based Operations" (V3 partial, subject to WS1) AO-0703 "Aircraft Noise Management and Mitigation at and around Airports" (V3 partial, subject to WS1)
Applicable Operational Context	Complex TMAs
Expected results per KPA	No detriment to Safety (SAF1) Improvement to Environmental Sustainability (ENV1) Improvement to Local Airspace Capacity (CAP2) No detriment to Airport Capacity (CAP3) Improvement to ATM Cost Effectiveness (CEF1)
Validation Technique	Real Time Simulation

Table 2: Concept Overview – Milan TMA

2.1.1 Exercise Scope London TMA

The RTS was run using the LTS Real Time Simulation platform at NATS Corporate & Technical Centre, Whiteley, Hampshire, UK.

1. **Location**. The simulation used 12 TC workstations in the CTC RTS facility: 8xMeasured & 4xFeeds.
2. **System**. The changes to be assessed by P5.7.4 are procedural and airspace design only (no system change). Operational radar (Node-L) emulation was used. Both baseline and new concept used the current TC system (i.e. paper strips and CCTV) without AMAN.
3. **Feed Sector ATG**. Area Control sectors used Auto Track Generation (ATG); acting as automated Feeds to the feed TC sectors. No AC sectors were simulated. All measured TC sectors were fed by staffed TC sectors.
4. **Data recording**: Full scientific data logging and video capture at one workstation were.

The simulation floor plan is contained in Appendix B.

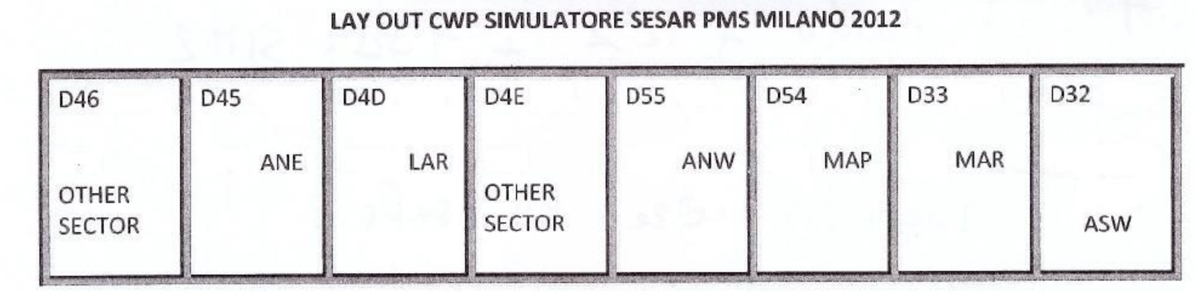
P-RNAV and Baseline airspace designs are contained in Appendix C.

Full details of the Exercise Scope are presented in SESAR P 5.07.04 – WS2 Validation Plan [5].

2.1.2 Exercise Scope Milan TMA

The RTS was run using the Rome ACC Validation platform located at Ciampino Rome Control Centre.

1. **Location**. The simulation used 8 operational positions simulating 6 sectors and 2 feeders;
2. **System**. The changes to be assessed by P5.7.4 are only procedural and airspace design so no change in the system is expected. Both baseline and new concept uses the current system without AMAN.
3. **Feed Sector ATG**. 2 positions were used as automatic feeding sectors supervised by two air traffic controllers.



Simulation platform layout for Milan TMA RTS V3

P-RNAV and Baseline airspace designs are contained in Appendix F.

Full details of the Exercise Scope are presented in SESAR P 5.07.04 – WS2 Validation Plan [5].

2.2 Summary of Validation Exercise/s

2.2.1 Summary of Expected Exercise/s outcomes

Stakeholder	Stakeholder Validation Expectations
NATS Swanwick Terminal Control Centre and ENAV Milan Area Control Centre	The expectations of NATS Swanwick Terminal Control Centre and ENAV Milan Area Control centre are as follows: • Point Merge provides sufficient flexibility to a P-RNAV TMA route structure to maintain runway throughput at current day levels. • A Point Merge centric P-RNAV design provides simplified traffic sequencing and merging. As a result: o Approach Controller workload is reduced when compared to current day operations. o Approach Controller training needs are reduced when compared to current day operations. • Homogenous designs can be applied to multiple airports across the TMA. • Departure routes are deconflicted from Arrivals and improved. • There is no negative impact to safety. • Service continuity maintained under non-nominal scenarios
Airspace Users	The expectations of Airspace Users are as follows: • A Point Merge centric P-RNAV design provides simplified traffic sequencing and merging so that: o Flight Crew workload is reduced when compared to current day operations (inclusive of situational awareness). • Point Merge provides sufficient flexibility to a P-RNAV TMA route structure to maintain or reduce Time in Stack when compared to current day operations. • A Point Merge centric P-RNAV design provides a positive net benefit in terms of Fuel Burn and CO_2 emissions from TMA entry to stand to TMA exit.
Airport Operators	The expectations of Airport Operators are as follows: • Point Merge provides sufficient flexibility to a P-RNAV TMA route structure to maintain runway throughput at current day levels.
Local Communities	The expectations of the Local communities are as follows: • A Point Merge centric P-RNAV design provides a positive net benefit in terms of local noise pollution.
ATCO trade unions (IFATCA)	The Trade Unions will expect the validation process to provide evidence that the concept: • Is acceptable to the operational users; • Does not lead to unwanted changes to procedure, roles or responsibilities for the operational staff

Stakeholder	Stakeholder Validation Expectations
SESAR Joint Undertaking	The SESAR JU will expect the validation process to: •Provide evidence that the concept will make a positive contribution to European ATM; •Be completed within timescales and budget.
Regulators (ICAO, EASA, national)	The Regulatory Bodies will expect the validation process to: •Assist in understanding the impact of the concept on current and future standards and regulations; •Provide evidence that the concept meets the required performance levels in terms of safety, capacity, access, security etc.

Table 2: Stakeholder Validation Expectations

The Stakeholder expectations drive the objectives 01-08 that are validated and reported against in this document.

2.2.2 Benefit mechanisms investigated

Benefit Mechanisms – showing the links to proposed operational changes and KPIs - apply as illustrated:

Benefit Mechanisms

2.2.3 Summary of Validation Objectives and success criteria

2.2.3.1 London TMA

The exercise validation objectives are presented below. At the time of the production of the Validation Plan [5] the SESAR KPIs were yet to be formalised. The exercises objectives were therefore derived from stakeholder expectations. The relevant SESAR KPA is indicated along with each exercise objective.

574Obj_01 - Assess impact to Runway Throughput (CAP3 – Airport Capacity)

574Obj_01_01	Runway Throughput maintained at Current Day levels or increased for the TMA as a whole
574Obj_01_02	Runway Throughput maintained at Current Day levels or increased for each individual Airfield

574Obj_02 - Assess workload impact of procedures for Approach Controllers & Flight Crew (CAP2 Local Airspace Capacity)

574Obj_02_01	Approach Controller Workload reduced for the TMA as a whole
574Obj_02_02	Approach Controller Workload reduced for each individual Approach operation
574Obj_02_03	Flight Crew R/T Workload reduced for the TMA as a whole
574Obj_02_04	Flight Crew R/T Workload reduced for each individual Approach operation

574Obj_03 - Assess Human Performance levels (such as Situational awareness, effective communication/teamwork detection/recovery of human error) (contributory factor to CAP2 Local Airspace Capacity and SAF1 Safety)

574Obj_03_01	Approach Controllers' Human Performance levels are maintained at Current Day levels or enhanced.

574Obj_04 – Assess TMA Safety levels (SAF1 Safety)

574Obj_04_01	Safety levels for the TMA as a whole are maintained at Current Day levels or improved
574Obj_04_02	No new Safety Hazards added that cannot be mitigated

574Obj_06 - Assess the impact to Hold Occupancy & Flight Levels (contributory factor to CAP2 Local Airspace Capacity, SAF1 Safety and ENV1 Environmental Sustainability)

574Obj_06_01	Hold Occupancy & Levels are maintained at Current Day levels or reduced for the TMA as a whole
574Obj_06_02	Hold Occupancy & Levels are maintained at Current Day levels or reduced for each individual Approach operation

574Obj_07 - Assess the impact to Fuel Burn / CO2 Emissions (ENV1 – Environmental Sustainability)

574Obj_07_01	Net benefit per flight to Fuel Burn **/ CO_2 Emissions** for the TMA as a whole
574Obj_07_02	Net benefit per flight to Fuel Burn **/ CO_2 Emissions** for each Airfield Approach + Departure operation

574Obj_08 - Assess the impact of Noise pollution to the local Environment (there is no formal KPA for Noise defined by B4.1 [6] but it is considered as part of the Environmental Sustainability KPA)

574Obj_08_01	Noise pollution is maintained at Current Day levels or reduced for each Airfield Approach + Departure operation

Security objectives were identified as part of the Safety Assessment process. Therefore Security objectives are considered as a sub-set of 574Obj_04; the full results of which will be documented in the Safety Assessment report to be contained in an appendix of the P05.07.04 OSED [2].

2.2.3.2 Choice of metrics and indicators London TMA

The metrics to be used are those supported by the platform and detailed in Section 2.1.8.

2.2.3.3 Milan TMA

The exercise validation objectives related success criteria and scenarios involved are detailed below. Relevant SESAR KPA is indicated together with each exercise objective.

574Obj_01 - Assess impact to Runway Throughput (CAP3 – Airport Capacity)

Identifier	Success Criteria
574Obj_01_01	Runway Throughput maintained at Current Day levels or increased for the TMA as a whole

574Obj_02 - Assess workload impact of procedures for Approach Controllers & Flight Crew (CAP2 Local Airspace Capacity)

Identifier	Success Criteria
574Obj_02_01	Approach Controller Workload reduced for the TMA as a whole
574Obj_02_02	Approach Controller Workload reduced for each individual Approach operation
574Obj_02_03	Flight Crew R/T Workload reduced for the TMA as a whole
574Obj_02_04	Flight Crew R/T Workload reduced for each individual Approach operation

574Obj_03 - Assess Human Performance levels (such as Situational awareness, effective communication/teamwork detection/recovery of human error) (contributory factor to CAP2 Local Airspace Capacity and SAF1 Safety)

Identifier	Success Criteria
574Obj_03_01	Approach Controllers' Human Performance levels are maintained at Current Day levels or enhanced

574Obj_04 – Assess TMA Safety levels (SAF1 Safety)

Identifier	Success Criteria
574Obj_04_01	Safety levels for the TMA as a whole are maintained at Current Day levels or improved
574Obj_04_02	No new Safety Hazards added that cannot be mitigated

574Obj_05 – Assess the effectiveness of Arrival and Departure Management (Airspace Capacity, Cost effectiveness, Predictability)

Identifier	Success Criteria
574Obj_05_01	Efficiency of Arrival & Departure management improved for the TMA as a whole
574Obj_05_02	Efficiency of Arrival & Departure management improved for each Airfield

574Obj_07 - Assess the impact to Fuel Burn / CO2 Emissions (ENV1 – Environmental Sustainability)

Identifier	Success Criteria
574Obj_07_03	Evaluation of average vertical profile efficiency in terms of availability of CDO operations compared to the actual scenario[1]

1: Due to the lacking of log data the assessment regarding Obj_07 has been only partially done since it was not possible to compute track miles flown but only assess them.

2.2.3.4 Choice of metrics and indicators Milan TMA

The metrics to be used are those supported by the platform and detailed in Section 2.1.8:

2.2.4 Summary of Validation Scenarios

2.2.4.1 London scenarios

<u>Nominal Scenarios</u>

The following nominal scenarios were assessed:

574V3_01 – Nominal Current Day operations with traffic levels scaled up to 2015 levels. Traffic input to the scenario replicates Arrival Management efficiency at 100%: all traffic in sequence with optimum spacing.

574V3_02 - Nominal Current Day operations with traffic levels scaled up to 2015 levels. Traffic input to the scenario replicates Arrival Management efficiency at sub-100%: some traffic out-of-sequence, with variations in spacing.

574V3_03 - Nominal operations using Point Merge centric P-RNAV TMA route structure.
Traffic input to the scenario replicates Arrival Management efficiency at 100%: all traffic in sequence with optimum spacing.

574V3_04 - Nominal operations using Point Merge centric P-RNAV TMA route structure.
Traffic input to the scenario replicates Arrival Management efficiency at sub-100%: some traffic out-of-sequence, with variations in spacing.

These scenarios relate to high-level "Sub-Scenario 1" of Section 2.1.2 of the WP5 Validation Strategy [[8]: Implement TMA/APPROACH arrivals processes in a High Complexity, High Density environment, using a ground solution (i.e. PBN route structures as opposed to ASAS procedures).
In addition to Sub-Scenario 1, this Validation exercise also covers departures.

Validation Method

It is important to discuss the validation method in the context of the validation scenarios. Each objective presented in Section 2.2.2 is phrased in relative terms: that the change relative to Current Day levels shall either be neutral or show a net benefit. In order to assess these objectives a 'Matched' simulation design was applied. This design compares the 'Current' scenarios above to the corresponding 'P-RNAV' scenario while keeping all other variables (controller, traffic sample, weather, non-nominal scenarios) the same. This allows the effect of 'P-RNAV' change to be measured.

The introduction of the P-RNAV system into the LTMA formed part of a wider set of changes considered in the NATS LAMP project. For this reason individual controller roles also changed between 'Current' and 'P-RNAV' scenarios. The key role changes were as follows:

- The current shared hold at LOREL for EGGW and EGSS arrivals was removed and replaced with the respective Point Merge systems. Under the Point Merge System the EGSS INT controller is no longer required to manage the holding and release of inbound EGGW traffic from the East. These tasks are transferred to the EGGW INT controller. In current day operations it is often possible to staff EGGW with a single controller as the EGSS INT effectively manages the stack departure process on behalf of EGGW.
- In the 'Current' scenario there is no facility for the TMS controller to hold inbound EGLC aircraft. Should aircraft need to hold, this is done by other TMA sectors. The 'Point Merge' system therefore introduces a holding facility for TMS for EGLC inbound aircraft.
- In the 'Current' scenario EGLC prefer to operate with a single TMS controller and a co-ordinator. In the 'Point Merge' scenario EGLC operated with a TMS controller and an EGLC director. The distribution of tasks between these two controllers therefore differs between 'Current' and 'Point Merge' scenarios.
- A Transition Altitude of 18,000ft was introduced as part of the P-RNAV implantation. The impact of this change will have been most apparent on the TC North sectors. It is also noted that should the final Transition Altitude differ from 18,000ft then the impact described in this report may not necessarily be the same.

The impact of these additional changes is considered against each analysis objective separately in Section 4.2. Overall it is considered that these do not affect the validation exercise conclusions. However, it is important to consider each validation measure in the context of the changes introduced specifically for the LAMP project and not to confuse the impact of these with those enabled by the introduction of P-RNAV, in particular the Point Merge System.

Further, it is also noted that this validation exercise assessed the proposed P-RNAV TMA implementation **as a whole**. That is, the effect of introducing the P-RNAV route structure, including three closely located Point Merge Systems, into a busy TMA. Therefore while the changing roles may impact different airfields in different ways it is important to consider the results at an overall level, across all airfields and for arrivals and departures.

Non-nominal Scenarios

The simulation also utilised specific targeted scenarios to investigate certain safety, workload, and non-nominal events. These can be split into two groups: those specific to the introduction P-RNAV in the TMA with no corresponding event in current day operations (Table 3) and those applicable to both current day and P-RNAV operations (Table 4).

Reference	Scenario Description
574V301	Aircraft not stable at the required level/altitude prior to reaching the start of the sequencing leg (when other traffic is present on the sequencing legs).
574V302	Wrong aircraft turns to the Merge Point from the sequencing leg when the 'direct-to' instruction is given.
574V303	Aircraft turns the wrong direction off the sequencing leg when the 'direct-to' instruction is given.
574V304	Aircraft does not turn off the sequencing leg when required, (e.g. pilot doesn't hear the 'direct to' instruction or doesn't realise who it is for).
574V305	Horizontal separation not maintained on the sequencing leg.
574V306	Aircraft does not apply the required speed constraint while on the sequencing leg.
574V307	Arrivals aircraft non-conformance to specified route profile, (e.g. due to single aircraft equipment failure (both P-RNAV and non-PRAV), GNSS signal corruption etc.)
574V308	When reaching the end of a sequencing leg without receiving a turn to merge instruction, the pilot will turn to the merge point via a fly-by waypoint and request clearance to descend to the Merge Point.
574V309	The controller cannot give clearance to descend without breaching separation so he looks at the option of vectoring aircraft within the PMS.
574V310	P-RNAV equipage failure - aircrew notify ATC, follow route as per unequipped (BRNAV capable) if able, else radar vectors.
574V311	Level bust on sequencing leg.
574V312	On long P-RNAV leg longitudinal spacing has been eroded - Approach controller uses speed control to manage spacing.
574V313	Non P-RNAV equipped, but BRNAV capable a/c, controller treats as P-RNAV
574V314	Aircraft descends too early after receiving the 'turn to merge' instruction (i.e. descend instruction has not yet been issued by pilot descends anyway without the Controller expecting it).
574V315	Aircraft merges to the incorrect waypoint (i.e. pilot sets the incorrect waypoint instead of the PMS designated Merge Point)
574V316	Aircraft does not meet the required vertical profile after leaving the sequencing leg leading to potential conflict with other aircraft.
574V317	Departures aircraft non-conformance to specified route profile, (e.g. due to single aircraft equipment failure (both P-RNAV and non-PRAV), GNSS signal corruption etc.)
574V318	A BRNAV aircraft flying the sequencing arc flies a shorter route due to fewer waypoints being stored in the FMS and catches up with a P-RNAV aircraft flying the true arc.
574V319	An aircraft reaches the end of the sequencing leg and routes toward the merge point, but does not descend. This could put the aircraft in conflict with other aircraft in the contingency hold situated at / near Merge Point at the same level.

Table 3: P-RNAV Specific Scenarios

The following table includes scenarios that were evaluated in the December aspect of the simulation:

Reference	Scenario Description
574V320	Following pilot's request Missed Approach Procedure (MAP) is followed, the PMS is fully loaded and Approach requests the controller responsible for loading the sequencing leg to make a gap to allow re-insertion of aircraft into traffic flow.
574V321	Gap is created in traffic flow; MAP aircraft is instructed to hold at pre-defined waypoint on the MAP while waiting for gap to form
574V322	Aircraft is released from temporary hold in order to commence another approach - speed control used to ensure separation is maintained.
574V323	Loss of surveillance (single radar)
574V324	The TMA controller looks at options to expedite emergency flight, and where to integrate flight into sequence.
574V325	Handling emergency flight. TMA controller hands over to approach early to enable Approach to provide 'direct to' clearance to the merge point. The approach controller alleviates traffic pressure on the point merge system by moving flights into the holding stack.
574V326	Handling emergency flight. The Approach controller uses speed control and lateral holding capacity of the sequencing legs to create a gap in the sequence for the emergency aircraft.
574V327	Requirement to rearrange traffic due to poor sequencing (according to their wake vortex separation) by TMA controllers (High ATCO workload).
574V328	Strong cross wind on PMS causing tail wind on one of the sequencing legs; approach controller compensates by using adapted speed instructions and/or increased longitudinal separation.
574V329	Approach controller takes account of wind effect when instructing 'direct to' due to differing wind effects/speed controls on the two sequencing legs.
574V330	Category B flights (SAR etc)
574V331	Temporary runway closure, controller actions as per MOps - aircraft already on PMS and have been given clearance to descend to merge will be instructed to level off at a unique flight level/altitude and then hold in a stack at the merge point.
574V332	Runway re-opens - aircraft in temporary stacks cleared starting with the hold at the merge point (descending aircraft through the levels in the stack) - Mops.
574V333	Normal operations resume, following runway closure.
574V334	Thunderstorm directly affecting P-RNAV route - controller instructs flights to follow transition that avoids the weather pattern, if not possible, radar headings given to avoid affected area.
574V335	In the event of thunderstorms directly affecting P-RNAV routes controllers will revert to radar headings to avoid affected area, stacks used to control flow of traffic.
574V336	Loss of dedicated airborne hold
574V337	To compensate for strong wind conditions the TMA controller exercises speed controls to increase longitudinal separation between traffic on STAR
574V338	Total loss of R/T - fallback mode
574V339	Single aircraft R/T failure (squawk 7600, aircraft to follow STAR, then maximum transition along point merge sequencing leg via flyby waypoint, descend to Merge Point then FAF to intercept

Reference	Scenario Description
	localiser.
574V340	Change of runway direction, (e.g. causing potential conflict between arrivals and departures that have already left the runway, or Pilot takes incorrect transition after merge point)
574V341	Category B flights (SAR etc)

Table 4: P-RNAV and Current Day Scenarios

2.2.4.2 Milan scenarios

The following nominal scenarios were assessed	Scenario Description	Description
574V3_01	PMS normal operations arrivals at Milan Malpensa only with traffic levels scaled up to 2015 levels.	Only arrival at LIMC, With spacing of 1/1.5 min (simulating the presence of an arrival manager). RWYs in use were either 35R or 35L.
574V3_02	PMS design, mixed sequence (arr+dep) all TMA, with traffic levels scaled up to 2015 levels and simulated arrival manager.	This scenario included departures/arrivals at LIMC on both RWYs (35R or Dependent Parallel Approach). Departures/arrivals also at LIML and LIME.
574V3_03	PMS design, mixed sequence (arr+dep) all TMA with increased landing rate due to bad weather and traffic levels scaled up to 2015	This scenario included arrivals and departures at all airports. Non-nominal meant a capacity below the maximum one. Increase of landing rate due to TWR request or LVP conditions.
574V3_04	PMS design mixed sequence (arr+dep) all TMA with go-around procedure and traffic levels scaled up to 2015 levels	This scenario included arrivals and departures at all airports. Non-nominal meant a capacity below the maximum one. Same traffic load as scenario 3, but instead of increasing the spacing on final approach, the Missed Approach (MA) was introduced.

In addition to these nominal scenarios also some non-nominal situations were addressed in order to check the answer of the whole system to the unusual situation.

The non nominal scenarios are reported in the table below.

Reference	Scenario Description	Description
574V3_05	Non-nominal scenario: Excess of Go-around procedures with traffic merging inside PMS;	This scenario included arrivals and departures at all airports. Airports at full traffic load.
574V306	Non-nominal scenario: Single runway operation due to emergency;	This scenario foresaw the single runway use (RWY35L). In this case the minimum spacing was 6NM. In case of heavy category departure the spacing increased to 9NM.
574V307	Non-nominal scenario: Aerodrome closed;	This scenario included arrivals and departures at all airports. Traffic after overflying FAF went ahead along the localizer without intercepting the glide path, overflying the RWY and reaching then the missed approach. The whole holding system was planned to have a capacity of over 40 aircraft.

Reference	Scenario Description	Description
574V308	Non-nominal scenario: Heavy traffic departure on opposite direction	This scenario included arrivals and departures at all airports. Incoming traffic was spaced of 20/25 NM to allow the departure from opposite runway. This wide spacing is obtained with the aid of the holding system.
574V309	Non-nominal scenario: Opposite take-off direction in Linate. Stress unbalanced traffic management between different PMS sectors.	This scenario included arrivals and departures at all airports. At LIML departures occurred on RWY18, heavily affecting operations in the eastern sectors.

The Validation has been conducted by a comparison between current day operations practices and Point Merge design evaluations. In a typical day scenario, taking into account usual traffic flows and analysing benefits and bottlenecks about the design under evaluation.
Baseline scenarios were not tested again in V3 since they were already performed during V2 simulations taking into account the same conditions of V3 (increased traffic sample).

2.2.5 Summary of Assumptions

I. All traffic into the TMA will be metered by Arrival Management or an equivalent way of queue management the effectiveness of which can be varied (ASM-05.02-VALS-0001.0003 [8]).

II. En-Route operations will not be adversely affected by the revised TMA procedures and airspace designs[1].

III. P-RNAV equipage is mandated in the TMA (ASM-05.02-VALS-0001.0002 [8]).

IV. Aircraft will be able to fly the P-RNAV routes as defined (ASM-05.02-VALS-0001.0001 [8]).

V. A wider TMA design can be found that allows for the test designs to be incorporated. The test cases for London and Milan do not cover the whole TMA in either case; therefore, additional airspace designs would be necessary for TMA implementation.

VI. No future change to the number of runways for the airfields under test.

VII. Increases in demand are proportional to the current demand for each airfield under test ASM-05.02-VALS-0001.0004 [8]).

2.2.6 Choice of methods and techniques

2.2.6.1 London simulation

Supported Metric / Indicator	Platfor m / Tool	Method or Technique	Objective
ATC Workload		Bedford Workload Scale China Lakes (situational awareness of AMAN task) Controller Acceptance Rating Validation Questionnaire Debriefing ISA	574Obj_02 574Obj_03
Minimum achieved	ACE	Data recording (operational Analysis)	574Obj_04

[1] This will be tested as part of V3 Validation "Phase 2": SWP5.3 will integrate 5.7.4 and 5.6.4 concepts so that the 'Point Merge in Complex TMA' concept will validated in combination with En Route operations using dynamic Arrival Management.

Separation STCA Metrics			
Noise	ACE	Data recording (operational Analysis)	574Obj_08
Aircraft on Frequency	ACE	Data Recording (Validation)	574Obj_02
Tactical Instructions	ACE	Data Recording (Validation)	574Obj_02
Number of Multiple Instructions	ACE	Data Recording (Validation)	574Obj_02
Fuel Burn & emissions (KERMIT)	ACE	Data Recording (Validation)	574Obj_07
Radio Telephony (R/T) Loading	VCS	Data Recording (Validation)	574Obj_02
Runway Throughput	RTSA Metrics	Post Ops Analysis	574Obj_01
Hold & Occupancy, time in stack	RTSA Metrics	Post Ops Analysis	574Obj_06

Table 5: Methods and Techniques

2.2.6.2 Milan simulation

The following table presents the data collection methods used during the simulation

Supported Metric / Indicator	Platform / Tool	Method or Technique	Objective
TMA and runway throughput	- Direct not intrusive observation	- Over the shoulder observation - User feedback collection	574Obj_1 574Obj_2 574Obj_5
Perceived Workload	- Direct not intrusive observation	- Over the shoulder observation User feedback collection - Debriefing at the end of the day	574Obj_2 574Obj_3 574Obj_4
Situational Awareness	- Direct not intrusive observation	- Over the shoulder observation User feedback collection - Debriefing at the end of the day	574Obj_2 574Obj_3 574Obj_4
Teamwork	- Direct not intrusive observation	- Over the shoulder observation User feedback collection - Debriefing at the end of the day	574Obj_2 574Obj_3 574Obj_4
Radio and phone communications	- Direct not intrusive observation	- Over the shoulder observation	574Obj_2
Tactical Instructions	- Direct not intrusive observation	- Over the shoulder observation	574Obj_2 574Obj_4 574Obj_5
Descent Management	- Direct not intrusive observation	- Over the shoulder observation	574Obj_7

Table 6: General Metrics

In this context over the shoulder observations mean that a validation team composed by ATCO and Human factors experts observed all the simulations performing de-briefings and collective post-simulation feedbacks and then writing down the conclusion in this Report.

2.2.7 Validation Exercises List and dependencies

The following V3 Validation exercises apply to this OFA:

- EXE-05.07.04-VP-228 – P-RNAV & Point Merge using Milano TMA test case
- EXE-05.07.04-VP-229 – P-RNAV & Point Merge using London TMA test case

These two exercises are run in parallel and the outcomes of them are used to inform the OSED for the 'Point Merge in Complex TMA' OFA.

3 Conduct of Validation Exercises

3.1 Exercise Preparation

3.1.1 London test case

Two base traffic samples were used:

- Friday 10 July 2009
- Monday 10 August 2009

The dates were chosen to reflect the typical busy operation of LTC. Traffic levels were 4080 movements for 10 July 2009 and 3825 movements for 10 August 2009.

The two days cover the variation of North Atlantic (NAT) tracks: 10 July 2009 was a ‘southabout jet stream’ day (meaning that eastbound transatlantic traffic routed south, whilst westbound traffic routed north), whilst 10 August 2009 was a ‘northabout jet stream’ day (meaning that eastbound traffic routed north and westbound traffic routed south).

The traffic sample entry points were at the Extended TMA boundary.

These traffic samples are grown to represent the levels and complexity of traffic expected at the point of delivery (2015) by extrapolating demand levels from the current samples, using future demand profiling. Each sample was then prepared to either Easterly of Westerly runway operations. Finally, each sample was then manipulated to simulate either:

- the effect of 100% efficient AMAN (all traffic fed into the ETMA in sequence with optimum spacing); or
- the effect of sub-100% efficient AMAN (some traffic fed into the ETMA out-of-sequence, with variations in spacing) arrival sequencing.

Note that no AMAN system was simulated during the exercise.

This resulted in the following 16 simulation configurations.

Point Merge Run Options				
Run	Airspace	AMAN Efficiency	Runway Ops	Atlantic Tracks
1	Current	100%	Easterly	North
2	Current	100%	Easterly	South
3	Current	100%	Westerly	North
4	Current	100%	Westerly	South
5	Current	Sub 100%	Easterly	North
6	Current	Sub 100%	Easterly	South
7	Current	Sub 100%	Westerly	North
8	Current	Sub 100%	Westerly	South
9	Point Merge	100%	Easterly	North
10	Point Merge	100%	Easterly	South
11	Point Merge	100%	Westerly	North
12	Point Merge	100%	Westerly	South
13	Point Merge	Sub 100%	Easterly	North
14	Point Merge	Sub 100%	Easterly	South
15	Point Merge	Sub 100%	Westerly	North
16	Point Merge	Sub 100%	Westerly	South

Table 7: Summary of Validation Scenarios

The full simulation timetable is presented in Appendix D. The nominal scenarios, as discussed in Section 2.2.4, were timetabled into the simulation based on the configurations above. Non-nominal scenarios, also as discussed in Section 2.2.4, were introduced into individual exercise runs.

In November 2011 a series of exercise runs were dedicated to assessing non-nominal scenarios associated only to the P-RNAV concept (see Table 3). The results of these exercises do not feed into the comparative analysis presented here, but have instead been used for the purposes of the safety assessment (574Obj_04).

In December 2011 a separate set of exercise runs were used to assess the impact of P-RNAV across both nominal and non-nominal scenarios (see Table 4). The same nominal and non-nominal scenarios were run in Baseline and P-RNAV organisations and the results used to evaluate all comparative objectives reported in this document.

For further details please refer to SESAR P 5.07.04 – WS2 Validation Plan [5].

3.1.2 Milan Test case

The preparation interested technical and validation aspects.

On technical side, ENAV engineers prepared the validation infrastructure based on the Industrial Based Platform placed at Rome ACC, in a dedicated simulation room.

Technicians performed the following main activities:

- acknowledgement of operative modifications to the case study (i.e. Milan TMA with P-RNAV procedures and PMS) based on feedbacks and user requirements collected during the first exercise;

- update of the related navigation charts and procedures;
- implementation of new Milan TMA case (i.e. revised P-RNAV procedures and PMS layout) on the CWPs placed in the simulation room.

At the end of the technical preparation, technicians performed technical and operational acceptance tests (i.e. TAT and OAT) which purposes were the verification of correct behaviour of the simulation platform and the operational correctness of the information displayed on the CWPs, respectively.

On validation side, the exercise preparation was mainly made up of the following activities:

a) selection of the participants at the evaluation sessions;
b) definition of experimental plan (i.e. experimental conditions, number of simulated sectors, number of runs, traffic load per each run);
c) definition of simulation scenarios (i.e. normal and unusual scenarios);
d) definition of agenda;
e) training of participants.

a) Regarding participants, only ATCOs from Milan ACC were involved in the validation activities, considering their past involvement in the first exercise and their knowledge of Milan operational environment. The exercise involved around 50 ATCOs.

b) The experimental plan was based on several criteria. As first, the exercise foresaw three weeks for the simulation. Each week lasted four days, from Monday to Thursday. During each week two batteries of controllers performed simulation according to the two couples of days of the week: the first group (made up of 8 ATCOs) was involved in Monday and Tuesday activities, the second group (made up of 8 different ATCOs) was involved in Wednesday and Thursday activities. In addition, runs were executed only in “PMS condition”, i.e. only considering the new Milan TMA case study. The baseline was discarded due to the fact that the comparison between it and “PMS condition” had already been performed during the first exercise. One of the main purposes of EXE-228 was to evaluate the correctness and suitability of the modified PMS. So, effort (i.e. available runs) was channelled in the evaluation of it in case of normal and unusual events. Six sectors were simulated, testing combinations among LAR, ADE, ANE, ANW, MAP, MAR, ASV sectors. Mainly three runs were executed every day. The tested traffic load varied from the baseline load augmented of 15% to the baseline load augmented of 50% (i.e. the one named “high traffic load” in Table 9).

c) Simulated scenarios foresaw usual and unusual conditions. The following table presents a short description of selected events, with the associate rationale and the expected behaviour of the controllers.

Scenario Definition	Description	Aim of the scenario	ATCO Expected Behaviour
1. PMS normal operations, only arrivals at LIMC	Only arrival at LIMC, with spacing of 1/1.5 min (simulating the presence of an arrival manager). RWYs in use were either 35R or 35L.	To get ATCOs familiarization with PMS procedure and allow ATCOs to perceive the workload variation (if compared with the radar vectoring technique)	To work in accordance with the procedure avoiding the radar vectoring. Controllers were expected to not be aware of the high amount of traffic.
2. PMS normal operations, arrivals and departures	This scenario included departures/arrivals at LIMC on both RWYs (35R or Dependent Parallel Approach). Departures/arrivals also at LIML and LIME.	To test the no interference of PMS with departures/arrivals at all airports and the decrease of coordination between sectors that were working at their full capacity.	For ATCOs, to work on own traffic without being disturbed by a high number of coordination.
3. PMS with arrivals and increased landing	This scenario included arrivals and departures at all airports. Increase of landing rate due to	To test whether under conditions of increased landing rate or more	To understand how to handle the traffic in case of increased landing rate. This would imply

Scenario Definition	Description	Aim of the scenario	ATCO Expected Behaviour
rate at LIMC.	TWR request or LVP conditions.	extensively in "critical condition", PMS could still be convenient. To test the use of holding patterns. Validating the total capacity of PMS system for LIMC case study.	for ATCOs to understand the decrease of PMS capacity and the adoption of holding patterns. Finally to understand the total capacity of the holding points associated with PMS.
4. PMS with arrivals and departures with go-around	This scenario included arrivals and departures at all airports. Same traffic load as scenario 3, but instead of increasing the spacing on final approach, the Missed Approach (MA) was introduced.	To test the MA procedure and allow ATCOs to become familiar with it. In particular, assessing the suitability of the procedure considering the arrival sequence and the coordination to be performed among different sectors. To test the role of coordinator.	To become confident with the missed approach path and its flying time. To understand how to manage the aircraft performed MA providing appropriate spacing in re-inserting it into the arrival sequence.
5.Non-nominal scenario: Excess of Go-around procedures with traffic merging inside PMS;	This scenario included arrivals and departures at all airports. Airports at full traffic load.	To test the MA procedure stressing the PMS up to its maximum capacity and beyond. To test the saturation of the PMS. To evaluate the ole of coordinator in managing these conditions.	To understand the management of a high number of aircraft in case of MA, with the support of the coordinator. To check how the coordinator facilitates operations.
6. Non-nominal scenario: Single runway operation due to emergency;	This scenario foresaw the single runway use (RWY35L). In this case the minimum spacing was 6NM. In case of heavy category departure the spacing increased to 9NM.	To test the validity of the PMS with a wider spacing distance during departures, in different cases. To test how long to resume to normal operations after having temporarily reduced the capacity of PMS.	To become confident in managing a reduced capacity of the system and in instructing a large number of aircraft to join the holding patterns. To be able in resuming normal operations after an emergency that temporarily reduced the PMS capacity. To understanding how to use graphic references of PMS procedure.
Non-nominal scenario: Aerodrome closed;	This scenario included arrivals and departures at all airports. Traffic after overflying FAF went ahead along the localizer without intercepting the glide path, overflying the RWY and reaching then the missed approach. The whole holding system was planned to have a capacity of over 40 aircraft.	To demonstrate the suitability of the holding patterns related to PMS allowing the management of a large number of aircraft on holding points. To test this scenario affects very little the work of adjacent sectors. To assess the ATCO workload during the management of the holding procedure.	To become confident in handling traffic already established on final approach and forced in performing the missed approach before reaching the holding patterns.
Non-nominal scenario: Heavy traffic departure on opposite direction	This scenario included arrivals and departures at all airports. Incoming traffic was spaced of 20/25 NM to allow the departure from opposite runway. This wide spacing is	To demonstrate that departures on opposite runway could be handled during PMS operations. To test how long to resume to	To figure out how to manage the wide spacing and how to position in the PMS all arrival traffic in order to reduce delay as much as possible.

Scenario Definition	Description	Aim of the scenario	ATCO Expected Behaviour
	obtained with the aid of the holding system.	normal PMS operations	
Non-nominal scenario: Opposite take-off direction in Linate. Stress unbalanced traffic management between different PMS sectors.	This scenario included arrivals and departures at all airports. At LIML departures occurred on RWY18, heavily affecting operations in the eastern sectors.	To test a condition of high stress in managing the eastern sectors. To assess if such type of operations at LIML could affect the PMS operations. To test, on the other side, if PMS could affects the possibility to release these clearances (i.e. departure on RWY18 at LIML).	To manage traffic in the eastern area without operational criticalities during PMS operations. To assess the impact and ATCOs workload with respect to the current procedures.

d) Controllers performed the planned runs across all sessions, playing alternatively the role over the different simulated sectors. Priority was given in assuring that each controller rotated in those sectors strictly related to PMS, i.e. in MAP, MAR, ANW and ANE sectors. All the ATCOs involved in the simulation had specifying licenses and several years of experience in managing the sectors reproduced in simulation.

e) A theoretical training was performed at the beginning of each two-day simulation session i) to refresh concept to controllers that had already been involved in the first exercise and that also participated to EXE-228 and ii) to introduce the operational concept and associated working methods to controllers involved at a first time in the PMS evaluation. In addition, the first run of each two-day simulation session was devoted to practical training working with 4 opened sectors and with a low traffic load. The purpose was to allow to 4 ATCOs to execute simulation and the other 4 to stay behind the CWP in order to easily observe the application of new procedures and working methods.

As already reported in previous paragraphs, baseline scenarios were not run during V3 since already evaluated during V2 phase, where the PMS structure tested demonstrated to be a good instrument to manage traffic, when compared to the baseline, even if some issues needed to be solved within the tested PMS structure in order to improve some bottlenecks observed and linked to the TMA complexity.

So the main achievement for V3 phase is to assess benefits and limitations of the modified PMS structure (V2 -> V3) with respect to the objective reported in paragraph 2.1.5.3.

3.2 Exercises Execution

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise start analysis date	Actual Exercise end date
EXE-05.07.04-VP-229	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	Nov-11	Dec-11	Jan-12	Feb-12
EXE-05.07.04-VP-228	Real Time Simulation of Point Merge Procedures in a Multi airport TMA	Jan-12	Jan-12	Feb-2012	April-12

Table 8: Exercises execution/analysis dates

3.2.1 Detailed exercise execution Milan test case

The exercise foresaw three weeks for the simulation (four-day session per week, from Monday to Thursday).
Each week was further split into a couple of validation sessions:

- the first session was performed on Monday and Tuesday with a dedicated group of 8 ATCOs,
- the second one was executed on Wednesday and Thursday with another different group of 8 ATCOs.

Three runs were planned each day of the simulation. There was a difference both in terms of simulated scenarios and in terms of traffic sample for each run.

During each two-day session, controllers rotated over all the simulated sectors. Priority was given to assure that *all* controllers worked in the sectors directly interested by the PMS (i.e. MAP, MAR, ANW and ANE). Minor priority was given in assuring the rotation over the other two positions (i.e. LAR collapsed with ADE, ASW).

The following table provides the schedule of activities in terms of validation sessions and respective group of controllers. For each validation session, information about the amount of runs and operational description of each run is provided.

First RTS week	ATCOs Group 1 – Validation Session 1		ATCOs Group 2 – Validation Session 2	
	Monday	**Tuesday**	**Wednesday**	**Thursday**
	Run 1: High traffic load, only arrival to LIMC	Run 4 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 1: High traffic load, only arrival to LIMC	Run 4 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach
	Run 2: departure and arrival at LIMC, LIML, LIME	Run 5 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 2: departure and arrival at LIMC, LIML, LIME	Run 5 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach
	Run 3: - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 6 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 3: - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 6 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach
Second RTS week	**ATCOs Group 3 – Validation Session 3**		**ATCOs Group 4 – Validation Session 4**	
	Monday	**Tuesday**	**Wednesday**	**Thursday**
	Run 1 (familiarisation): low traffic load, only arrival to LIMC	Run 4 - departure and arrival at LIMC, LIML, LIME	Run 1 (familiarisation): low traffic load, only arrival to LIMC	Run 4 - departure and arrival at LIMC, LIML, LIME

		- unusual scenarios and missed approach		- unusual scenarios and missed approach
	Run 2: High traffic load, only arrival to LIMC	Run 5 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 2: High traffic load, only arrival to LIMC	Run 5 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach
	Run 3: departure and arrival at LIMC, LIML, LIME	Run 6 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 3: departure and arrival at LIMC, LIML, LIME	Run 6 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach
Third RTS week	**ATCOs Group 5 – Validation Session 5**		**ATCOs Group 6 – Validation Session 6**	
	Monday	**Tuesday**	**Wednesday**	**Thursday**
	Run 1 (familiarisation): low traffic load, only arrival to LIMC	Run 4 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 1 (familiarisation): low traffic load, only arrival to LIMC	Run 4 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach
	Run 2: High traffic load, only arrival to LIMC	Run 5 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 2: High traffic load, only arrival to LIMC	Run 5 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach
	Run 3: departure and arrival at LIMC, LIML, LIME	Run 6 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach	Run 3: departure and arrival at LIMC, LIML, LIME	Run 6 - departure and arrival at LIMC, LIML, LIME - unusual scenarios and missed approach

Table 9: RTS Agenda

The first day of each session started with a briefing with all ATCOs. The briefing allowed (i) to explain the new concept, procedures and working methods, (ii) to summarize the expected activities.

A debriefing was executed every day, at the end of the runs, to collect controllers' feedback.

Additionally, EXE-228 allowed the simulation of a greater amount of Milan sectors, with respect to the previous exercise. Six operative positions were available and used to test those sectors directly interested by PMS (i.e. MAP, MAR, ANW and ANE) and the ones preparatory/indirectly affected by the PMS operations (i.e. LAR collapsed with ADE, ASW), it implies a higher number of ATCOs when compared with V2 simulation so increasing the operational actors involved and supporting for a better solidity of the feedbacks.

As it's possible to observe in the tables above groups 1 & 2 start simulation with already high traffic while other groups not. The reason for this lies in the fact that the first two groups were the one already employed during V2 and already familiar with PMS design and traffic management.

3.2.2 Deviations from the planned activities

According to Milan test case the most significant deviations observed during the preparation of exe-228 were the following:

Item	Deviation	Description	Mitigation	Effects
1	Delay of exercise execution	Exercise was initially planned to be executed in December 2011	Exercise was actually executed in January 2012	No impact
2	System log unavailability	Technical problem did not let the recording of system log	Analysis was performed on the basis of qualitative data. Qualitative data was collected by over-the-shoulder observation technique and debriefings.	Collection of subjective data
3	Unavailability of simulated wind	Technical problem did not let the simulation of wind, both in terms of direction and speed	Scenario that foresaw the presence of a strong wind able to affect the landing rate was replaced with a scenario that included a specific landing rate requested by the TWR	No impact

Table 10: EXE-228 Deviations

These deviations have been already taken into account inside the Validation Plan so no impact is expected in terms of deviation from the Validation Plan.

3.2.3 Deviations with respect to the Validation Strategy

No deviations with respect to the Validation Strategy were noted during the activity.

OFAs, OI Steps, Maturity, Scenarios and Stakeholders (ANSP, Airspace Users (Civil) & Airborne Industry[2]) were covered in the validation, as per Section 2 the WP5 Validation Strategy [8].

The Validation Expected Outcomes identified in Section 3 of the WP5 Validation Strategy [8] are also covered:

- Refinement/confirmation of V2 outcomes
- Performance assessment (prove benefits) in terms of
  - Airspace capacity (reduced workload)
  - Safety (reduced workload, improved situation awareness)
  - Efficiency (fuel efficiency, CDA, use of vertical guidance)
  - Environmental sustainability (fuel consumption and gaseous emissions)
  - Cost effectiveness (standardisation, training).
- Except for:
  - Predictability (TP accuracy, closed loop, maintaining FMS calculation)

“Point Merge in Complex TMA” will deliver improved predictability in a ‘position/heading’ sense, but this is a factor of Airspace Capacity; it cannot deliver improvement in time Predictability (as defined by the B4.1 KPAs [6]) in either Departures or Arrivals. This can only be controlled by Traffic Synchronisation in PAC04.

The following validation assumptions apply, as per Section 3 of the WP5 Validation Strategy [8]]:

- ASM-05.02-VALS-0001.0001 - Equipped aircraft are at least RNAV1 capable
- ASM-05.02-VALS-0001.0002 - Significant proportion of equipped aircraft
- ASM-05.02-VALS-0001.0003 - Suitable level of traffic debunching (e.g. with an AMAN)
- ASM-05.02-VALS-0001.0004 - Representative traffic patterns (e.g. traffic demand, aircraft mix)
- ASM-05.02-VALS-0001.0005 - Compliance with existing standards and guidelines
- ASM-05.02-VALS-0001.0006 - Separation standards and responsibilities unchanged (sectorisation unchanged).

[2] Commercial Pilots & Airbus Test Pilots were involved in the Cockpit Sessions at the Eurocontrol Experimental Centre, Brétigny, that were run to establish feasibility of airspace/procedures.

3.2.4 Deviations with respect to the Validation Plan

3.2.4.1 London simulation

Controller resource

Approach controller resource was not sufficient to fully staff each approach position for all runs. While this did not affect the ability of the simulation to run and for valid measurements to be taken, the following mitigations were made:

EGGW was one controller short for day 1 of the matched exercises. It was possible to run EGGW bandboxed in both Baseline and P-RNAV exercises.

EGSS was one controller short for part of day 4 of the matched exercises. It is not possible to staff EGSS in a bandboxed configuration for either Baseline or P-RNAV exercises scenarios. An EGGW controller (valid on EGSS) therefore staffed EGSS and EGGW was again run bandboxed.

EGLC was one controller short for days 1 and 2 of the matched exercises. EGLC was run bandboxed for Baseline exercises (matching current day operations) and with an experienced Air Traffic Project Specialist (APS) for P-RNAV exercises.

Scenarios

In consultation with the NATS project lead and SESAR project safety specialist it was agreed that the following scenarios did not require evaluation:

Reference	Description	Rationale
574V305	Horizontal separation not maintained on the sequencing leg.	Despite numerous attempts to engineer this scenario (principally though the use of non-conformant speed on the Point Merge sequencing leg), the controller always identified the situation and maintained separation. It was agreed that this was sufficient evidence of controller mitigation for this scenario
574V308	When reaching the end of a sequencing leg without receiving a turn to merge instruction, the pilot will turn to the merge point via a fly-by waypoint and request clearance to descend to the Merge Point.	It was agreed that a controller would not intentionally route aircraft level from the end of the sequencing leg with contingency stack full. Evaluation of this scenario was therefore combined with scenario 574V311 (temporary runway closure).
574V313	Non P-RNAV equipped, but BRNAV capable a/c, controller treats as P-RNAV	It was agreed that as no P-RNAV indication was provided on the strips that it was not possible to run this scenario.

Table 11: Unevaluated Scenarios

While all attempts were made to evaluate the scenarios, in certain situations the scenario failed to execute as needed. Therefore the following are scenarios that are not reported against due to a lack of evidence:

Reference	Description	Rationale
574V322	Aircraft is released from temporary hold in order to commence another approach - speed control used to ensure separation is maintained.	574V322 is the subsequent step to 574V321 in the Missed Approach Procedure but could not be executed because, in the PMS, there was no need for the aircraft to hold at the pre-defined waypoint, and that standard speeds were issued to maintain separation on final.
574V328	Strong cross wind on PMS causing tail wind on one of the sequencing legs; approach controller compensates by using adapted speed instructions	The difficulties with simulated wind conditions [see Section 4.2.3] meant that the correct conditions could not be achieved to determine a reliable result.

	and/or increased longitudinal.	
574V329	Approach controller takes account of wind effect when instructing 'direct to' due to differing wind effects/speed controls on the two sequencing legs.	The difficulties with simulated wind conditions [see Section 4.2.3] meant that the correct conditions could not be achieved to determine a reliable result.
574V336	Loss of dedicated airborne hold	This scenario was considered similar to 574V335; due to its highly disruptive nature, it was difficult to engineer without affecting other necessary scenarios within the limited timeframe available.
574V337	To compensate for strong wind conditions the TMA controller exercises speed controls to increase longitudinal separation between traffic on STAR	Strong winds were introduced into the scenarios being evaluated with no significant issues reported by the controllers in either configuration for any aspect of the flight profile, i.e. no speed controls required.

Table 12: Failed to execute Scenarios

The impact of these scenarios should therefore be assessed under local implementations of P-RNAV in the TMA.

Metrics

With reference to Table 5, the time each aircraft spent on the Sequencing Leg was not available as an output from the RTSA metrics. The analysis of holding has therefore been conducted without the use of this measure. Due to this limitation, the results against 574Obj_06 measure the change in “Time in Stack Holding”. There is no formal KPA directly associated with “Time in Hold”.

With agreement from the P5.7.4 NATS and project safety lead it was agreed that analysis of ‘Minimum Separation’ and STCA was not required as part of this validation exercise. The safety analysis, documented in the Safety Assessment Report appendix of the P5.7.4 OSED [2] will focus on the higher levels of the barrier model. That is safety assessment will be based on evidence and mitigation provided in this report against the operational scenarios detailed in 2.2.4 that may lead to losses of separation

It is not considered that pseudo-pilot responses are suitably representative of cockpit R/T. It is therefore not possible to fully validate the sub-objectives 574Obj_02_03 and 574Obj_02_04 based solely on real time simulation metrics. The likely state of these objectives has been inferred from the controller R/T loading and landing rate metrics, so no further validation of these criteria is deemed necessary.

4 Exercises Results

4.1 Summary of Exercises Results

This chapter collects results for both V3 simulations. Results have been organized on common tables arranged for Objective/KPA and showing results for each exercise ID (229 – 228) with some comments or explanations when needed.

4.1.1 Results on concept clarification

The exercise results for both test cases are summarised below. Without further guidance from the Validation Plan it has been assumed that all success criteria must be achieved for the overall validation objective to be classed as 'OK'. Where a validation objective has been assessed as 'NOK' a footnote is added to explain the precise reason for this result.

Validation Objective ID	Validation Objective Title	Success Criterion	Exercise ID	Exercise Results
574Obj_01	Assess impact to Runway Throughput	Runway Throughput maintained at Current Day levels or increased for the TMA as a whole	*EXE-05.07.04-VP-229*	**OK**
		Runway Throughput maintained at Current Day levels or increased for each individual Airfield	*EXE-05.07.04-VP-228*	**OK**
574Obj_02	Assess workload impact of procedures for Approach Controllers & Flight Crew	Approach Controller Workload reduced for the TMA as a whole Approach Controller Workload reduced for each individual Approach operation	*EXE-05.07.04-VP-229*	**NOK**[3]
		Flight Crew R/T Workload reduced for the TMA as a whole Flight Crew R/T Workload reduced for each individual Approach operation	*EXE-05.07.04-VP-228*	**OK**
574Obj_03	Assess Human Performance levels (such as Situational awareness, effective communication/team work detection/recovery of human error)	Approach Controllers' Human Performance levels are maintained at Current Day levels or enhanced.	*EXE-05.07.04-VP-229*	**OK**
			EXE-05.07.04-VP-228	**OK**
574Obj_04	Assess TMA Safety levels	Safety levels for the TMA as a whole are maintained at Current Day levels or improved	*EXE-05.07.04-VP-229*	**OK, subject to Safety Assessment Report**
		No new Safety Hazards added that cannot be mitigated	*EXE-05.07.04-VP-228*	**OK**
574Obj_05	Assess the effectiveness of Arrival and Departure Management	Efficiency of arrival & departure management for TMA as a whole	*EXE-05.07.04-VP-228*	**OK**

[3] Assessed as 'NOK' solely due to the individual results for EGGW which are, at least in part, a result of localised considerations as discussed in 2.2.4. TMA overall, EGSS and EGLC results passed the relevant success criteria.

Validation Objective ID	Validation Objective Title	Success Criterion	Exercise ID	Exercise Results
574Obj_06	Assess the impact to Hold Occupancy & Flight Levels	Hold Occupancy & Levels are maintained at Current Day levels or reduced for the TMA as a whole Hold Occupancy & Levels are maintained at Current Day levels or reduced for each individual Approach operation	*EXE-05.07.04-VP-229*	**NOK**[3]
574Obj_07	Assess the impact to Fuel Burn / CO_2 Emissions	Net benefit per flight to Fuel Burn **/ CO_2 Emissions** for the TMA as a whole Net benefit per flight to Fuel Burn **/ CO_2 Emissions** for each Airfield Approach + Departure operation	*EXE-05.07.04-VP-229*	**OK**
		Net benefit per flight to Fuel Burn **/ CO_2 Emissions** for the TMA as a whole	*EXE-05.07.04-VP-228*	**Not measured (*)**
		Net benefit per flight to Fuel Burn **/ CO_2 Emissions** for each Airfield Approach + Departure operation		**Not measured (*)**
		Evaluation of average vertical profile efficiency in terms of availability of CDO operations compared to the actual scenario		**OK**
574Obj_08	Assess the impact of Noise pollution to the local Environment	Noise pollution is maintained at Current Day levels or reduced for each Airfield Approach + Departure operation	*EXE-05.07.04-VP-229*	**OK**

Table 13: Summary of Validation Exercises Results

(*) Since no data recording was available from simulation it was not possible to obtain figures per single aircraft but only to assess indirect benefit arising from improved vertical profile efficiency when compared to actual scenario. So this objective in case of Milan exercise has been only partially assessed.

4.1.1.1 Results per KPA

At the time of the production of the Validation Plan [5] the SESAR KPIs were yet to be formalised. The exercises objectives were therefore derived from stakeholder expectations. The mapping of exercise objectives to SESAR KPI is presented in Table 14 below. These are based on the SESAR B4.1 Validation Target Allocation for Step 1 [7], supported by the methodology presented in [8].

KPA	KPI	Exercise objective	Exercise ID	Exercise Results
SAF1	ATM Induced accidents and incidents SAF11 O1 I1	574Obj_04	*EXE-05.07.04-VP-229*	Refer to Safety Assessment Report appendix of P5.7.4 OSED [2]
			EXE-05.07.04-VP-228	•TMA safety levels maintained at current day levels and improved; • Strong reduction of tactical vectoring. • Single leg design allowing descent enables an easy management of traffic not adequately spaced in the horizontal plane • Increased situational awareness Strong reduction in R/T communication leaving more time for planning

KPA	KPI	Exercise objective	Exercise ID	Exercise Results
ENV1	Atmospheric Effects (Fuel) ENV1111 O1 I1	574Obj_07	*EXE-05.07.04-VP-229*	2% decrease in fuel burn per flight (TMA overall)
			EXE-05.07.04-VP-228	• Improved vertical profile allowing continuous descent from FL120/FL130 until landing against today stepped descent thus allowing for less fuel consumption and less emissions • New STARs longer than nowadays STARs, even if these are often replaced by tactical vectoring. On average it's possible to expect that new design accounts for the same distance when compared with tactical vectoring, even if this achievement couldn't be measured due to lack of data. • Benefits observed also for Milan Linate and Milan Malpensa departures due to the availability of higher level for initial climb
ENV1	Atmospheric Effects (CO2) ENV1111 O1 I2	574Obj_07	*EXE-05.07.04-VP-229*	2% decrease in CO2 per flight (TMA overall)
			EXE-05.07.04-VP-228	•Improved vertical profile allowing continuous descent from FL120/FL130 until landing against today stepped descent thus allowing for less fuel consumption and less emissions • New STARs longer than nowadays STARs, even if these are often replaced by tactical vectoring. On average it's possible to expect that new design accounts for the same distance when compared with tactical vectoring, even if this achievement couldn't be measured due to lack of data. Benefits observed also for Milan Linate and Milan Malpensa departures due to the availability of higher level for initial climb
CAP2	Local Airspace Capacity CAP2 O1 I1	574Obj_02	*EXE-05.07.04-VP-229*	16% reduction in controller Workload, taken as an aggregate of Bedford workload and No. of Tactical Instructions (TMA overall)*
			EXE-05.07.04-VP-228	• 20% increase in the number of handled traffic per hour as inbound arrival capacity for Malpensa airport; • Surrounding aerodromes not impaired;
CAP3	Single Runway Airport Capacity CAP311 O1 I1	574Obj_01	*EXE-05.07.04-VP-229*	4% increase in average runway throughput (TMA overall)
			EXE-05.07.04-VP-228	Increase in runway throughput potentially achievable depending on aerodrome layout
CEF1	G2G ANS costs CEF112 O1 I1	574Obj_02 574Obj_03	*EXE-05.07.04-VP-229*	16% reduction in controller Workload, taken as an aggregate of Bedford workload and No. of Tactical Instructions (TMA overall)* Enabled by homogenous design
			EXE-05.07.04-VP-228	• Estimated 50% reduction in R/T communication (**) •Estimated 75% reduction in radar vectoring use (**) • Estimated 20-25% time saving in handling the same number of arrivals to Malpensa airport as today (**)

Table 14: Summary of Validation Exercises Results

(*) Controller workload can have an impact on Safety, Capacity and/or Cost Effectiveness. If workload is too high or too low then this can affect controller concentration and effectiveness, therefore impacting Safety. If controller workload is reduced per flight handled then the controller has the potential to manage a greater number of flights over a set period, so the potential Capacity and Cost Effectiveness is increased (e.g. if a new runway opened in the TMA, this could be accommodated without increase in delay or the need for additional working hours or staff).

The 16% reduction in controller Workload indicates a potential increase in Local Airspace Capacity of a similar order of magnitude, if the following is considered as valid:

> "Hourly number of flights able to enter airspace volume", as per the B4.1-defined KPI [6], was not considered an appropriate metric for the Real-Time Simulation because the traffic loading into the TMA was pre-defined by the traffic samples so was a 'constant'. The 'variable' was the level of controller workload experienced under the constant traffic loading per airspace design or scenario. Controller workload is also the most capacity-constraining factor in a Complex TMA, so a change in controller workload can be assumed to be representative of a change in local airspace capacity.
> Of the all the workload measures analysed the most representative figure is deemed to be an aggregate score of the number of tactical instructions given (for the TMA as a whole) and the Bedford Workload Scale (for the TMA as a whole). See Section 4.3.2 for a discussion of this measure.

(**) Results have to be intended as estimates and based on:

i. Direct observations performed by the Validation team during exercise execution;
ii. De-briefing
iii. feedback collection from ATCOs involved

Results collected in this way leads with enough confidence to assess a strong reduction in R/T communication and radar vectoring estimating this reduction respectively in -50% and -75%, which are to intended in this context nota numerical values assessed through system logs or tools but trends obtained by an expert qualitative evaluation. In this context the term expert qualitative evaluation refers to an analysis performed by people having adequate and solid knowledge of the operational concept under evaluation.

4.2 Analysis of Exercises Results

4.2.1 London test case

The following table shows a summary of the Validation results. For clarity, adjectives contributing towards a positive validation result are highlighted in **green** while adjectives contributing to a negative validation result are highlighted in **red**. Adjectives in **black** indicate the result is not considered as significant. Further explanation is available below Table 14. Without further guidance from the Validation Plan it has been assumed that all success criteria must be achieved for the overall validation objective to be classed as 'OK'.

A more detailed description of each objective is then presented below the summary table.

Validation Objective ID	Validation Objective Title	Success Criteria[4]	Exercise Results	Validation Objective Analysis Status per exercise	Val'd Objective Analysis Status
574Obj_01	Assess impact to Runway Throughput	Runway Throughput maintained at Current Day levels or increased for the TMA as a whole Runway Throughput maintained at Current Day levels or increased for each individual Airfield	**Increase** of 3 a/c per hour in TMA (SS, GW, LC) landing rate for non-disruptive matched exercises. **Increase** of 2 a/c per hour in TMA (SS, GW, LC) landing rate for all matched exercises. EGSS **increase** of 1 a/c per hour for non-disruptive exercises; **decrease** of 1 a/c per hour for all matched exercises. EGGW **increase** of 0 a/c per hour for non-disruptive exercises; **decrease** of 1 a/c per hour for all matched exercises. EGLC **increase** of 3 a/c per hour for non-disruptive exercises **decrease** of 2 a/c per hour for all matched exercises. 17/17 **positive** controller responses to volume of traffic that can be handled using Point Merge.	**OK**	OK
574Obj_02	Assess workload impact of procedures for Approach Controllers &	Approach Controller Workload reduced for the TMA as a whole Approach Controller	0.6 point **reduction** to 3.2 on the Bedford workload scales for TMA overall (3 = "enough spare capacity for all desirable additional	**NOK**[5]	NOK[5]

[4] Note that a validation objective can have more than 1 success criterion, please make them appear in the same cell.
[5] Assessed as 'NOK' solely due to the individual results for EGGW which are, at least in part, a result of localised considerations as discussed in 2.2.3. TMA overall, EGSS and EGLC results passed the relevant success criteria.

Validation Objective ID	Validation Objective Title	Success Criteria[4]	Exercise Results	Validation Objective Analysis Status per exercise	Val'd Objective Analysis Status
	Flight Crew	Workload reduced for each individual Approach operation Flight Crew R/T Workload reduced for the TMA as a whole Flight Crew R/T Workload reduced for each individual Approach operation	tasks). 16/17 controller responses that Point Merge had a **positive** impact of R/T loading and workload. A 16% **reduction** in tactical instructions for the TMA as a whole A 2 percentage point **reduction** in the R/T occupancy of the FIN for the TMA overall. A 13 percentage point **reduction** in the R/T occupancy for INT for the TMA overall. An **increase** of 1 in the maximum aircraft on frequency for FIN for TMA overall No change to maximum aircraft on frequency for INT for TMA overall 0.6 point **increase** on Bedford workload scale to 4.1 for EGGW (4="insufficient spare capacity for early attention to additional tasks") **Decrease** on Bedford workload scale of 1.2 to 3.2 for EGLC and 1.1 to 3.1 for EGSS. Increase of 12% in tactical instructions for EGGW. **Decreases** of 48% and 30% for EGLC and EGSS respectively. **Increase** of EGGW FIN R/T occupancy from 17% to 21%. Increase in EGLC Director R/T occupancy due to changing role. **Decrease** in R/T occupancy of all other individual TMA approach positions (as well as TC North).		

Validation Objective ID	Validation Objective Title	Success Criteria[4]	Exercise Results	Validation Objective Analysis Status per exercise	Val'd Objective Analysis Status
			Increase of 1 aircraft maximum on frequency for EGGW FIN, EGGW INT and EGSS FIN. Increase of 9 for EGLC Director due to changing roles. Decrease of 1 aircraft maximum on frequency for EGSS INT and 3 for TMS. Not possible to validate pilot R/T workload in simulation environment. Given that similar traffic levels were worked the results at the approach controller level are inferred for the pilot level (decrease for TMA overall, increase for EGGW and decreases for EGLC and EGSS)		
574Obj_03	Assess Human Performance levels (such as Situational awareness, effective communication/teamwork detection/recovery of human error)	Approach Controllers' Human Performance levels are maintained at Current Day levels or enhanced.	0.6 point reduction to 3.2 on the Bedford workload scale for TMA (EGSS, EGGW, EGLS) overall (3 = "enough spare capacity for all desirable additional tasks). 0.2 point increase in China Lakes Situation Awareness score to 8.3 (8="My Situation Awareness with respect to the task was good. I was able to perform the task well most of the time") Small increase of 0.1 point to 6.2 (out of 7) in the NATS Situation Awareness Picture Scale. Average CARS (user acceptance) score of 7.8 (8="System is acceptable and minimal compensation is needed to meet desired performance") Average NATS confidence diamond score of 7.4 / 10 indicating reasonably high level of confidence in the	OK	OK

Validation Objective ID	Validation Objective Title	Success Criteria[4]	Exercise Results	Validation Objective Analysis Status per exercise	Val'd Objective Analysis Status
			P-RNAV and Point Merge concept.		
574Obj_04	Assess TMA Safety levels	Safety levels for the TMA as a whole are maintained at Current Day levels or improved No new Safety Hazards added that cannot be mitigated	Refer to Safety Assessment Report appendix of P5.7.4 OSED [2] Evaluation of validation scenarios listed in Section 2.2.4. Acceptable impact on Safety subject to suitable mitigations for the following issues: **Skills**. In non-nominal scenarios under Point Merge controllers will often need to revert to vectoring. This is safe. However, following prolonged use skill fade may become an issue. Newly validated controllers may not develop the necessary vectoring skills. TRUCE training should be updated as a result. **Monitoring**. The approach controller's role becomes more passive. This may affect situation awareness. **Contingency Holding**. There should be sufficient contingency holding to accommodate as many aircraft as may be present in the Point Merge system at any one time. **Min-Stack + 1 for silent release**. It is recommended that the silent release to approach is done at Min-Stack + 1 rather than Min-Stack. **Mode-S IAS**. It is recommended the Mode-S IAS is displayed on the FIN's TDB during Point Merge operations. Use of the Abnormal Indicated	**OK, subject to SAR**	**OK, subject to SAR**

Validation Objective ID	Validation Objective Title	Success Criteria[4]	Exercise Results	Validation Objective Analysis Status per exercise	Val'd Objective Analysis Status
			Airspeed Monitor should be considered.		
574Obj_06	Assess the impact to Hold Occupancy & Flight Levels	Hold Occupancy & Levels are maintained at Current Day levels or reduced for the TMA as a whole Hold Occupancy & Levels are maintained at Current Day levels or reduced for each individual Approach operation	Total TMA (EGGW, EGSS, EGLC) holding **decreased** by 42%. Total holding for EGGW aircraft **increased** by 56%. Total holding for EGLC aircraft **decreased** by 66%. Total holding for EGSS aircraft **decreased** by 50% While some simulation effect is noted, the proportion of holding time spent in outer holds **reduced** from 70% to 4% under P-RNAV operations.	**NOK**[5]	**NOK**[5]
574Obj_07	Assess the impact to Fuel Burn / CO_2 Emissions	Net benefit per flight to Fuel Burn **/ CO_2 Emissions** for the TMA as a whole Net benefit per flight to Fuel Burn **/ CO_2 Emissions** for each Airfield Approach + Departure operation	Combined (arrival and departure) fuel burn **decreased** by 2% for the TMA (EGSS, EGGW, EGLC) overall. Combined fuel burn at EGGW **increased** minimally by 0.4% Combined fuel burn at EGLC **decreased** by 4.1% Combined fuel burn at EGSS **decreased** by 1.2%	**OK**	**OK**
574Obj_08	Assess the impact of Noise pollution to the local Environment	Noise pollution is maintained at Current Day levels or reduced for each Airfield Approach + Departure operation	No noise benefit for arrival aircraft Noise **benefit** for departing aircraft due to unrestricted climb phase As assessed by P16.06.01. See Ref [3]for further details.	**OK**	**OK**

Table 15: Overview: Validation Objectives, Exercises Results and Validation Objectives Analysis Status

The previous table shows an overview of each validation objective. The following information takes each Validation Objective and its Success Criteria and presents a more detailed analysis of each:

574Obj_01 - Assess impact to Runway Throughput

574Obj_01_01: Runway Throughput maintained at Current Day levels or increased for the TMA as a whole.

Across the TMA as a whole the average landing rate (movements / hour) using P-RNAV operations increased by two compared to the baseline. The TMA was taken to be the adjusted average (see below) of all movements at EGSS, EGGW and EGLC across all eight matched exercise design. This gives a total number of observations (N) of 24 for the three airfields.

	Baseline	P-RNAV	Difference	N
TMA (SS, GW, LC)	65	67	2	24

Table 16: TMA landing rate. All matched exercises.

The adjusted number of movements is the hourly landing rate as calculated between the time of the first aircraft to land and the end of the exercise. It was found that, especially for Easterly operations, the first aircraft was later to land in the P-RNAV exercises compared to the baseline. This biases the results in favour of the baseline exercises if only the total movements during the exercise were considered.

A number of scenarios were run during the matched exercises that were disruptive to the landing rate. These scenarios may potentially have affected the landing rate for one organisation (Baseline or P-RNAV) to a greater degree than the other. The total TMA movements have therefore been calculated excluding the following five observations:

- Match 4 for EGLC. The EGLC director position was staffed by a support assistant due to staff shortages. The reaction to an aircraft R/T failure was not consistent between the two matched exercises.
- Match 5 for EGGW and EGSS. CB activity across the EGGW and EGSS approach was extremely disruptive, closing the approach to arrivals for a significant portion of the exercise. It is not possible to state that the effect on the landing rate was the same in both matched exercises.
- Match 6 for EGSS. An infringer was dealt with differently between the baseline and P-RNAV exercise. In one case the arrivals needed to be broken off, whereas they were able to continue in the other.
- Match 8 for EGLC. A CAT B flight was dealt with differently between the baseline and P-RNAV exercise. In one case the arrivals needed to be broken off, whereas they were able to continue in the other.

The total TMA movements with the above exercises excluded are presented in Table 17 below. The result is an increase of three movements per hour for P-RNAV compared to the baseline. This gives reassurance that the results across all exercises present a fair reflection of the P-RNAV impact on the landing rate.

	Baseline	P-RNAV	Difference	N
LTMA (SS, GW, LC)	67	70	3	19

Table 17: TMA landing rate. Selected matched exercises.

It is therefore concluded that at the TMA level P-RNAV has a small positive impact on the landing rate for the TMA overall.

574Obj_01_02: Runway Throughput maintained at Current Day levels or increased for each individual Airfield.

Across each airfield the landing rate (movements / hour) using P-RNAV operations increased by three for EGLC and decreased by one for EGGW and EGSS as shown in the table below.

	Baseline	P-RNAV	Difference	N
EGLC	20	24	3	8
EGGW	21	20	-1	8
EGSS	23	22	-1	8

Table 18: Landing rate by airfield. All matched exercises.

When the same five exercises are removed as above the results are as shown in the table below. Again the impact is relatively minor, removing the small decrease at EGSS and EGGW. Given the small sample sizes for each individual airfield it cannot be concluded that the landing rate has changed with the introduction of P-RNAV at the airfield level.

	Baseline	P-RNAV	Difference	N
EGLC	22	24	3	6
EGGW	22	22	0	7
EGSS	23	24	1	6

Table 19: Landing rate by airfield. Selected matched exercises.

These results are supported by the qualitative end-of-simulation questionnaire feedback. All (9 out of 9 in November and 8 out of 8 in December) controllers felt that the P-RNAV implementation would have a positive impact on the volume of traffic that can be handled.

Correspondingly, controllers also noted that the increased systemisation may make the P-RNAV implementation marginally less resilient to abnormal events. The additional distance between the inner hold locations and touchdown meant that once aircraft begin to hold, for example following an unplanned runway closure, it will take slightly longer to re-establish arrivals.

The landing rate will also be affected by the quality of service offered by the FIN controllers using the Point Merge system. It was not possible to quantitatively assess this during the simulation due to the aircraft airspeed performance limitations noted in Section 4.2.3 below.

The qualitative opinion of controllers was that the accuracy and consistency of delivery should not be affected by the introduction of P-RNAV, and specifically the introduction of Point Merge for approach. 14 out of 17 responses indicated that the accuracy of delivery would be improved and 13 out of 17 responses indicated that the consistency of delivery would be improved under Point Merge.

EGLC controllers did raise one reservation with regards to the accuracy and consistency of delivery. On Westerlies controllers noted that the sequencing legs effectively act as a Base Leg 25Nm from touchdown. This means they have 'one shot' to get the spacing correct compared to a Base Leg at approximately 10Nm from touchdown today. The set-up on Easterlies may provide for more accurate spacing as they are able to short-cut aircraft off the P-RNAV transition to refine the spacing. However, it was also acknowledged that this Point Merge design has greater track distance.

574Obj_02 - Assess workload impact of procedures for Approach Controllers & Flight Crew

574Obj_02_01: Approach Controller Workload reduced for the TMA as a whole.
574Obj_02_02: Approach Controller Workload reduced for each individual Approach operation

The workload impact of the P-RNAV procedures on Approach controllers was assessed through a range of measures.

End-of-run self-reported Bedford Workload Scale

The Bedford workload data collected during the matched exercises indicates that overall there was a slight reduction in the level of workload experienced during the P-RNAV exercises compared to the

Baseline. A level of 3.8 (4=insufficient spare capacity for early attention to additional tasks) was recorded during Baseline exercises compared to 3.2 (3=enough spare capacity for all desirable additional tasks) during Point Merge exercises.

This is based on an analysis of 40 pairs of matched observations: 14 for EGGW, 10 for EGLC and 16 for EGSS.

	Baseline	P-RNAV	Difference
LTMA (SS, GW, LC)	3.8	3.2	-0.6

Table 20: LTMA (SS, GW, LC) Bedford workload scores

This reduction is reflected in the ISA scores where controllers, particularly at EGSS and EGLC recorded slightly lower levels of workload over the course of the P-RNAV exercises when compared against the Baseline.

The average Bedford scores are presented by airfield, and including TC NORTH, in Table 21 below. EGGW demonstrated an increase of reported workload in contrast with EGLC and EGSS which reported larger decreases. These results needs to be considered in light of the changing roles discussed in 2.2.4. A slight increase in EGGW workload may be expected given the transfer of LOREL traffic from EGSS. A small decrease in EGSS may also be expected for the same reason.

TC North controllers felt the P-RNAV implementation provided a number of benefits that reduced workload. Departure routes were generally de-conflicted from arrivals, the change in the transition altitude to 18,000ft was a benefit, R/T was reduced due to the silent release procedure and the redistribution of traffic (between TC N sectors and with other TC sectors) all reduced TC N workload. A TC co-ordinator was required more often during baseline exercises compared to Point Merge exercises.

However, it is also noted that the perception of controllers attending the November simulation was less positive. They felt they had less space with which to manoeuvre aircraft and found it difficult to get the outbounds up and over the inbound traffic.

Airfield / Sector	Baseline	P-RNAV	Difference
GW	3.5	4.1	0.6
LC	3.4	2.3	-1.2
SS	4.2	3.1	-1.1
NORTH	4.1	3.1	-1.1

Table 21: LTMA (SS, GW, LC, NORTH) Bedford workload scores by airfield

End-of-simulation questionnaire

The Bedford and ISA results are supported by the end of simulation questionnaire feedback in which 16 out of 17 controller responses indicated that there had been a positive impact on the overall levels of R/T occupancy and workload.

Debrief and questionnaire comments

TC North controllers cited the increased use of silent procedures with respect to inbound aircraft and the reduced need to issue vectoring instructions as reasons for lower workload. It was also commented that the reduced amount of transmissions during the P-RNAV exercises provided more thinking time; a result supported by the analysis of tactical instructions presented below.

Tactical Instructions

The average number of tactical instructions for the TMA as a whole (EGLC, EGGW, EGSS) per exercise was found to reduce by 16% between baseline and P-RNAV exercises. The distribution of tactical instructions was also found to change. The number of heading instructions (including 'route direct') reduced by 44% while the number of speed instructions increased by 18%. This reflects controllers' comments that speed control becomes the primary tool to maintain separation when operating under RNAV procedures. It is therefore concluded that the P-RNAV reduced the total number of tactical instructions for the TMA as a whole.

	Baseline				P-RNAV			
	FL	HDG	SPD	TOTAL	FL	HDG	SPD	TOTAL
TMA (LC, GW, SS)	266	352	166	783	261	198	196	656
% Change					-2%	-44%	18%	-16%

Table 22: TMA average number of tactical instructions per exercise

The average number of instructions by airfield are presented in the table below. These show a 12% increase at EGGW, a 19% increase at EGLC and a 48% decrease at EGSS.

As discussed in Section 2.2.4 the controller roles at EGGW, EGSS and EGLC also changed between Baseline and P-RNAV scenarios. In particular, it may be expected that:

- The number of FL instructions at EGLC will increase due to the introduction of holds at ROACH and WHITS in P-RNAV exercises compared to no holding facilities in the Baseline;
- The overall number of instructions will increase at EGGW and decrease at EGSS due to the transfer of LOREL traffic from EGSS to EGGW between Baseline and P-RNAV exercises.

While not an airfield, there was also a significant reduction in the number of tactical instructions on TC North (TC North East and TC North West combined). While these sectors did not directly interact with the Point Merge systems, this decrease will be, at least in part, attributable to the increased systemisation and de-conflicted routes introduced by the P-RNAV changes.

	Baseline				P-RNAV			
	FL	HDG	SPD	TOTAL	FL	HDG	SPD	TOTAL
EGGW	45	87	53	185	82	71	55	207
% Change					***81%***	***-18%***	***4%***	***12%***
EGLC	61	99	45	206	105	61	80	246
% Change					***72%***	***-39%***	***76%***	***19%***
EGSS	160	166	68	393	75	67	62	203
% Change					***-53%***	***-60%***	***-9%***	***-48%***
NORTH	271	152	23	446	245	36	31	311
% Change					***-10%***	***-77%***	***34%***	***-30%***

Table 23: Average number of instructions per exercise by airfield

It is therefore difficult to assign the increases at EGGW and EGLC and decrease at EGSS solely to the introduction of the Point Merge system. A more representative assessment would be to compare the total number instructions at EGGW and EGSS combined. Overall there was a reduction of 29% in the average number of instructions.

	Baseline				P-RNAV			
	FL	HDG	SPD	TOTAL	TOTAL	FL	SPD	TOTAL
GW+SS	205	253	120	578	156	137	116	410
% Change					***-24%***	***-46%***	***-3%***	***-29%***

Table 24: Average number of instructions per exercise for EGGW and EGSS combined

Controllers from all airfields commented that they felt R/T workload and the number of transmission were significantly reduced in P-RNAV exercises due to the Point Merge system, freeing up capacity for other tasks. This is reflected in these quantitative results.

R/T Occupancy

It was the opinion of controllers that R/T occupancy was reduced using the Point Merge system for approach. A quantitative analysis of R/T occupancy is complicated by the changing roles discussed in Section 2.2.4. In particular, it may be expected that:

- R/T will increase at EGGW and decrease at EGSS due to the transfer of LOREL traffic from EGSS to EGGW between Baseline and P-RNAV exercises; and
- The distribution of R/T will change at EGLC as a single controller (TMS) used the R/T supported by a co-ordinator in Baseline exercises compared to a TMS and LC Director in P-RNAV exercises.

Further, due to the controller shortages discussed in Section 3.2.4 EGGW was staffed with a single controller for Baseline exercises on two out of four of the days when matched exercises were conducted. For this reason it is not possible to compare R/T loading between Baseline and P-RNAV exercises on these days at EGGW.

Given the above, at the TMA level it is considered that a combined EGGW and EGSS analysis is most appropriate for Workload, which is the metric that is most heavily impacted by the shift in responsibilities between EGSS and EGGW controllers. This is therefore based on 3 pairs of matched exercises for EGGW and 8 pairs of matched exercises for EGSS. Split by transmit (Tx), receive (Rx) and overall the results are presented in Table 25 below. These indicate a drop of 13 percentage points for the INT controller and a drop of two percentage points for the FIN controller.

	Baseline			P-RNAV		
	RT Tx	RT Rx	**Total**	RT Tx	RT Rx	**Total**
FIN (GW, SS)	15%	11%	**26%**	13%	11%	**24%**
INT (GW, SS)	21%	15%	**36%**	13%	10%	**23%**

Table 25: TMA average R/T occupancy

By airfield the results are presented in Table 26 and for TC North in Table 27. As may be expected, the biggest decrease is seen at EGSS INT and FIN with EGGW FIN showing an increase. The TC North sectors are also included; showing a decrease for both positions.

Across the three airfields the distribution of R/T appears more equitable under P-RNAV operations. In the baseline the total R/T occupancy of EGSS INT and EGLC TMS are 47% and 42% respectively. In the P-RNAV exercise the maximum approach position R/T occupancy is 28% at EGLC DIR.

	Baseline			P-RNAV		
	RT Tx	RT Rx	**Total**	RT Tx	RT Rx	**Total**
GW FIN	8%	5%	**13%**	12%	10%	**21%**
GW INT	15%	10%	**25%**	12%	9%	**21%**
SS FIN	22%	16%	**38%**	15%	12%	**27%**
SS INT	28%	19%	**47%**	13%	12%	**25%**
LC DIR		n/a		17%	11%	**28%**
TMS	23%	18%	**42%**	14%	12%	**26%**

Table 26: Average R/T occupancy by airfield

	Baseline			P-RNAV		
	RT Tx	RT Rx	**Total**	RT Tx	RT Rx	**Total**
TC NE	28%	20%	**48%**	27%	20%	**47%**
TC NW	25%	17%	**42%**	20%	16%	**36%**

Table 27: Average R/T occupancy for TC North

Aircraft on Frequency

Analysis of aircraft on frequency is also complicated by the changing roles between Baseline and P-RNAV exercises. Again, it is considered that at the TMA level a combined analysis of EGSS and EGGW is the most valid comparison of Baseline and P-RNAV. The measure used for this analysis is the maximum aircraft on frequency during an exercise.

Due to the controller shortages discussed in Section 3.2.4 EGGW was staffed with a single controller for Baseline exercises on two out of four of the days when matched exercises were conducted. For this reason it is not possible to compare aircraft on frequency for these days at EGGW.

Overall this analysis is therefore based on 3 pairs of matched exercises for EGGW and 8 pairs of matched exercises for EGSS.

At the TMA level the maximum number of aircraft a FIN controller worked was, on average, one aircraft more during the P-RNAV exercises compared to the Baseline. The maximum number of aircraft on frequency for the INT controller remained unchanged. This finding is also supported by the debrief comments of controllers. Given the reduced number of tactical instructions and R/T per aircraft it was possible to safely handle more aircraft at the same time.

	Baseline	P-RNAV	Difference
FIN (GW, SS)	6	7	1
INT (GW, SS)	7	7	0

Table 28: TMA Average maximum a/c on frequency

The results by airfield show more variability, as would be expected given the changing controller roles already discussed. It may be considered that the FIN role at EGSS and EGGW will be the least affected by the change. The EGSS and EGGW FIN controllers show an increase of one aircraft in the P-RNAV exercises compared to the Baseline and it is recommended that this result would be reflective of the impact of Point Merge at an individual airfield. For INT controllers it is recommended that the TMA level results (neutral impact) are taken as representative of the effect of introducing Point Merge at an individual airfield.

	Baseline	P-RNAV	Difference
GW FIN	4.8	5.8	1
GW INT	5.8	7.0	1
SS FIN	6.4	7.3	1
SS INT	7.4	6.3	-1
LC DIR	n/a	9.0	9
TMS	10.0	7.0	-3

Table 29: Average maximum a/c on frequency by airfield

Overall, given that requirement that workload is not increased for the TMA as a whole and for each individual airfield, it is not possible to pass this validation objective based on the results of this exercise due to the results for EGGW.

However, it is considered that the issues at EGGW are implementation specific and, at least in part, caused by the additional workload of transferring the LOREL holding traffic to EGGW. Subject to the implementation issues raised in this report being addressed, it is considered that this validation objective 547Obj_02_02 can be passed for the project as whole.

574Obj_02_03: Flight Crew R/T Workload reduced for the TMA as a whole

The impact of the Point Merge procedures on the Flight Crew were evaluated in the simplified cockpit simulation at EUROCONTROL. The results of this analysis are based on EGSS approaches to runway 22 and 04 flown in a simulated A320 FMGS trainer with external view. Three pilots, from Swiss International, Novair and Airbus took part in this assessment.

The general feedback from the evaluation was that the concept is feasible under high and low traffic density conditions. This does not provide qualitative results but provides a positive indication: no concerns were raised with respect to additional R/T workload that may result from the implementation of the Point Merge procedure at EGSS.

Pseudo-pilot R/T cannot be taken as a totally representative of true pilot readback and controller interaction. It is therefore not possible to completely validate this objective using the real time simulation outputs. However, given that the level of traffic landed at each aircraft remained broadly the same with no significant negative impacts on controller R/T workload it may be inferred that pilot R/T workload will be affected in similar way.

574Obj_02_04: Flight Crew R/T Workload reduced for each individual Approach operation

As discussed above, it is not possible to completely validate this objective using the real time simulation outputs. The results for controller R/T workload are therefore inferred for Flight Crew R/T workload.

574Obj_03 - Assess Human Performance levels (such as Situational awareness, effective communication/teamwork detection/recovery of human error).

574Obj_03_01: Approach Controllers' Human Performance levels are maintained at Current Day levels or enhanced

Human Performance is concerned with the level of performance that can be achieved by the person using the new system. It is the extent to which goals for speed, accuracy, quality and other criteria are met by people functioning in their work environment. The evidence collected via the feedback on workload, situational awareness, user confidence and acceptance, together with the debrief comments and objective data can all be used to indicate the level of human performance.

China Lakes Situation Awareness Scale

Information regarding controllers situational awareness, that is their ability to integrate information, develop and retain the 'picture' was gathered at the end of each run using the China Lakes scale. This 10 point scale ranges from 1= SA with respect to task was far too low to 10= SA with respect to the task was excellent.

This is based on an analysis of 40 pairs of matched observations: 14 for EGGW, 10 for EGLC and 16 for EGSS.

The feedback regarding levels of situation awareness collected from participants at the end of each run during the matched exercises shows overall there was a very slight increase in the level of situation awareness during the P-RNAV exercises compared to the baseline.

	Baseline	**P-RNAV**	**Difference**
LTMA (SS,GW,LC)	8.1	8.3	0.2

Table 30: LTMA(SS, GW, LC) Average China Lakes Situation Awareness scores

Average rating of Situation Awareness following Baseline airspace runs was 8.1, where the average rating immediately following Point Merge runs was 8.3. This is based on a 1 to 10 scale with 10 being the highest level of situation awareness. A score of 8 reflects a response of "My SA with respect to the task was good. I was able to perform the task well most of the time."

The results by airfield are presented in Table 31 below. In line with other self-assessed workload and human performance measures a slight degradation is observed for EGGW [See details under 574V335 below] compared to increases at all other airfields, as well as TC North.

Airfield	Baseline	P-RNAV	Difference
EGGW	8.6	7.6	-1.0
EGLC	8.4	9.2	0.7
EGSS	7.7	8.1	0.4
NORTH	7.6	8.4	0.8

Table 31: LTMA Average China Lakes Situation Awareness scores by airfield

NATS Picture Dimensions Scale

Additional data was collected via the NATS Picture Dimensions which are four dimensions; (being ahead of the game, understanding of traffic situation, control of the RT and aware of a/c before they call you). Dimensions are rated on a 7 point scale and then combined to deliver a single measure of SA. Scale dimensions were developed in conjunction with controllers and reflect specific ATC qualities experienced with lower and higher SA. The sample size is the same as that already presented for China Lakes and Bedford measures.

A similar improvement was also reflected in the average overall Picture ratings which were also slightly better following Point Merge runs. (Average rating for current was 6.08 and following Point Merge runs 6.32 in December, where '7' is the highest rating available to select).

	Baseline	P-RNAV	Difference
LTMA (SS,GW,LC)	6.1	6.2	0.1

Table 32: LTMA (SS, GW, LC) Average NATS Picture rating scores

User Confidence measures
Controller Acceptance Rating Scale (CARS):
This CARS scale was issued to controllers at the end of each day. The scale is used to assess controller confidence of the system. The four main dimensions in CARS are controllability, tolerability, satisfaction and acceptability. The controllers are led through a decision tree which test for all four dimensions.

NATS Confidence Diamond
An indication of controllers' confidence in people, procedures and equipment was obtained at the end of each day via the NATS Confidence Diamond scale. Feedback on these aspects is then combined with the CARS dimensions, to give an overall judgement of User confidence. This is based on 34 observations across all approach positions.

Evidence from the user confidence scores (CARS and NATS confidence diamond) were collected at the end of each day and as such scores obtained are based on the handling of scenarios in both current and point merge configurations. This means that it is not possible to discriminate levels of confidence between the current and point merge. However, overall the CARS average 'user acceptance' score was 7.8 which equates towards the descriptor of "mildly unpleasant deficiencies. System is acceptable and minimal compensation is needed to meet desired performance".

The NATS Confidence Diamond score of 7.4 is similarly towards the positive end of the 10 point scale used. This would support the other evidence collected during debriefs that users have a reasonable high level of confidence in the point merge concept, although further work is required to refine the concept and optimise procedures before it would be suitable for a live complex TMA operational environment.

574Obj_04: - Assess TMA Safety levels

574Obj_04_01: Safety levels for the TMA as a whole are maintained at Current Day levels or improved

Note that the final assessment of this objective is deferred to the Safety Assessment Report. This will form an appendix of the P5.7.4 OSED [2].

Analysis of the subjective evidence collected on workload, situational awareness, user confidence and acceptance, together with the debrief comments and objective data are all indications of human performance. These indicators can all be used to infer how levels of safety may be being affected when operating in a 'current baseline' configuration as compared to applying the point merge concept of operation. Individuals reporting high levels of workload, poor situational awareness and low user acceptance are likely also to report that their level of performance is being compromised and the probability of making errors is likely to increase. This also provides an indication that safety levels are also likely to be adversely impacted.

Recommendations made with regards the overall Safety findings are contained in Section 5.2.

Safety Findings: General

The data collected on the level of work, situation awareness and user confidence/acceptance all lead to the conclusion that the levels of safety will be no worse than current day operations and in fact imply that some aspects of safety within the TMA, may improve.

The use of Point Merge System was considered to improve controllers' ability to determine a safe and efficient tactical plan for flights that penetrate their area of responsibility. Feedback from participants stated that they considered they could work and communicate with other sector team members effectively when applying the Point Merge System.

Some further work needs to be undertaken to develop procedures; however participants all felt that they were clear about what their responsibilities were, whether they were working as an INT, FIN or TMA controller.

There were a few issues that were considered to have the potential to impact upon Safety and appropriate mitigations will have to be put in place to ensure that these do not adversely affect performance. These are discussed under the following headings.

Skills

The ability of controllers to recover effectively from situations in which aircraft have deviated from the P-RNAV routing, including the Point Merge System (e.g. due to weather avoidance) may reduce over time. Some controllers were concerned that, over time, their skills to vector aircraft while maintain optimum spacing may become less effective. In particular, if the airspace in which to vector has been reduced (due to the benefits of point merge) and the vectoring situations that occur are "difficult" in nature (which is likely as vectoring would typically only happen when there is a problem) there may be a significant increase in effort required to resolve the situation and maintain the 'picture'. This may ultimately have a negative impact upon safety. This effect may be further exacerbated by the observed increase in the number of aircraft on frequency – particularly for EGSS on Easterlies using the Point Merge system.

Furthermore, new staff who would not have the previous experience of providing this type of intervention may not have developed their vectoring skills and find it difficult to provide effective vectoring instructions. Ultimately this may result in some reduction in performance.
It is not possible to determine the level of risk associated with skills fade at this point because although during the simulation, when scenarios such as weather avoidance, aircraft emergencies etc were tested, controllers did apply their vectoring skills, their actions were similar to current day operations and therefore familiar and so considered safe.

Change to a monitoring role

Related to this, is the introduction that the Point Merge concept has on the role of controllers. Their role will become more passive and involve a greater about of monitoring with less proactive intervention. It is difficult for humans to maintain the same high levels of concentration and attention if monitoring for prolonged periods. A potential mitigation to this is due to the reduction in R/T workload, controllers should have more "thinking time" and thus more capacity to resolve any situations that may arise.

Several controllers did comment that the introduction of P-RNAV in the TMA increased the predictability of aircraft and reduce workload but made their job less interesting. The impact of these aspects will need to be monitored to ensure that levels of job satisfaction do not decrease.

Contingency Holding

It was felt that more contingency holding is required within the Point Merge Systems evaluated at EGGW, EGSS and EGLC. There should be sufficient capacity to hold aircraft up to the maximum number that may be in the Point Merge System at any one time. This was most noticeable for EGSS on Easterly operations. The extended P-RNAV transition after the EGSS Merge Point (NAILS) meant that the SS FIN controller reported 7-8 aircraft on frequency during a runway closure scenario compared to 4-5 under current day operations. The NAILS hold did not have sufficient capacity to handle these aircraft and the SS FIN controller was required to orbit and vector aircraft in the Point Merge System with high workload as a result.

Further, training for the use of Point Merge should emphasise the importance of 'triggers' that indicate when to start holding. The procedure notes for the simulation recommended controllers consider holding once aircraft begin to use approximately half of the sequencing leg. This should be emphasised. It was felt there will be a temptation to keep accepting aircraft onto the sequencing legs until it is too late. The point at which aircraft need to hold may be earlier than it intuitively feels to the controller given the reduced R/T usage and number and vectoring instructions.

Increased Reliance on Speed Control

Speed control becomes a key factor in separation assurance when using the Point Merge system. Airspeed non-conformance may lead to losses of separation on the P-RNAV transitions. Many controllers recommended that Mode-S IAS is displayed permanently on the third line of the TDB to identify such situations. Alternatively (or in addition), the Abnormal Indicated Airspeed Monitor (AIM) tool currently in development for Heathrow Approach could also provide mitigation against this risk. This tool alerts approach controllers, most notably FIN, to Mode-S down linked IAS values outside pre-defined ranges at different stages of the approach.

It was, however, also noted that some approach operations, such as EGLC, have a very diverse range of arrivals and therefore arrival speeds. The coverage of Mode-S equipped aircraft will also differ between European airfields.

Use of Min-Stack + 1 for silent release

During the November simulation the TC North controllers suggested that the silent release procedures should be modified to be at Min-Stack + 1. While the silent release procedure did reduce workload, TC North controllers felt they still had to monitor the aircraft onto the P-RNAV transition. For safety purposes, it was suggested that TC hand aircraft over at Min-Stack + 1 using this procedure. If an aircraft needs to return to the hold (or holds when it was assumed it would transition) then this is potentially unsafe if following aircraft are also being cleared onto the transition. The extra level would improve safety. The approach controller would then descend aircraft onto the sequencing leg in the Point Merge System.

574Obj_04_02: No new Safety Hazards added that cannot be mitigated

A full safety analysis of the P-RNAV implementation has been conducted and is contained in a separate report as an Appendix to the OSED [2]. The following are the scenarios embedded within the simulation that focused on safety related situations.

574V301: *Aircraft not stable at the required level/altitude prior to reaching the start of the sequencing leg (when other traffic is present on the sequencing legs).*

Examples were presented for London City and Stansted. In the example the subject a/c was given a slow rate of descent to the commencement of the sequencing leg in order to create the conditions required. The slow rate of descent was issued by the simulation team to the pseudo pilot without the controller's knowledge.

In both situations the controllers noticed the slow rate of descent and instructed the a/c to expedite its descent in order to achieve the required level. In one situation the controller queried the aircraft on its ability to achieve 7000ft at entry point to EGSS outer sequencing leg (SCREW), and this become unlikely the controller vectored the aircraft and in order to achieve the required level. The controller noted an increase in workload for the vectoring element of the situation.

In another situation the simulation team asked the pseudo pilot to ignore the expedite order to try and "force" the issue of the a/c not being stable at the required level prior to commencing the sequencing leg. In this situation the controller re-issued the order and the pilot complied.
In both situations the controllers were monitoring the entry conditions for the sequencing leg and provided the correct instructions to the pilots to ensure the scenario did not materialise.

574V302: *Wrong aircraft turns to the Merge Point from the sequencing leg when the 'direct-to' instruction is given.*

Examples were presented for London City, Stansted and Luton. In total, five examples of this scenario were evaluated. Where possible a/c of similar callsign were turned at the same time, simulating a callsign confusion. Where this occurred the intended a/c was left to continue as required, whereas the "confused" aircraft was vectored, usually within the RMA, or was noticed early enough to be instructed to cancel its turn and continue as normal. Where vectoring was required then controllers stated this increased the workload as would be expected. No significant safety issues were raised by the controllers as most noticed the wrong a/c turning early enough to stop the situation developing. Where the a/c was vectored, it was then placed back into the sequence when possible. A issue that was raised, and continued throughout the simulation period was the concern that the lack of vectoring that PMS would introduce may make situations such as this, where vectoring is required, more of an training/ familiarity issue, and hence may have safety connotations.

574V303: *Aircraft turns the wrong direction off the sequencing leg when the 'direct-to' instruction is given.*

Examples were presented for London City and Stansted. In total, two examples of this scenario were evaluated. In both situations the controller noticed the a/c turning the wrong direction. In one situation the controller let the aircraft make the turn and then vectored to allow a trail aircraft to take its place in the sequence.

574V304: *Aircraft does not turn off the sequencing leg when required, (e.g. pilot doesn't hear the 'direct to' instruction or doesn't realise who it is for).*

Examples were presented for all three airports, London City, Stansted and Luton. In total, three examples of this scenario were evaluated. The lack of response from the pilot to the turn request was dealt with as an R/T failure unless the pilot then responded to the turn at a later point in time. With the lack of response meaning the controllers were working to an R/T failure, then allocation of a/c onto the PMS had already been tailored to suit the evolving situation. The simulation team asked the pseudo pilots to ignore at least the first two requests to turn, but then informed them to act on any future request. In the situations seen, this delayed the turn by only a limited amount but may have added additional workload due to the R/T requests by the controller and the increase in monitoring required on a non-responsive a/c. A lack of traffic within the PMS meant this was managed comfortably by the controllers.

574V305: *Horizontal separation not maintained on the sequencing leg.*

Numerous examples of this scenario were attempted but the controllers mitigated against the start conditions, i.e. the horizontal separation distance was maintained. Therefore this scenario was removed from the simulation as it was not believed it could be created with any degree of realism. Reference is also made to scenarios 574V302, 574V303, 574V304, 574V315 and 574V318 which may also result in horizontal separation not being maintained on the sequencing leg.

574V306: *Aircraft does not apply the required speed constraint while on the sequencing leg.*

Examples were presented for two airports, London City and Stansted. In total, three examples of this scenario were evaluated.

This scenario was used to raise an important issue relating to the display on the TDB of the IAS. There was a consensus that IAS should be displayed on the TDB at all times when using Point Merge. The controllers believe speed plays a much greater role in maintaining separation using Point Merge, and non-conformance to airspeed will cause problems. The controllers therefore believe they should have IAS displayed to detect any potential speed non-conformance. This was reiterated by one scenario where TMS did not have IAS displayed and did not notice the CFE36F had increased its speed from 180kt to 220kt on sequencing leg without instruction. This resulted in the controllers stating a high workload was experienced and eventually the aircraft being place in the hold while the overall situation was resolved.

Because of this stance, and the experiences of the TMS controller mentioned above, the controllers then picked up on the non-conformance speed issue very quickly and corrected it. For those controllers that don't use a displayed IAS in current operations today, both said they would turn it on when using Point Merge.

574V307: *Arrivals aircraft non-conformance to specified route profile, (e.g. due to single aircraft equipment failure (both P-RNAV and non-PRAV), GNSS signal corruption etc.)*

The scenario was evaluated once with Stansted. The aircraft reported a P-RNAV failure following turn-to-merge instruction. The controller devised a plan for the P-RNAV failure early and vectored the aircraft accordingly. No safety concerns were raised by the controllers.

574V308: *When reaching the end of a sequencing leg without receiving a turn to merge instruction, the pilot will turn to the merge point via a fly-by waypoint and request clearance to descend to the Merge Point.*

Three examples of this scenario were evaluated, concentrating on London City and Luton. This proved difficult to simulate as the controllers rarely let the a/c reach the end of the sequencing leg. In order to force this issue, the INT controllers were asked to "load" the sequencing legs in order to increase the workload on the FIN to try and engineer the situation to occur. This unrealistic workload increase on the FIN meant they tended to vector a/c within the RMA or PMS, or hold a/c at selected points. In one situation an aircraft reached the end of the outer sequencing leg (CARPE) and turned to the merge point on its own accord. The controller identified that this had happened, and descended the aircraft. This aircraft was then vectored heavily around the PMS. There was holding at the EGLC Merge Point (TIDLA) at the same time, due to the traffic loading in the exercise.

574V309: *The controller cannot give clearance to descend without breaching separation so he looks at the option of vectoring aircraft within the PMS.*

A single example of this scenario was evaluated on Stansted. The situation was such that the RYR was at 10,000ft and EZY at 9,000ft just behind on the same arc. The RYR turned to merge, so the EZY was turned and vectored due to potential conflict. The RYR didn't make the level for the merge point and then needed vectoring as well. As a knock on effect, RYR8747 and EXS12BP also needed vectoring (by INT, not FIN) prior to handing over. The situation was stated as "difficult" but with four aircraft needing vectoring in total. However the FIN felt this situation was still easier than stacks and open vectoring.

574V310: *P-RNAV equipage failure - aircrew notify ATC, follow route as per unequipped (BRNAV capable) if able, else radar vectors.*

Five examples of this scenario were evaluated over all three airports, London City, Luton and Stansted. In all situations a/c were placed on headings and dealt with using vectoring. No issues were raised as the vectoring was similar to present day operations. However, controllers mentioned that the scenario works better when longer P-RNAV legs exist after the merge point (as more vectors for the controller to issue), therefore worked better with GW on westerlies.

574V311: *Level bust on sequencing leg.*

Two examples of this scenario were evaluated on Stansted and London City. For one situation, this caused no major issue to the controller. For the other, the RYR5997 busts its level coming into the IAF feeding the EGSS inner sequencing leg (SHELF); it descends to 8,000ft rather than 9,000ft as cleared. This makes it a dead-ringer with EZY71ZS coming towards SHELF from the north. The controller picked up when RYR5597 was at 083, and took immediate avoiding action. This required a lot of vectoring. The controller commented that this would be similar to what would be required in current operations with the same scenario. The reversion to vectoring was not a problem, though controllers comment this possibly will become more of an issue with continued PMS usage and potential skills fade. The controller said they experienced high workload to recover the situation, and the after effects rippled through, lasting until the end of the run.

Where controllers believe the PMS may have a safety concern was in the fact that if vectoring skills degrade over time with the use of PMS, then the ability to rapidly react to a situation like this, with vectoring, and be able to recover in an acceptable level of time would become an issue. The safety issue is therefore related to the degradation of skills more than the actual scenario being evaluated.

574V312: *On long P-RNAV leg longitudinal spacing has been eroded - Approach controller uses speed control to manage spacing.*

This was evaluated twice on Luton. In both instances the ability to erode the longitudinal spacing was limited by the controllers having the IAS displayed on the TDB. When a speed instruction was given by the simulation team to the pseudo pilots to decrease the lead a/c IAS to 160kts and increase the trail to 270kts (to generate the eroded spacing), then the controllers saw this immediately and re-issued the required speed instructions. This re-iterated the common agreement that IAS should always be displayed on the TBD when using PMS.

574V313: *Non P-RNAV equipped, but BRNAV capable a/c, controller treats as P-RNAV*

The simulation team, after discussion with the controllers agreed that this scenario would not be evaluated as there was no P-RNAV indicator on the strip.

574V314: *Aircraft descends too early after receiving the 'turn to merge' instruction (i.e. descend instruction has not yet been issued by pilot descends anyway without the Controller expecting it).*

This scenario was evaluated three times on Luton and Stansted. On Stansted the controller had believed they had in fact issued the descent order (when they had not) as once the turn order is issued, the descent order usually follows within a few seconds. The aircraft in question was descended by the pseudo pilot on the request of the simulation team. As the controller was about to perform the same action anyway, the controller let the situation develop without questioning the pilot (as they believed they had issued the order).

On Luton the controller identified quickly the descending aircraft, the EZY1RS (from West) which drops to 8,000ft (from 11,000ft) when given turn instruction off the sequencing leg. This would conflict with the EZY2164 at 10,000ft on the opposite sequencing leg. The Luton controller identifies the situation early, before the aircraft came into conflict. He allows the EZY1RS to continue descent and then turns other EZY behind.

574V315: *Aircraft merges to the incorrect waypoint (i.e. pilot sets the incorrect waypoint instead of the PMS designated Merge Point)*

This was evaluated five times over all three of the airports in question. The controllers quickly realised the a/c in question was not heading to the PMS merge point and where possible let the situation develop if the incorrect merge point would be on the route anyway, once they had questioned the pilot over their intended routing. Controllers didn't comment on any safety related issues with this, they just dealt with the situation as required, i.e. let it develop in a managed way, or re-issued the merge order.

574V316: *Aircraft does not meet the required vertical profile after leaving the sequencing leg leading to potential conflict with other aircraft.*

This was evaluated once on Luton. The EZY11HP was climbing slowly out of GW. The QGA was descending slowly into GW. The routes were such that the aircraft will interact if left. The simulation team also requested the pseudo pilot to input a low descent rate for the QGA after leaving the sequencing leg causing the conflict with the EZY. In this case the controller spotted the issue early and put both aircraft on headings but felt this was managed comfortably with only a slight increase in workload. There were no safety issues raised.

574V317: *Departures aircraft non-conformance to specified route profile, (e.g. due to single aircraft equipment failure (both P-RNAV and non-PRAV), GNSS signal corruption etc.)*

The scenario was focused on TC NE Sector and was evaluated twice. In one situation the Luton departure was going NE and the simulation team allowed the aircraft to run for 15nm then turned it hard left. The aircraft stopped its climb at 6,000ft but reads back 9,000ft to conflict with inbound RYR2613. The controller spots that aircraft has levelled in the climb, and so issues a continue climb order to avoid any issues. Other than the non-compliance the controllers did not mention any other safety related issues.

574V318: *A BRNAV aircraft flying the sequencing arc flies a shorter route due to fewer waypoints being stored in the FMS and catches up with a P-RNAV aircraft flying the true arc.*

This scenario was evaluated three times using Stansted and London City. The simulation team instructed the pseudo pilots to fly a shorter route on the arc by missing a number of waypoints from the route. This was achieved but with little or no safety or workload related comments from the controllers. Where a possible catch was envisaged, the controller place the subject aircraft on a heading, otherwise the already established spacing on the sequencing leg ensured the catch-up would not impact the desired separation needed.

574V319: *An aircraft reaches the end of the sequencing leg and routes toward the merge point, but does not descend. This could put the aircraft in conflict with other aircraft in the contingency hold situated at / near Merge Point at the same level.*

This scenario was discussed with the simulation team and controllers. All agreed that this scenario would not be evaluated. The GS safety notes indicate that controllers would not route aircraft level from the end of the sequencing leg with the contingency stack full, therefore the scenario was not evaluated.

574V320: *Following pilot's request Missed Approach Procedure (MAP) is followed, the PMS is fully loaded and Approach requests the controller responsible for loading the sequencing leg to make a gap to allow re-insertion of aircraft into traffic flow.*
A "Missed Approach" was generated for this activity and covered both this scenario and 574V321 below.

574V321: *Gap is created in traffic flow; MAP aircraft is instructed to hold at pre-defined waypoint on the MAP while waiting for gap to form*
The missed approach in the baseline was described as standard by the controllers, with no issues with dealing with the situation. In the PMS exercise, the aircraft arrived slightly later than in baseline which had no impact on the comparison. The standard missed approach occurred at 17:43. The aircraft was vectored left. The controller then vectored other aircraft to make space for the EXS to re-sequence and land. There was no need to hold. While vectoring was required, the SS controller felt they had more capacity to work due to less vectoring than in the baseline. The controllers believed this helped when dealing with the missed approaches. In the PMS the controllers stated that there was no need for the aircraft to hold at the pre-defined waypoint, and that standard speeds were issued to maintain separation on final.

574V322: *Aircraft is released from temporary hold in order to commence another approach - speed control used to ensure separation is maintained.*
No data for this Scenario was gathered.

574V323: *Loss of surveillance (single radar)*
The INT Radar screen for Luton was failed by the simulation team to simulate a Loss of Surveillance, single radar. The INT position moves to the FIN position in both baseline and point merge with limited response from the controllers about safety or workload related concerns. The GW INT mentioned they would inform Stansted of the failure given their workstations are on the same hardware, just in case the failure spreads.

574V324: *The TMA controller looks at options to expedite emergency flight and where to integrate flight into sequence.*
An "Emergency Flight" scenario was evaluated which incorporated 574V324, 574V325, and 574V326.

This scenario was evaluated on Stansted. In the baseline the emergency flight, RYR8747 was at a waypoint on an EGSS STAR (BPK) and declared smoke in the cockpit and descending to SS. TC N requested a co-ordinator (role fulfilled by an ATCO who was not actively working a radar position at that time in the simulation) who discussed the plan with SS FIN. The aircraft was turned left to lose height, then given to Stansted on 04. Stansted made room on final and the aircraft landed.

In the PMS equivalent, the RYR reports smoke in the cockpit to TC NE. TC NE controller probably did more with the aircraft than needed, and the TC co-ordinator felt it should have been passed to Stansted earlier. The emergency aircraft was vectored directly onto approach, not necessarily towards the merge point. The gap in the sequence was created by vectoring rather than use of the sequencing legs (the gap would not be soon enough if it was created on the sequencing legs - in this scenario at least).

For the PMS, Stansted had more aircraft off the holds compared to baseline, which is a consequence of the system, holds further out and the extended 'trombone' on Easterlies. Stansted commented that they had 4-5 aircraft on frequency today compared to 7-8 under PMS. The SS FIN broke aircraft off that were past the merge point and vectored these to fit the emergency in. Stansted required aircraft to orbit in the PMS which raised the workload level over that in the baseline

574V325: *Handling emergency flight. TMA controller hands over to approach early to enable Approach to provide 'direct to' clearance to the merge point. The approach controller alleviates traffic pressure on the point merge system by moving flights into the holding stack.*
An "Emergency Flight" scenario was evaluated which incorporated 574V324, 574V325, and 574V326 and is therefore included in the previous description.

574V326: *Handling emergency flight. The Approach controller uses speed control and lateral holding capacity of the sequencing legs to create a gap in the sequence for the emergency aircraft.*

An “Emergency Flight” scenario was evaluated which incorporated 574V324, 574V325, and 574V326 and is therefore included in the description under 574V324.

***574V327:** Requirement to rearrange traffic due to poor sequencing (according to their wake vortex separation) by TMA controllers (High ATCO workload).*

This covered all sectors. The feed controllers were requested not to stream traffic and re-sequence for approach. In both baseline and PMS the participants commented that this had no effect, and there were no comments in the debrief that traffic presentation caused any problems.

***574V328:** Strong cross wind on PMS causing tail wind on one of the sequencing legs; approach controller compensates by using adapted speed instructions and/or increased longitudinal separation.*

No data for this Scenario was gathered.

***574V329:** Approach controller takes account of wind effect when instructing 'direct to' due to differing wind effects/speed controls on the two sequencing legs.*

No data for this Scenario was gathered.

***574V330:** Category B flights (SAR etc) over GW*

This scenario was modified to a CAT B flight that influence TMS and not GW as GW was bandboxed at the time of the scenario and therefore not suitable to use as an example.

Note, this scenario affects a different controller when compared to the baseline as TMS operates differently in PMS compared to Current Day, i.e. CAT B in current day Westerlies with second controller acting more as a co-ordinator.

In the baseline, TMS dropped aircraft below the CAT B to 2,000ft (outside controlled airspace) to avoid having to stop the approaches. There was some simulation effect here, as it is probable that airlines would not accept this in reality. Also aircraft were held out at LOGAN.

In the PMS variant, having holds at TMS was stated as improving the situation compared to current day baseline. However, Thames resulted in slightly higher levels of workload and a slight reduction in situation awareness being recorded with this situation with PMS organisation. It is possible that this is due to the different way Thames operates in the PMS configuration, and the set of P-RNAV route structures

Reference is also made to 574V338 which simulated the impact of CAT B flights at EGSS.

***574V331:** Temporary runway closure, controller actions as per MOps - aircraft already on PMS and have been given clearance to descend to merge will be instructed to level off at a unique flight level/altitude and then hold in a stack at the merge point.*

A “runway closure” scenario was evaluated that included this situation and 574V331, 574V332, and 574V333. See below for the details.

***574V332:** Runway re-opens - aircraft in temporary stacks cleared starting with the hold at the merge point (descending aircraft through the levels in the stack) - MOps.*

A “runway closure” scenario was evaluated that included this situation and 574V331, 574V332, and 574V333. See below for the details.

In the baseline SS has to deal with GW aircraft at the combined EGSS/EGGW hold point (LOREL), hence significant R/T was observed. With approx 4 a/c off the stack there were still problems finding where to put them, so they were vectored at 3,000ft around the RMA. SS FIN ran out of space on strips, which were full of instructions and need replacements. The situation was managed, but SS would have needed a Support (SPT) controller (which was not required on PMS exercise). The joint GW + SS hold means SS workload higher from the start.

In the PMS where possible aircraft returned to the two holds, if not then orbited in the PMS or holding at the EGSS Merge Point (NAILS). SS INT keeps aircraft in holds and reported an approx 20 mins delay. FIN gave some aircraft back to INT if feasible. Both SS FIN and SS INT experience a perceived high workload.

In this situation INT had around 6-7 aircraft on frequency. The controller felt that some 'system' is required (at SS, potentially confined to Easterlies). Suggested a 'merry go-round' (for want of a better description), downstream of the Point Merge System, where aircraft orbit in a circuit at 6,000ft. This would have multiple aircraft at same level, but orbiting on a large pattern so separated. The controllers felt the situation as simulated not totally satisfactory as westerly would have been better as less aircraft off the hold and in the PMS. Holding at NAILS may be sufficient but there were too many aircraft to do this on easterly.

***574V333:** Normal operations resume, following runway closure.*

The Runway Closure scenario was evaluated as mentioned above. There were no issues mentioned in regards to returning back to normal operations that differed between present day and when using the PMS.

***574V334:** Thunderstorm directly affecting P-RNAV route - controller instructs flights to follow transition that avoids the weather pattern, if not possible, radar headings given to avoid affected area.*

The results from this scenario are included jointly with 574V335 below.

***574V335:** In the event of thunderstorms directly affecting P-RNAV routes controllers will revert to radar headings to avoid affected area, stacks used to control flow of traffic.*

A general thunderstorm influencing scenario was evaluated as it was difficult to split this scenario and the previous.

In the baseline the scenario was generated as such: The CB activity started west of EGGW (at CLIPY) moving East, FL140 and below. At 17:30 it begins to impact GW. At 17:36 aircraft are unable to continue the approach at GW. The airport re-opened at 17:52. The QNH was initially changed to 985, but simulator fault meant this had a detrimental effect on Mode-S SFL. In this situation the CB affected SS more, as they manage the hold for GW.

The controllers mentioned that the scenario wasn't totally realistic, but as realistic as possible for the simulation. The pilot responses were also very difficult to simulate. The biggest impact at GW / SS was the high workload and a lot of vectoring with the runway closure and the need to split the sector. Knock-on impact on SS as they had to hold aircraft at the combined EGSS/EGGW hold point (LOREL).

In PMS, the same CB activity was moving slightly faster to interact sooner. The CB activity caused significant issues at GW, aircraft unable to continue the approach and runway effectively closed. Aircraft were holding at 3/4,000ft south of the airfield. The CB was over the EGSS Merge Point (NAILS) by 17:43, requiring a lot of aircraft in the hold at the IAF feeding the EGGW inner sequencing leg (BRACK).

In PMS this impacted SS less than in baseline as they were not having to deal with the disruption at GW as well. Where possible they were holding at the merge point and inside the RMA, but there was not enough space for the number of aircraft that may be off in the PMS. The controller felt it was not realistic for GW, as aircraft would not hold indefinitely at 3/4,000ft - they would find or look for a way round.

The GW controllers, both new to the concept, felt that there was too much distance on the P-RNAV tracks with 9-10 aircraft in the system and outbounds going through a lot of airspace. GW INT had to dial radar range out due to distance from holds to runway. SS / GW suggest the need for more contingency holding. With additional distance there are more aircraft to deal with in unusual circumstances which was a key result. With this in mind, for GW especially this resulted in a considerable reduction in levels of situation awareness and higher workload for both Luton and Stansted controllers when operating in PMS configuration. This was attributed to the significant amount of vectoring required and the distance of P-RNAV tracks.

***574V336:** Loss of dedicated airborne hold*

No data for this Scenario was gathered.

***574V337:** To compensate for strong wind conditions the TMA controller exercises speed controls to increase longitudinal separation between traffic on STAR*

Strong winds were introduced into the scenarios being evaluated with no significant issues reported by the controllers in either configuration for any aspect of the flight profile.

574V338: *Total loss of R/T - fallback mode*
This scenario was not evaluated in the simulation.

574V339: *Single aircraft R/T failure (squawk 7600, aircraft to follow STAR, then maximum transition along point merge sequencing leg via flyby waypoint, descend to Merge Point then FAF to intercept localiser.*
This was evaluated to influence all three airports, with GW taken as an example here. In the baseline this scenario was difficult under current day operations. The GW controller said they had never seen an aircraft fly the published procedure which did not assist in the scenario. The procedure would be the aircraft squawks 7600, flies 3mins on current heading and turn toward a waypoint at the start of an EGGW SID (LUT). This had a knock-on workload effect on SS due to having to holding GW inbounds.
In PMS, the controller held the other aircraft behind the failed aircraft. This allowed aircraft back onto the PMS after it became clear what the R/T fail aircraft was doing (one orbit in hold, fly full P-RNAV transition and descend on own accord). The controller commented that they were a little unclear of the procedures, but it was more systemised than today which helped. They also commented that an R/T fail on the arc would be more difficult (as aircraft already committed to the P-RNAV approach in a sequence).

574V340: *Change of runway direction, (e.g. causing potential conflict between arrivals and departures that have already left the runway, or Pilot takes incorrect transition after merge point)*
The scenario was evaluated on all three airports, but not in a comparative manner, i.e. there was no baseline.

In all cases, the aircraft cleared onto the P-RNAV transition were vectored for the new runway, in particular those past the merge point and therefore on the wrong transition for the change in runway. Those prior to merge were generally vectored, and also instructed of the new runway so as to update their FMS.

A scenario where aircraft have not updated FMS was discussed. For W to E change SS and LC have a similar set-up, where aircraft continuing on the 'old' transition will be heading towards departures. However, the feeling was that all aircraft were informed and, in general aircraft in the PMS at the time of the change were vectored anyway. It was noted that the procedures are still in development. The TMS controller identified one aircraft that appeared to have remained on a 27 transition (due wider turn at the EGLC Merge point (TIDLA)), so there was an awareness of this issue.

The general feeling amongst the controllers was the scenario went smoothly with no issues. The controllers felt as good, if not better, than current day operations. The SS controller said aircraft often confuse a change of runway in current day operations (they call to clarify the new runway 10mins after it has changed). GW didn't need to co-ordinate with SS, which would have to happen today.

574V341: *Category B flights (SAR etc) over SS*
In the baseline, the CAT B Flight was created from a Ryanair as one was not present in the baseline traffic sample. The aircraft flew to BCY, not NAILS (as NAILS does not exist in the baseline) which interrupted the vectoring area. The controllers commented that the workload very high on Stansted, with SS INT being particularly badly affected. The controllers noted that in reality they would have had all positions open, and it would still have been extremely busy. Additionally a co-ordinator would be required for the CAT B and departures.

In the PMS exercise, the CAT B Flight departed EGWU and was directed towards NAILS. The aircraft holds at 6,000ft (in the way of merging traffic) then climbed to 8,000ft. SS FIN kept the other aircraft over the CAT B when it was at NAILS initially, then under when it climbed. The PMS was able to continue during the scenario with no need to vector or hold aircraft. This differed significantly in terms of perceived workload between baseline and PMS. The controller felt that PMS allowed more time to deal with the CAT B flight, more aircraft were passively proceeding along the route. There was less vectoring of the other aircraft in the PMS, and this meant more time to deal with CAT B. Filling up the arc didn't increase the workload comparatively, giving the spare capacity to deal with CAT B.

574Obj_06: - Assess the impact to Hold Occupancy & Flight Levels

574Obj_06_01: Hold Occupancy & Levels are maintained at Current Day levels or reduced for the TMA as a whole

The average amount of holding (in minutes) for the TMA as a whole reduced by 57% between the Baseline and Point Merge exercises. However, the following caveats needs to be considered when interpreting this statistic:

- This includes all inner and outer holding. The outer holds were maintained by feed sectors, some of which were not staffed by operational controllers and were typically under-staffed for the given traffic levels.
- In some exercises the level of outer holding was excessive and would not have occurred in operations. The feed sectors would have been fully staffed and flow control would have been applied; in particular during the highly disruptive scenarios (thunderstorm activity for example).
- The P-RNAV procedures introduced three new inner holds to the TMA. It is likely these holds were utilised in the P-RNAV exercises to reduce the level of outer holding in the TMA. In particular, a point of EGLC merging STARs (SPEAR) was heavily utilised for EGLC arrivals in the baseline exercises but not at all in the P-RNAV exercises.
- Time spent on Point Merge sequencing leg could not be accurately determined and so were not captured.

A direct comparison of the level of holding at the inner holds will therefore not be totally representative, as the complete picture across the TMA needs to be considered. However, given the staffing and unrealistic traffic situations the level of outer holding is also not representative of the true effect to operations. The following figures are the cumulative output of scenarios with metered and unmetered inbound traffic. For scenarios with unmetered inbound traffic, the feed and TMA sectors used the outer holds to meter the traffic flow to the Approach sectors.

	Baseline	P-RNAV	Change
Grand Total	241	103	-57%

Table 33: Average total TMA (GW, LC, SS) holding in minutes

The following table therefore presents the average TMA holding (inner and outer) excluding highly disruptive exercises. This removes two exercises for EGSS (thunderstorm activity and runway closure) and one exercise for EGGW (thunderstorm activity). Overall this is based on 169 aircraft holding during the eight Baseline exercises compared to 126 aircraft holding during the eight P-RNAV exercises.

	Baseline	P-RNAV	Change
TOTAL	108	63	-42%

Table 34: Average total TMA (GW, LC, SS) holding in minutes excluding disruptive exercises

Further, the breakdown between time spent in the inner[6] holds and outer TMA holds changed at the LTMA level. The proportion of holding time spent in the outer holds reduced from 70% in the Baseline exercises to 4% in the P-RNAV exercises with the same traffic samples. While there is a degree of simulation effect in the large outer holding times (in particular at SPEAR for EGLC) this indicates that the P-RNAV system may be able to reduce the more disruptive outer holds are used operationally.

	Baseline		P-RNAV	
	Outer	Inner	Outer	Inner
TOTAL	76	32	2	60
% Outer / Inner	70%	30%	4%	96%

Table 35: Split of Inner vs Outer holding for TMA (GW, LC, SS) excluding disruptive exercises

[6] LOREL and ABBOT for Baseline; BRACK, GRAVE, WHITS, ROACH, DEBAK, SHELF for P-RNAV. See Appendix C for airspace details.

The holding times presented above do not include time spent on the Point Merge sequencing legs. The NATS RTSA metrics were not able to accurately process this information. The large reduction of 42% in average hold time should therefore be considered in light of this limitation.

574Obj_06_02: Hold Occupancy & Levels are maintained at Current Day levels or reduced for each individual Approach operation

The average holding by airfield (excluding highly disruptive exercises) is presented in Table 36 below. As can be seen this is driven by a large increase at EGGW partially offset by a decrease at EGLC.

	Baseline	P-RNAV	Difference
EGGW	17	27	56%
EGLC	57	19	-66%
EGSS	34	17	-50%

Table 36: Average holding in minutes excluding disruptive exercises

The split of inner versus outer holding demonstrates a similar patter to the overall LTMA results. The proportion of holding time spent in the outer holds decreases for all airfields under the P-RNAV scenario.

	Baseline		P-RNAV	
	Outer	Inner	Outer	Inner
EGGW	20%	80%	0%	100%
EGLC	100%	0%	6%	94%
EGSS	45%	55%	7%	93%

Table 37: Split of Inner vs Outer holding by airfield excluding disruptive exercises

574Obj_07: - Assess the impact to Fuel Burn / CO2 Emissions

574Obj_07_01: Net benefit per flight to Fuel Burn / CO_2 Emissions for the TMA as a whole

Across the TMA as a whole the exercises recorded a decrease in average Fuel Burn of 2% for the P-RNAV design compared to the baseline exercises. All landing arrivals and all departures to and from EGLC, EGSS and EGGW have been included in this analysis. This is with the exception of aircraft excluded during a pre-processing stage due to performance bound checks. 198 aircraft were excluded from 772 aircraft in total giving a total sample size of 574. On the advice of the NATS Environment and Airspace Simulation team these aircraft have remained excluded from the analysis.

The average fuel burn for arrivals was found to increase overall but was offset by a greater decrease in the fuel burn for departures. Controllers, especially at EGGW, commented that they felt inbound aircraft were flying slightly further during P-RNAV exercises which will have contributed to the increase. However, the increased systemisation for arrivals has provided a less restricted climb profile for departures resulting in a net benefit to fuel burn for the TMA as a whole.

	Baseline	P-RNAV	Change
Inbound	583	614	5%
Outbound	945	878	-7%
Combined	1527	1492	-2%

Table 38: Average fuel burn (kg) per landing aircraft (EGLC, EGSS, EGGW)

574Obj_07_02: Net benefit per flight to Fuel Burn / CO_2 Emissions for each Airfield Approach + Departure operation

The results by airfield are largely consistent with the fuel burn results overall. The benefits at EGGW are again marginally less than at the other two airfields, showing a negligible increase overall. This small increase of 0.4% is not considered as sufficiently strong evidence to fail the validation objective for EGGW.

Airfield	Baseline	P-RNAV	% Change
EGGW	552	598	8%
EGLC	412	435	6%
EGSS	781	831	6%

Table 39: Average fuel burn (kg) per Inbound aircraft by airfield

Airfield	Baseline	P-RNAV	% Change
EGGW	1,016	977	-4%
EGLC	513	452	-12%
EGSS	1,225	1,150	-6%

Table 40: Average fuel burn (kg) per Outbound aircraft by airfield

Airfield	Baseline	P-RNAV	% Change
EGGW	1,568	1,575	0.4%
EGLC	924	887	-4.1%
EGSS	2,006	1,982	-1.2%

Table 41: Average combined (Inbound + Outbound) fuel burn (kg) per aircraft

Finally, an analysis of the track distance flown for inbound and outbound aircraft supports the views that the unrestricted climb of departures has contributed most to the overall fuel burn. Overall the total track distance increased slightly by 4% in the P-RNAV exercises.

EGGW controllers typically found that they used the Point Merge System less than other approach positions. The traffic did not always necessitate use of the sequencing legs, despite being grown to 2015 levels. Airspace constraints, principally from the incorporation of two Point Merge systems (EGGW and EGSS) in closer proximity meant that the distance from the holds to touchdown was large, with almost 30Nm to fly after the EGGW Merge Point (SHUVL). As a result aircraft were frequently vectored off the Point Merge System, or given Direct-To <waypoint> clearances, during the system to reduce the distance to run. One EGGW controller noted they would prefer the Point Merge System either ‘smaller, lower and closer’ or ‘bigger, higher and further away’ from touchdown.
Radar track plots are

A method was developed whereby aircraft were sent direct to point downstream of the Merge Point (GW5), rather than SHUVL and the use the P-RNAV transition more as a ‘trombone’ to refine the spacing. This approach offered aircraft (from the North / West especially) less distance to run on final but still made use of the P-RNAV capabilities.

While there is a trade-off between flexibility and systemisation, a recommendation from this analysis is to investigate whether it is possible to introduce further flexibility into the Point Merge designs for arrivals without compromising the clear benefits of increased systemisation for the departures.

	Baseline	P-RNAV	Change
Inbound	313	351	12%
Outbound	247	230	-7%
Combined	560	581	4%

Table 42: Average track distance (km) for the TMA overall

574Obj_08 - Assess the impact of Noise pollution to the local Environment

574Obj_08_01 - Noise pollution is maintained at Current Day levels or reduced for each Airfield Approach + Departure operation

The noise assessment was undertaken using the Integrated Noise Model (INM).

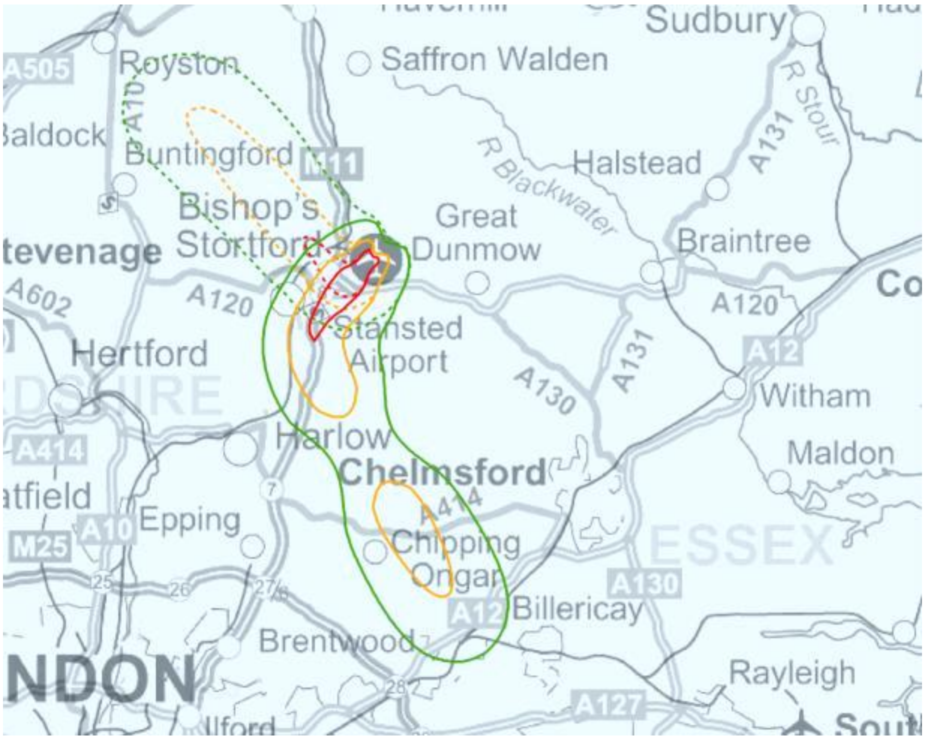
1. A maximum of 6 aircraft types were chosen to model during the assessment. The aircraft types cover the range expected to be using the airspace at the proposed implementation date and based on the aircraft types used in the RTS. All aircraft types not directly modelled were grouped to one of the modelled types based on aircraft size, aircraft weight and propulsion type.

2. Output track data from the RTS was used to calculate the average track flown for each procedure affected by the proposed changes.
3. Output radar data from the RTS was used to calculate the average vertical profile flown for each aircraft and each procedure affected by the proposed changes. INM has a number of standard vertical profiles for each aircraft type and these were used where possible. Other profiles have been user input to model the effect of holding in the arrival phase, for example.
4. The number of each aircraft type using each procedure were based on the output from the RTS and scaled to the required time period as appropriate
5. Terrain information was taken from the Ordnance Survey data supplied on their website.
6. Noise estimates for each aircraft type modelled was calculated using the in-built noise database in the INM tool.

The INM results were passed to P16.06.03 for impact assessment. This assessment is provided in a separate report: 'Point Merge Noise Analysis – P5.7.4' [3]. It is the conclusion of P16.06.03 that there is no significant noise benefit for arrivals. Some benefits are noted in the case of some departures due to the fact that by introducing Point Merge Systems in these cases has led to removing constraining level segments on departure.

It is therefore concluded that noise pollution is at least maintained at current day levels for each airfield and that this validation objective is met.

Three examples are presented below to illustrate the most significant changes in noise impact of the P-RNAV implementation per airfield. These are all observed for departing aircraft. The de-confliction of departure and arrival routes enables a greater overall benefit to the noise footprints for departing aircraft. A less restricted climb phase typically allows for a reduced noise footprint. However, as well as an overall reduction it is also important to note that the location of the footprints has, in some cases, also changed.

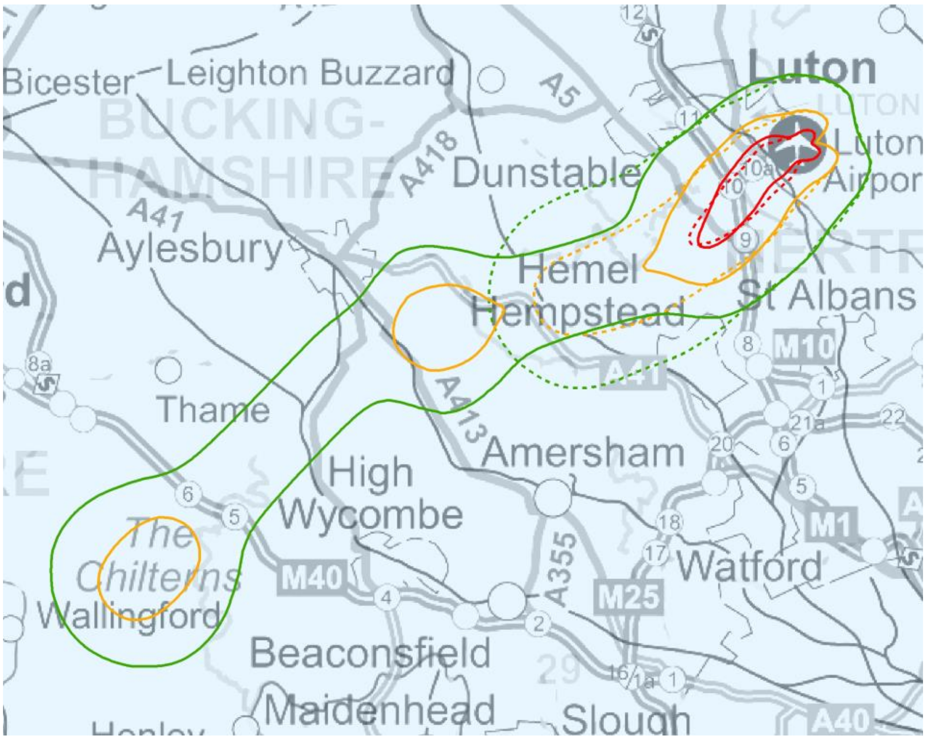


Contour	Area (km^2)
Curr 60db	268.4
Curr 70db	81.0
Curr 80db	11.9
PM 60db	212.4
PM 70db	74.0
PM 80db	11.3

Current Procedure
SEL 60db
SEL 70db
SEL 80db

Point Merge Procedure
SEL 60db
SEL 70db
SEL 80db

Figure 2: Stansted A319 Departure South 22

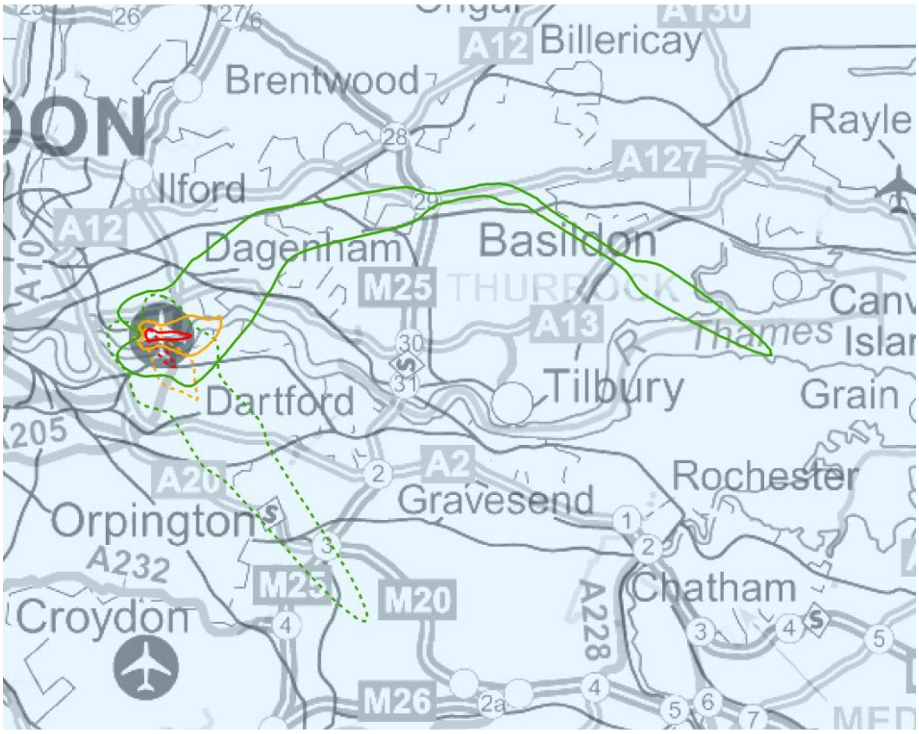


Contour	Area (km²)
Curr 60db	534.0
Curr 70db	141.8
Curr 80db	24.1
PM 60db	302.8
PM 70db	128.7
PM 80db	24.2

Current Procedure
- SEL 60db
- SEL 70db
- SEL 80db

Point Merge Procedure
- SEL 60db
- SEL 70db
- SEL 80db

Figure 3: Luton B738 Departure South-West 26



Contour	Area (km²)
Curr 60db	102.3
Curr 70db	8.1
Curr 80db	1.2
PM 60db	76.8
PM 70db	7.9
PM 80db	1.2

Current Procedure
- SEL 60db
- SEL 70db
- SEL 80db

Point Merge Procedure
- SEL 60db
- SEL 70db
- SEL 80db

Figure 4: London City F50 Departure South 09

A summary of the noise modelling outputs by arrival / departure and aircraft type is presented in **Table 43** to **Table 45** below for each airfield.

STANSTED	Current Footprint Size (sq/km)			P-RNAV Footprint Size (sq/km)		
Procedure	60db	70db	80db	60db	70db	80db
A319 Arrival 04	175	47	8	176	47	8
A319 Arrival 22	176	47	8	176	47	8
B738 Arrival 04	226	70	15	221	69	15
B738 Arrival 22	225	70	15	222	69	15
CRJ9 Arrival 04	148	43	6	148	43	6
CRJ9 Arrival 22	148	43	6	147	43	6
DH8D Arrival 04	67	9	1	64	8	1
DH8D Arrival 22	66	9	1	67	8	1
A319 Departure East 04	216	75	12	218	75	12
A319 Departure East 22	213	75	12	213	74	12
A319 Departure South 04	263	81	12	213	74	12
A319 Departure South 22	268	81	12	212	74	11
A319 Departure North-West 04	262	81	12	214	74	12
A319 Departure North-West 22	261	81	12	214	74	11
B738 Departure East 04	403	167	29	438	167	29
B738 Departure East 22	394	167	30	424	162	30
B738 Departure South 04	408	170	29	334	145	28
B738 Departure South 22	417	172	29	332	144	28
B738 Departure North-West 04	431	174	29	337	145	28
B738 Departure North-West 22	425	175	29	335	144	28

Table 43: Baseline and P-RNAV Noise footprint size for EGSS

LUTON	Current Footprint Size (sq/km)			P-RNAV Footprint Size (sq/km)		
Procedure	60db	70db	80db	60db	70db	80db
A319 Arrival 08	177	48	8	176	48	8
A319 Arrival 26	174	46	7	173	46	7
B738 Arrival 08	183	58	12	183	58	12
B738 Arrival 26	178	55	11	177	56	11
CRJ9 Arrival 08	149	44	6	149	44	6
CRJ9 Arrival 26	146	42	5	145	43	5
A319 Departure East 08	236	73	12	221	76	12
A319 Departure East 26	235	73	12	209	73	13
A319 Departure North 08	199	77	12	217	75	12
A319 Departure North 26	216	76	12	197	75	12
A319 Departure South-West 08	241	62	12	195	71	13
A319 Departure South-West 26	240	63	12	227	72	12
B738 Departure North 08	360	139	25	296	126	25
B738 Departure North 26	379	142	24	268	119	25
B738 Departure South-West 08	499	152	24	241	107	27
B738 Departure South-West 26	534	142	24	303	129	24
CRJ9 Departure North 08	174	36	6	147	40	7
CRJ9 Departure North 26	175	36	7	137	43	7
CRJ9 Departure South-West 08	178	39	7	148	33	7
CRJ9 Departure South-West 26	177	39	7	164	35	7

Table 44: Baseline and P-RNAV Noise footprint size for EGGW

LONDON CITY	Current Footprint Size (sq/km)			P-RNAV Footprint Size (sq/km)		
Procedure	60db	70db	80db	60db	70db	80db
C560 Arrival 09	68	15	3	68	15	3
C560 Arrival 27	68	15	3	68	15	3
F50 Arrival 09	60	8	0	57	8	0
F50 Arrival 27	57	8	1	58	8	1
RJ85 Arrival 09	136	41	7	135	41	7
RJ85 Arrival 27	136	41	7	136	41	7
C560 Departure East 09	168	33	6	170	33	6
C560 Departure East 27	165	33	6	166	32	6
C560 Departure North 09	206	26	6	174	33	6
C560 Departure North 27	206	26	6	166	32	6
C560 Departure South 09	189	26	6	171	33	6
C560 Departure South 27	187	26	6	164	32	6
F50 Departure East 09	98	8	1	78	8	1
F50 Departure East 27	103	8	1	79	8	1
F50 Departure North 09	91	9	1	79	8	1
F50 Departure North 27	93	8	1	79	8	1
F50 Departure South 09	102	8	1	77	8	1
F50 Departure South 27	104	8	1	92	8	1
RJ85 Departure East 09	343	86	16	284	77	16
RJ85 Departure East 27	337	86	16	277	76	16
RJ85 Departure North 09	352	68	16	282	77	16
RJ85 Departure North 27	350	70	16	277	76	16
RJ85 Departure South 09	380	73	16	286	77	16
RJ85 Departure South 27	371	73	16	278	79	16

Table 45: Baseline and P-RNAV Noise footprint size for EGLC

The following are summarised recommendations for future SESAR noise assessment from the P16.06.03 analysis. For more detail please refer to [3].

- INM standard profiles should be extended beyond 10,000ft by adding more procedure steps or profile points.
- The potential benefits of CDAs should also be investigated, as it is not clear that INM fully acknowledges the benefits to CDAs enabled by P-RNAV operations.
- The analysis should be conducted over an average, representative period
- A cumulative metric such as Leq may also be considered; or Lmax for single events.
- The population of the surrounding area should be taken into account when new routes are designed. Population analysis should be made for each alternative under study.

For each operational requirement, the following table aims to provide a summary of their assessment. Req V&V status is ‘COVERED’ if the Operational Requirement has been assessed as part of this validation and ‘NOT COVERED’ if it has not. Operational Requirements ‘MET BY DESIGN’ have not been directly validated during this validation exercise but are implicit in the P-RNAV designs which formed the basis of the real time simulation.

Ops. Req ID	Ops. Req Title	Ex ID	Ex Title	Validation Objective ID	Validation Objective Title	Validation Objective Analysis Status per exercise	Validation Objective Analysis Status	Req. V&V Status
5.7.4-HLReq -001	Runway Throughput shall be maintained at Current Day levels or increased.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	547Obj_01	Assess impact to Runway Throughput	OK	OK	COVERED
5.7.4-HLReq -002	Controller and Flight Crew Workload shall be reduced.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	574Obj_02	Assess workload impact of procedures for Approach Controllers & Flight Crew	NOK	NOK	COVERED
5.7.4-HLReq -003	Approach Controllers’ Human Performance levels shall be maintained at Current Day levels or enhanced.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	574Obj_03	Assess Human Performance levels (such as Situational awareness, effective communication/teamwork detection/recovery of human error)	OK	OK	COVERED
5.7.4-HLReq -004	Safety levels for the TMA shall be maintained at Current Day levels or improved.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	574Obj_04	Assess TMA Safety levels	OK	OK	COVERED

5.7.4-HLReq -005	Efficiency of Arrival & Departure Management shall be improved,	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	-	-	NOT COVERED[7]
5.7.4-HLReq -006	Hold Occupancy & Levels shall be maintained at Current Day Levels or reduced.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	574Obj_06	Assess the impact to Hold Occupancy & Flight Levels	NOK	NOK	COVERED
5.7.4-HLReq -007	Fuel Burn and CO_2 Emissions shall be reduced.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	574Obj_07	Assess the impact to Fuel Burn / CO_2 Emissions	OK	OK	COVERED
5.7.4-HLReq -008	The impact of Noise pollution shall be reduced	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	574Obj_08	Assess the impact of Noise pollution to the local Environment	OK	OK	COVERED
5.7.4-HLReq -009	Security levels for the TMA shall be maintained at Current Day levels or improved.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	-	-	NOT COVERED*
5.7.4-TMAPerf001	Holding capacity shall be available to the TMA controllers.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN
5.7.4-TMAPerf002	Waypoints should be defined at the entry points of the sequencing to provide the controllers with the opportunity to direct traffic straight to the Point Merge arcs	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN

[7] To be covered by *EXE-05.07.04-VP-228.*

5.7.4-TMAPerf003	The operational procedures shall be able to cope with loss of dedicated airborne hold with minimal impact to service delivery.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	NOT COVERED*
5.7.4-TMAPerf004	CCDs shall be incorporated into the Departure routes.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN
5.7.4-TMAPerf005	CDAs shall be incorporated into the Approach routes.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN
5.7.4-PMSPerf001	Each Point Merge procedure shall be part of P-RNAV routes only.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN
5.7.4-PMSPerf002	Holding capacity shall be available to the controllers respons ble for managing the Point Merge System	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN
5.7.4-PMSPerf003	There shall be conventional routes that take traffic from missed approaches back onto the sequencing legs	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN
5.7.4-PMSPerf004	For each Approach function, a Radar Manoeuvring Area (RMA) should be defined to allow radar vectoring for path-shortening.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN
5.7.4-PMSPerf005	The airspace design shall be able to deliver Point Merge operations for easterly and westerly runway operations, without degradation of service level.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	MET BY DESIGN

5.7.4-PMSPerf006	The operational procedures shall be able to safely cope with Level Busts on sequencing legs.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	NOT COVERED*
5.7.4-PMSPerf007	The operational procedures shall be able to safely cope with induced conflicts.	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA	-	-	OK	OK	NOT COVERED*

Table 46: Requirements Coverage Synthesis

* These requirements not covered here, along with the specific Safety Requirements, shall be identified and covered in the relevant Safety Assessment Report produced in parallel to this document and incorporated into the OSED [2].

4.2.2 Milan test case

The following table highlights the results for each Validation Objective. On a general basis positive feedbacks have been assessed, even if the lack of log data allows only for a partial assessment of some objectives like for instance environmental one. In fact in this case the unavailability of a track miles measure but only of an estimate of its does not allow for a strict analysis about fuel consumption and comparison between the advantage in CDO availability and track miles length experienced.

Strong reduction in tactical instructions usage and R/T phraseology has been observed and also the system proved to be very efficient and practical in handling unusual situations and improving situational awareness of ATCOs; similar results are expected for flight crew.

Exercise ID	Validation Objective ID	Validation Objective Title	Success Criteria	Exercise Results	Validation Objective Analysis Status per exercise
EXE-05.07.04-VP-228	574Obj_01	Assess impact to Runway Throughput	Runway Throughput maintained at Current Day levels or increased for the TMA as a whole Runway Throughput maintained at Current Day levels or increased for each individual Airfield	Runway throughput depending not only on airspace capacity but also on aerodrome layout (rapid exit taxiway, complexity of ground taxi, etc). Airspace capacity may be increased at least about 20%. In order to stress the maximum capacity achievable without PMS collapse some tests have been performed during validation allowing for a number around 50-55 aa/cc per hour has been achieved. Runway throughput potentially improvable according to optimization of ground movement.	OK

Exercise ID	Validation Objective ID	Validation Objective Title	Success Criteria	Exercise Results	Validation Objective Analysis Status per exercise
EXE-05.07.04-VP-228	574Obj_02	Assess workload impact of procedures for Approach Controllers & Flight Crew	Approach Controller workload reduction for the TMA as a whole and for single approach R/T communications reduction for single approach and for TMA as a whole	• Estimated 50% reduction in R/T communication; • Air traffic controller perceived a weak workload even in case of number of aa/cc per hour similar to present figures; •Time saving in handling traffic allows air traffic controllers for performing other tasks (planning, coordination •Estimated 75% reduction in the need of vectoring aircraft: Aircraft are expected to enter the sequencing leg descending and horizontally spaced, assuming a virtual AMAN in the pre-sequencing sector. In case horizontal spacing is not adequate aa/cc have been handled providing vertical separation, and restoring horizontal separation by proper use of sequencing legs and direct to instructions	OK
EXE-05.07.04-VP-228	574Obj_03	Assess Human performance levels (such as Situational awareness, effective communication /teamwork detection/recovery of human error)	Approach Controllers human performance levels are maintained at current day level or enhanced	•Estimated 20-25% time saving in allocating the same aa/cc arriving at Malpensa as today; •Increased situational awareness on both operational sides (ATCOs and pilots) due to the reduction of vectoring needs •Better handling of unusual situations due to holding design and management	OK

Exercise ID	Validation Objective ID	Validation Objective Title	Success Criteria	Exercise Results	Validation Objective Analysis Status per exercise
				• Improved handling of missed approaches; • Reduced workload when compared to current operations and significantly better situational awareness •Holding design and use proved to be efficient, allowing nominal situation restore in a relatively short time when compared to current operations;	
EXE-05.07.04-VP-228	574Obj_04	Assess TMA Safety levels	Safety levels for the TMA as a whole are maintained at current day levels or improved No new Safety hazards added that cannot be mitigated	• Estimated 75% radar vectoring reduction; • Better traffic management and increased situational awareness; •Better management of unusual situations and shorter recovery of nominal situation after a contingency; •Less R/T communication needed •Important to maintain active radar vectoring skill in order to resume it whenever needed;	OK
EXE-05.07.04-VP-228	574Obj_05	Assess the effectiveness of Arrival and Departure Management	Efficiency of arrival & departure management for TMA as a whole and for each airport	•Estimated 20% increase for Malpensa arrivals; • Better vertical profile achieved by aircraft due to reduced interaction between departing and arriving flows from surrounding airports (Milan Linate); Better climb profiles expected for departures from Malpensa and Linate;	OK
EXE-05.07.04-VP-228	574Obj_07	Assess the impact to Fuel Burn	Net benefit per flight to fuel burn/CO2 emissions for the TMA as a whole and for each airfield Evaluation of average vertical profile efficiency in terms of availability of	•75% reduction in radar vectoring allows for a better trajectory predictability and profile planning; •Continuous Descent Operations available from FL120/FL130, representing a strong improvement from today stepped descent operations; •Better climb profiles expected for departures from Malpensa and Linate;	OK (*)

Exercise ID	Validation Objective ID	Validation Objective Title	Success Criteria	Exercise Results	Validation Objective Analysis Status per exercise
			CDO operations compared to the actual scenario		

(*) Since no data recording was available from simulation it was not possible to obtain figures per single aircraft but only to assess indirect benefit arising from improved vertical profile efficiency when compared to actual scenario. So this objective in case of Milan exercise has been only partially assessed.

Below each objective has been discussed in a more detailed way and grouped by the significant Key Performance Area:

Environment/Fuel Efficiency

Under this KPA the following objective have been evaluated:

574Obj_7: Assess the impact to fuel burn/CO2 emissions

In order to provide an estimation of this objective an evaluation of average vertical profile efficiency in terms of use of CDO operations compared to current operations have been used.

The design arrival route network is longer than current published STARs but, since these ones are rarely used preferring tactical instructions (vectoring) in order to manage traffic flows, the distance to touchdown actually flown compared to PMS design is almost equivalent in traffic peak situations.

Moreover the PMS design allows for the application of Continuous Descent from FL120/FL130 which accounts for an expected reduction of fuel consumption and consequent CO2 emissions reduction, when compared to actual application of stepped descent technique.

Anyway this objective could be only partially assessed since the lack of data logs did not allow for a comparison between CDO execution benefits and track miles length evaluation.

Airspace capacity

Under this KPA the following objective have been evaluated:

574Obj_2: Assess workload impact of procedures for approach controllers and flight crew

574Obj_5: Assess the effectiveness of arrival and departure management

Both objectives have achieved positive assessment and fulfilled, in particular strong benefits arose from the sensitive reduction in the use of tactical instructions (namely vectoring is expected to be reduced by almost 75%) and in a better management of traffic flows, due to the reduced interaction between arrivals and departures provided by the new design network.

Air traffic controller perceived low workload even in number of arrivals to LIMC as much as today.

An increased situational awareness, enhanced by the design, allowed for a better management of unusual situation and an easier recovery of normal operations after unusual events/contingencies.

Simulation runs allowed identification of the maximum number of simultaneous aircraft saturating the sequencing leg, which was determined in 7 aa/cc. Each exceeding aircraft will be handled by using the holding provided before the sequencing leg and introducing the role of the Coordinator between the feeding sectors (ASW and ANE) and the sequencing legs in order to relieve pressure on them.

Air traffic controllers experienced also a strong reduction (almost 50%) in R/T communication, allowing for a further reduction in the workload (taking into account also the one arising from radar vectoring reduction).

Aircraft sequence resulted always clear and unambiguous and easy to establish.

Easy dissemination of information concerning distance to go and sequence number.

Holdings proved to be very efficient in accommodating a huge amount of traffic, especially during contingencies, unusual events or operational needs (use of opposite direction runway).

Less pressure on the arrival sector, managing inbound sequence due to the new arrival route design.

Airport capacity

Under this KPA the following objective has been evaluated:

574Obj_1: Assess impact to runway throughput

This objective is someway linked with the preceding one. The possibility to achieve a higher airspace capacity prepares the floor to an increase also in runway capacity.

For sure the PMS system doesn't decrease present figures for runway throughput. Anyway, since airport capacity also depends on aerodrome layout and complexity of ground movements (rapid exit taxiways, runway crossing etc.) the amount of increase of runway throughput in the case of Milan Malpensa has to be verified taking into account these considerations, even if a slight increase may be expected.

Cost effectiveness

The objective linked to this area is the following one:

574Obj_3: Assess human performance levels (such as Situational awareness, effective communication/teamwork detection-recovery of human error)

An evaluation of the amount of time needed to handle actual figures of arrivals to Milan Malpensa showed a 20-25% time saving when using the Point merge structure.

Moreover there was a general improvement of situational awareness due to the reduction of radar vectoring technique (estimated 75% less) and a strong reduction in R/T communication (estimated 50% less) thus contributing to a wide increase of Human performances.

The new design coupled with new holding positioning allowed also for an improved management of unusual situations (such as runway closing, opposite departing traffic, several missed approaches), facilitating also the recovery of normal situations after unusual events/contingencies., when compared to present operations.

Safety

During the previous simulation exercise hold in May 2011, 11 hazards have been identified mostly linked to operational procedures. In order to give a solution to these hazards, new safety requirements has been identified, as showed in the following matrix (and reported into the Safety and Performance Requirements document):

Hazard ID	Hazard description	Safety Requirement ID	Safety Requirement description
Hazard_01	Subsequent aircrafts entering the PMS with reduced spacing	SR#2.1l	Allow for descent management along the sequencing leg structure
		SR#5n	Evaluation of maximum entry level should be performed considering the whole sequencing leg length and the geometry
Hazard_02	Level bust while aircraft on sequencing leg	SR#2.1l	Allow for descent management along the sequencing leg structure
Hazard_03	Larger amount of traffic, then the capacity, entering the PMS	SR#5o	Implementation of PMS should provide a definition of the maximum capacity
		SR#5q	Implementation of PMS should define operational procedures to avoid the overcoming of PMS capacity (e.g. introduction of the role of the coordinator)
Hazard_04	Anticipation of “direct to” instruction given by ATCOs with reduction of required spacing	SR#2.1l	Allow for descent management along the sequencing leg structure
Hazard_05	Interaction between PMS and departing traffic	SR#2.1l	Allow for descent management along the sequencing leg structure
		SR#2.1m	Implementation of PMS should provide a segregation from standard departures
Hazard_06	Interaction between PMS and other arriving traffic	SR#2.1l	Allow for descent management along the sequencing leg structure
Hazard_07	Label clutter between aircraft on adjacent sequencing leg	SR#2.1l	Allow for descent management along the sequencing leg structure
Hazard_08	Label clutter between aircraft on PMS and other aircraft	SR#5p	Label clutter with aircraft operations of closer airport have to be considered when implementing PMS
Hazard_09	Re-inserting Missed Approach in approach sequence	SR#1.1d	Implementation of PMS should provide a standardization of MA tactical management
Hazard_10	Management of traffic in contingency situation	SR#1.1e	Implementation of PMS should provide holding at MPs able to absorb all the traffic within the PMS and between the MPs and the runway
		SR#5q	Implementation of PMS should define operational procedures to avoid the overcoming of PMS capacity (for example the introduction of the role of the coordinator)
Hazard_11	Steady condition for PMS entry not achievable	SR#5q	Allow for descent management along the sequencing leg structure

The objective linked to this area is the following one:

574Obj_4: Assess TMA Safety levels

574Obj_04_01: TMA Safety Levels are maintained at current day levels or improved

The evidences to demonstrate that TMA safety level is maintained at its present level or improved are based on the results of simulations in terms of general workload of controllers, situational awareness, ability to learn new techniques and ability to safely handle unusual situations.

For a better picture of reality of operations, ATCOs that have participated to real time simulations had a wide range of operational experience, from a minimum of one year to a maximum of more than ten years.

General findings.

PMS has been well accepted by ATCOs, as their workload significantly decrease for the whole TMA sectors. The tactical intervention is reduced from current day operations, so they are able to manage a larger amount of traffic with less workload, less communication congestion and increased ability to monitor traffic for separation and sequencing purposes.

Pre-sequencing traffic

The tested design, allowing traffic descent on the sequencing leg, reduces the workload of upstream sectors which are expected to perform pre-sequencing tasks, since aa/cc entering PMS legs don't need to be at steady level.

In this case, in fact feeder sectors are allowed, if needed, to clear the traffic bound the sequencing leg providing only vertical separation between them, while the spacing would be provided by the sector who manage the traffic inside the PMS.

The upstream holdings are not used anymore in normal operations.

The safety levels of whole TMA seems to improve.

Sequencing traffic

The PMS facilitate the sequencing task, reducing the workload of ATCOs that are only requested to evaluate, with a graphical aid provided by concentric circles, the moment of providing "direct-to" clearance to aircrafts.

The safety levels of whole TMA seems to improve considering the decrease of workload, the decrease of communication, the standardization of operational procedures of different ATCOs, the predictability of flight, and then the increased capability of monitoring traffic and all the potential situation that could lead to a safety related event.

Separating traffic

As general workload of controllers decrease, the ability to solve potential conflicts increase.

Moreover the design solves also the issues of today operations about interaction between departing and arriving traffic since it provides separate trajectories between incoming traffic and outgoing traffic,

The whole TMA safety levels seem to increase on a general basis.

Vectoring skill.

PMS doesn't normally require tactical intervention based on vectoring traffic.

This has a positive impact on TMA safety levels considering the decrease of workload and the increased ability to provide radar monitoring.

The related safety issue that needs to be considered, already evaluated in safety assessment and already covered by safety requirements is the need to maintain the vectoring skill of controller with dedicated continuous training or with reversion to vector based operations with low or medium traffic amount.

The necessity to maintain the vectoring skill is essential also to face the non standard situation related, for example, to bad weather, where use of PMS is not possible.

Contingency situation

The ability to manage contingency situation seems to increase with PMS, because of the reduced workload of controller and because of better standardized use of holding, both placed upstream the PMS, both placed over the MPs.

In particular the possibility to concentrate aircraft inside an almost limited airspace volume while remaining separated each other, allows air traffic controllers to maintain a high situational awareness and an easy degree of traffic management.

Moreover, the re-activation of PMS and normal operation conditions, after a contingency situation, does not seem to introduce any safety related element, since it doesn't require a particular workload increase.

574Obj_04_02: No new Safety Hazards added that cannot be mitigated.

During the simulation various hazardous situation have been determined and evaluated.

01.Subsequent aircrafts entering the PMS with reduced spacing.

Especially in the absence of AMAN tool, traffic could entry within TMA limit not well metered.

So on a general basis an AMAN tool is strongly recommended.

Anyway, allowing aircraft descent on sequencing leg reduces the problem of reduced horizontal separation since the PMS controller will apply vertical separation with stepped descent inside the sequencing leg, using the sequencing leg to provide horizontal spacing. It reduces also the use of the holdings to restore horizontal separation. Anyway the reduced horizontal spacing in pre-sequencing sectors has to be accurately monitored since if experienced by too many aircraft it may cause PMS saturation, thus requesting the use of holdings to resume adequate horizontal spacing.

Moreover it is necessary to evaluate the maximum entry level, considering the maximum distance of the whole path and the maximum amount of aircraft that can enter the PMS which can be handling correctly for sequencing purposes. The maximum entry level for the tested design is FL 180.

02. Level bust while aircraft on sequencing leg.

This is a hazard already evaluated in the PMS Safety analysis, considering that in the most-used configuration of PMS two adjacent leg exists, with no lateral separation, in which aircrafts fly with a vertical separation of 1000ft.

In Milan TMA tested design this is not a particular hazard of PMS, but it's referred to what already could happen in actual operations, where aircraft are cleared to descend subject to level vacated from preceding aircraft, in case of lack of horizontal separation.

03. Larger amount of traffic, then the capacity, entering the PMS.

The risk is that the ATCOs are not able to give direct to instructions bound MPs to all the aircraft prior the end of sequencing leg.

To avoid this situation is necessary, when implementing a PMS structure, to define the capacity of the particular implementation, depending for example on landing spacing, on geometry of PMS.

In case of the geometry tested for Milan TMA, the PMS saturation was reached with 7 aircraft per each sequencing leg.

04. Anticipation of "direct to" instruction given by ATCOs with reduction of required spacing

This event can lead to a reduced spacing between subsequent aircraft leaving the sequencing leg bound to Merge Point.

This event has been evaluated during a contingency situation where, with a big amount of traffic (55 aircraft/hour) the MAR sector, under pressure, sometime was anticipating this instruction.

It resulted in an tactical intervention, by mean of vectoring, in order to provide adequate spacing.

05. Interaction between PMS and departing traffic.

In Milan TMA the potential interactions between arriving aircraft and departing aircraft from LIMC (Milan Malpensa) and LIML (Milan Linate) have been evaluated.

The proposed design solved this situation allowing to have more vertical airspace available for departures, facilitating Continuous Climb Operations, considering that arriving aircraft could enter at a quite high level and descending along the leg.

06. Interaction between PMS and other arriving traffic.

In Milan TMA has been evaluated the interaction between PMS and arriving aircraft to LIML (Milan Linate).

In present operations an interaction between Milan Malpensa and Milan Linate arrivals along the North West sector exists. This potential conflict has been solved in the proposed design due to selected position for PMS sequencing legs and new operational procedures.

07. Label clutter between aircraft on adjacent sequencing leg.

08. Label clutter between aircraft on PMS and other aircraft.

No particular hazard evidence has been collected especially because of the use of only one sequencing leg.

09. Re-inserting Missed Approach in approach sequence.

It has been evaluated to be more convenient to re-insert the missed approach as soon as possible by creating a gap along the sequence an vectoring the MA.

In configuration PMS_LIMM_02, considering that an aircraft leaving the sequencing leg has got about 40 track-miles, it has been evaluated that, inserting the MA after any aircraft that has already left the sequencing leg, the MA will have to fly about 45 track miles.

10. Management of traffic in contingency situation.

Several situations have been tested during the RTS, showing on a general basis an easier management of contingencies and unusual.

In case, for example of runway closure, the holdings defined at MPs, are able to absorb all the aircraft in the PMS and from MP to runway.

The aircraft that already passed the MP are cleared to go back to hold at the merge point holdings respectively at 3000/4000 ft and at 3000/4000/5000 ft. The other aircraft already within the PMS will be cleared to merge points holding that are segregated until FL100.

As usually appears in actual scenario the need to have a coordinator acting as a merger between feeding sectors and arrival sectors was clear also for PMS design. Its role proved to be very important in relieving pressure from arrivals, helping them in handling contingencies until PMS could be reactivated.

Moreover it has been observed that contingency situations management was improved with PMS due to the fact that aircraft are not spread inside TMA on different holding positions but they remain within PMS structure, allowing for an increased situational awareness of ATCOs and potentially flight crews and a better sequence management when re-activation of PMS occurs.

The other aircraft will hold at upstream holdings, without entering the PMS.

It has been evaluated that the re-activation of the PMS doesn't introduce any particular safety related issue.

11. Steady condition for PMS entry not achievable

In some TMAs the limited airspace availability to allow for a feeding of steady traffic inside PMS structure may represent a constraint. For Milan TMA it actually represented a constraint during V2 simulation, resulting in too much pressure in the feeder sectors and so not reaching all the potential benefits which a similar design may be entitled to achieve.

The modified design for V3 switched from the two legs with leveled off aircraft to a single leg allowing for aircraft descent structure, thus considering not steady aircraft entering PMS legs but descending ones.

This design proved to be very efficient in handling traffic solving all the issues arisen during V2 simulation.

This design, or more in general, the possibility to handle descent traffic inside PMS leg structure may be needed for TMAs characterized by constraints similar to those of Milan TMA where PMS with steady entry proved to be not so efficient in handling incoming traffic.

4.2.3 Unexpected Behaviours/Results

During the validation of the London TMA, a Problem Report was raised during the simulation in relation to aircraft speeds on final approach. Aircraft were frequently observed to fly non-sensical ground speeds. Two aircraft at the same level with the same IAS would be observed to fly ground speeds differing by 40kt-50kt. This frequency and impact of this issue was found to diminish, though not vanish, when wind was removed from the simulation. Wind was therefore removed from the majority of matched and scenario exercises and only introduced for specific scenario evaluations.

The result of the simulator issue is that some non-nominal scenarios could not be executed [see Section 3.2.4]. All nominal scenarios were successfully executed, although some runs assumed 'nil wind'.

4.3 Confidence in Results of Validation Exercises

4.3.1 Quality of Validation Exercises Results

The results presented in this document have a high associated level of confidence. The exercise ran in accordance to the associated Validation Plan with minimal modification.

Quantitative results are presented based principally on the results of the 'matched' exercises. Eight pairs of matched exercises, sixteen in total, were run in accordance with the timetable. Each airfield (EGSS, EGGW, EGLC) was simulated in every exercise.

A range of operational scenarios, as presented in 2.2.4, were also run during the 'matched' exercises. The same operational scenarios were run in both Baseline and P-RNAV parts of the matched exercise. As far as possible the each scenario was initiated in the same manner in both exercises. However, it is not possible to categorically state that the impact of each scenario will have been the same in P-RNAV and Baseline exercises.

Where significant differences are felt to have occurred these have been addressed on a measure by measure basis in Section 4.2 above. In some instances this has reduced the sample size of the measures. However, the benefits of measuring these scenarios in both Baseline and P-RNAV exercises is considered to outweigh the potential drawbacks.

Same considerations also apply to Milan TMA since the high experience of the controllers involved inside the Validation team. The inconvenience of logs unavailability didn't impair the results collection and post-analysis which allowed the team to draw important feedbacks and results.

4.3.2 Significance of Validation Exercises Results

4.3.2.1 London TMA

See Section 4.3 for a discussion of the sample size implications of running scenarios concurrent with matched exercises.

This simulation exercise was conducted in a representative simulation environment. Traffic was grown to 2015 levels and operational controllers were used to staff feed sectors felt to be essential for simulation realism. As has been discussed, the realism of the outer holding observed during the exercise is questionable and would likely not have occurred in operation. While the result that outer holding was reduced is considered valid, some caution is urged with regards to the precise reduction that may be realised in operations.

The role of the Air Arrivals controller was not simulated during this validation exercise. Therefore there was no feedback between the approach and tower operation. For this reason, and exacerbated by the speed control Problem Report noted in Section 4.2.3, some caution is also urged when interpreting the precise impact of the P-RNAV procedures on the landing rate. The qualitative feedback was unanimously positive, supporting the quantitative conclusions and there is therefore confidence in the overall conclusion of 'maintained or improved'.

A 16% improvement in Local Airspace Capacity (CAP2) is reported in Section 4.1.1.1. This is an aggregate measure of the change in reported workload (Bedford) and tactical instructions. However, it should be considered in light of the following caveats:

- Not all airports within the London TMA were included in the simulation. The impact of their traffic flows and the integration of the aircraft may restrict capacity increase.
- Bandboxing/Splitting or handover were not covered. The more proceduralised nature of the PMS concept and resultant increase in monitoring and decrease in interaction of controllers may impact upon on levels of situation awareness with respect to the on-coming controller. These changes may impact upon human performance, which would indirectly impact upon airspace capacity.
- The level of PRNAV equipped aircraft may be less and the handling of these aircraft will increase workload. Scenarios of what aircraft would do were limited and based on assumed rather than known behaviour.
- ACPOs do not have high degree of fidelity as they respond differently and possibly more promptly than pilots (there are no nationality issues etc). The impact of resultant deviations / delayed responses / non conformance with expected response may be greater with PMS than in current operations.

4.3.2.2 Milan TMA

The RTS performed for Milan TMA was conducted with a high degree of fidelity. Real traffic operations were simulated considering a configuration of 6 sectors and two feeders handled by operational controllers.

Traffic was grown to 2015 levels.

Results obtained were very positive, in particular with respect to workload and traffic management.

Several KPAs have been addressed, most of them with positive evaluation consequences from an operational point of view.

In particular, a sensitive reduction in radar vectoring (75% less) and R/T communications (50% less) may be expected leading toward a better and more predictable flight profile. What flight crew complaints today is in fact related to the heavy use of radar vectoring technique, which do not allow them to adequately plan in advance the flight profile for the approach in order to maximize flight efficiency. With the PMS structure in general , this information is available since the flight crew exactly knows how many miles is expected to flow once inside PMS and from which level Continuous Descent Operations shall be made available.

These key factors provide improved flight profiles, when compared with today mode of operations thus do not impairing Safety or even increase it.

The lack of logs didn't allow the validation team to perform computations about fuel consumption and CO2 emissions, even if it can be estimated that a fuel consumption reduction may be experienced since the possibility to perform Continuous Descent and Continuous Climb operations inside the airspace volume between FL 110/FL 130 and ground.

The configuration assumes the presence of all P-RNAV aircraft. This assumption is reasonable considering that in Milan TMA almost 80% of the traffic is P-RNAV compliant and that this figures are expected to increase in the future. Anyway non P-RNAV may be re-routed via conventional back-up procedures and tactical instructions, increasing slightly air traffic controller workload, even if the simulation showed that a proper sequencing leg management allowed air traffic controllers to provide the required spacing along the sequencing leg to insert tactical vectored aircraft.

5 Conclusions and recommendations

5.1 Conclusions

The London and Milan designs ('Invariant' and 'Dissociated Legs' respectively) differ significantly but both test cases have significant restrictions on the placement and size of Point Merge Systems. The resultant TMA designs were able to accommodate these restrictions and still show positive results. Therefore, it may be concluded that the concept of applying P-RNAV route structures with Point Merge is flexible enough to be applied to various Complex TMAs across the ECAC region.

Overall, approach controllers using the P-RNAV system reported reduced workload, improved situation awareness and reduced R/T. They issued fewer instructions than in current day operations and the spare capacity this provided improved their capability to deal with a range non-nominal scenarios simulated throughout the exercise.

Aircraft spent less time holding overall and a significant reduction was observed in the level of outer holding in the TMA. A slight increase in the distance flown, and therefore fuel burnt, for arrivals was more than compensated by a greater decrease in the fuel saved by allowing departing aircraft an unrestricted initial climb phase of flight and continuous descent operations inside the sequencing legs bound to Merge Points and Final approaches.. The noise impact (evaluated only for London test case) for arrivals was found to be neutral, but an improvement, also due to the unrestricted initial climb, has been identified for departures. As a result 574Obj_01, 574Obj_03, 574Obj_07 and 574Obj_08 have been assessed as 'OK' for this validation exercise. Against SESAR KPAs this results in benefits against Environmental Sustainability (ENV1) and Airport Capacity (CAP3).

Approach controllers considered that using the Point Merge System changed their method of operating. It is more passive form and monitoring of aircraft behaviour becomes a more important factor. Speed control becomes the principal method of separation assurance and the use of the Mode-S downlinked IAS value was found to support the controller task. For London TMA level constraints are also applied to manage separation, for example, level-offs prior to entry to the sequencing legs, while for Milan Malpensa the design allowed for descending aircraft inside the sequencing legs, leaving the feeding sectors the only task to horizontal pre-sequencing of traffic

For London test case a wide variety of non-nominal situations were run during the course of the simulation based on input from the P5.7.4 Safety Assessment. The controllers felt their ability to manage these scenarios was not affected by the introduction of Point Merge. In some cases, such as single aircraft R/T failure, the increased level of systemisation improved the system's response to the scenario. The final assessment of 574Obj_04 at the project level will be documented in the Safety Assessment Report, which will be included in the P5.7.4 OSED [2] as an appendix. This will also cover the Security assessment. The conclusions of this exercise were that 574Obj_04 is assessed as 'OK' subject to the mitigation of a small number of safety issues during implementation. Against the SESAR KPAs this indicates a potential benefit against ATM Related Safety Outcome (SAF1).
In almost all non-nominal scenarios controllers were required to revert to standard current day vectoring techniques. This was felt to be safe, but may introduce issues of skills-fade over time. This may be of concern as this reversion will occur in situations which are, by their nature, more challenging. This also raises the issues of the training of ab-initio trainees.

The results for EGSS and EGLC are almost entirely positive. The controller responses and quantitative analysis for EGGW raises more issues. Workload, subjective and objective, saw a marginal increase and situation awareness a marginal decrease. The distance flown by aircraft and time spent holding both increased. At least in part these impacts were due to the introduction of a two dedicated holding facilities at EGGW replacing the shared hold at LOREL which is operated by EGSS controller in current day operations.

EGGW controllers also commented that they used the Point Merge System less than other approach positions. The proximity to EGSS and other airspace constrains meant that the distance from the holds to touchdown was large. As a result aircraft were frequently vectored off the Point Merge System to reduce the distance to run. One EGGW controller noted they would prefer the Point Merge System either 'smaller, lower and closer' or 'bigger, higher and further away' from touchdown.

As a result, validation objectives 574Obj_02 and 574Obj_06 have been assessed as 'NOK' for this exercise despite the success at the TMA, EGSS and EGLC level. The project may wish to consider this result an implementation specific issue; rather than a reflection on the concept as a whole. The causes of this failure appear specific to EGGW. Against the SESAR KPA, a potential improvement in Local Airspace Capacity was indicated (CAP2) for the TMA as a whole.

An outstanding analysis is to assess the R/T workload impact of P-RNAV procedures on the cockpit.

The de-confliction of departure routes from arrivals, the change in the transition altitude to 18,000ft, R/T reduction due to the silent release procedure and the redistribution of traffic (between TC North sectors and with other TC sectors) all reduced reported TC North workload during the December portion of the exercise. However, it is also noted that the feedback from the 'scenario' portion of the exercise run in November was less positive; reporting that they had less space with which to manoeuvre aircraft and found it difficult to get the outbounds up and over the inbound traffic.

For Milan test case positive results and feedbacks were obtained.
On a general basis Air traffic controllers experienced less stress during their job, even in high traffic situation. Moreover the strong reduction in R/T communications and tactical instructions issuing allowed them to dedicate more time in managing traffic along the sequencing leg and establish a correct inbound sequence.

The position of the PMS legs coupled with the design of new procedures for departing aircraft showed a significant reduction in interactions between arrivals and departures from Milan Malpensa and Milan Linate, allowing more vertical airspace availability to perform Continuous Climb Operations at least until FL 100/FL130, and continuous descent inside the PMS sequencing leg.

The possibility to manage vertically moving traffic inside PMS, allow air traffic controller to issue Continuous Descent instructions even at higher level than FL120/FL 130 (optimum level for CDO inside the sequencing legs).

Use of holding is extremely rare, while it shows to be very efficient in manage unusual and contingencies, such as runway closure, aerodrome closure, bad weather conditions and missed approaches.
The possibility to manage all the traffic in a quite limited airspace volume increase situational awareness both landside and airside with positive fallbacks from an operational perspective especially in case of contingencies, where it proved to be needed the figure of the coordinator between feeding sectors and arrival sectors.

In particular the tested design may result very efficient for arrival management in case of very dynamic TMAs characterized by limited airspace availability and were the need of levelling traffic before entering PMS may generate severe limitations in concept applicability.

Relieving the feeding sectors to force descent leaving them the only task to adequately spacing traffic in the horizontal plane, leaving them a certain vertical availability to feed PMS (for Milan the maximum FL determined was FL180), resulted in a good trade-off between the job of arrivals and feeding sectors and flight efficiency (since more the aircraft is high and longer is the sequencing leg to be flown before receiving direct to at a proper altitude taking into account the track miles to be flown before landing).

Anyway particular care shall be placed in the job of the pre-sequencing sectors since it's very important to avoid PMS saturation, which will require the use of upstream holdings. In case of the Milan TMA geometry tested, it was determined in 7 aircraft per leg the maximum number of aircraft handled without using Holdings. In case of extremely high traffic or pre-sequencing troubles it was demonstrated very important the introduction of the PMS coordinator, performing a filter job between pre-sequencing sectors and arrival sectors, in order to restore PMS functionality.

Another issue observed is related to progressive switching of Air Traffic Controllers competencies from tactical traffic management (through radar vectoring) towards radar monitoring, thus requiring a continuous training activity in order to maintain at a proper operational level, radar vectoring skills which could be used to manage contingencies, as well as the few numbers of still potential existing non-PRNAV aircraft.

5.2 Recommendations

In order to fully validate the OI steps identified in this document these conclusions need to be taken in conjunction with the output of Work Stream 1. The combined results from the two test cases (London TMA and Milan TMA) will determine the readiness of the concept to complete V3 maturity.

The following safety related recommendations are made with reference to the conclusions of this validation exercise. The validation of 574Obj_4 is subject to these recommendations:

- Mitigation should be considered to address the issue of skill fade for approach controllers using a Point Merge system. Non-nominal scenarios will require reversion to vectoring in challenging situations. It is recommended that Training in Unusual Circumstances and Emergencies (TRUCE) is updated.
- The training of ab-initio trainees should also be assessed so as to develop the necessary vectoring skills to deal with non-nominal scenarios.
- The Point Merge system should provide sufficient contingency holding to accommodate as many aircraft as may be present in the Point Merge system at any one time.
- The silent release procedure to approach should be done at Min-Stack + 1 rather than Min-Stack.

The following implementation recommendations are made with reference to the conclusions of this validation exercise.

- Where available, the Mode-S IAS is displayed on the FIN's TDB during Point Merge operations. Use of monitoring tools, such as the Abnormal Indicated Airspeed Monitor should also be considered.
- The design of the EGGW Point Merge system should be revisited to address the issues raised in this report. Where possible this should retain the ability to short-cut aircraft. One method, using the GW5 point is discussed in this report.
- The use of the extended 'trombone' transitions at EGGW, EGSS (Easterly) and EGLC (Easterly) may provide greater flexibility to vector assure accurate delivery to the Air Arrivals controller at the Tower.
- The R/T workload of pilots is assessed. It has not been possible to validate this aspect of 574Obj_02 in a controller based real time simulation.
- The safety impact of non-nominal P-RNAV scenarios that were not possible to simulate should be assessed under any local implementation. For reference these are 574V313, 574V322, 574V328, 574V329, 574V336 and 574V337.

The following noise assessment recommendations are made with respect to future SESAR noise analysis:

- INM standard profiles should be extended beyond 10,000ft by adding more procedure steps or profile points.
- The potential benefits of CDAs should also be investigated, as it is not clear that INM fully acknowledges the benefits to CDAs enabled by P-RNAV operations.
- The analysis should be conducted over an average, representative period
- A cumulative metric such as Leq may also be considered; or Lmax for single events.
- The population of the surrounding area should be taken into account when new routes are designed. Population analysis should be made for each alternative under study.

The following validation recommendations are made with regards future SESAR approach related simulations:

- Where possible, in-the-loop involvement of Tower Air Arrival controllers should be considered for simulations where approach operations form a significant focus.

Proper continuous training shall be continued in order to maintain an adequate level of radar vectoring skills in order to face unexpected events or contingencies requiring;

A PMS system allowing for descent management inside sequencing leg may be needed for TMAs characterized by constraints similar to those of Milan TMA where PMS with steady entry proved to be not so efficient in handling incoming traffic.

An adequate holding system has to be provided in order to allow traffic management in case of PMS saturation and to efficiently manage unusual situation still maintaining PMS structure active;

The figure of the Coordinator resulted to be very important in case of high traffic demand and in handling contingencies. This role, in fact, acted as a merger between feeding sectors and arrival sectors with the aim of relieve pressure from the latter in order to restore PMS use as soon as possible.

Arrival manager use is recommended in order to help feeding sectors in providing adequate horizontal spacing under every traffic circumstances avoiding the PMS saturation.

An efficient structure of deconflicting P-RNAV arrivals and departures is required in order to reduce/prevent traffic interactions allowing a good management of arrivals while allowing, at the same time, the possibility to perform Continuous Climb Operation for departing aircraft.

6 References

[1] European Operational Concept Validation Methodology (E-OCVM) - 2.0 [March 2007]

[2] Operational Service and Environment Definition (OSED) for Point Merge in Complex TMA, Edition 00.00.05, 21st October 2011

[3] Point Merge Noise Analysis – 5.7.4; v00.00.01

[4] P5.7.4 Preliminary Validation Report for Point Merge – London TMA; v01.00.00

[5] SESAR P5.07.04 WS2 Validation Plan; v00.02.00

[6] SESAR B4.1 Validation Target Allocation for Step 1, Edition 00.02.00, November 2011 (KPI Targets & allocation)

[7] B4.1 Methodology for Allocating Targets and Performance Requirements at the Appropriate Levels, Edition 00.01.00, July 2010 (KPI Definition)

[8] WP5 Validation Strategy for Concept Step 1 – Time Based Operations, 00.00.04, July 2011

[9] Project Initiation Report 05.07.04 Full Implementation of P-RNAV in TMA, 00.02.02, December 2010

Appendix A1: Coverage Matrix London TMA

Requirement ID	Requirement Text	Req V&V Status	V&V Objective ID	V&V Objective Text	V&V Objective Analysis Status	V&V Objective Analysis Status per Exercise	Exercise ID	Exercise Title
5.7.4- HLReq -001	Runway Throughput shall be maintained at Current Day levels or increased.	-	OBJ-05.07.04-VALP-KPA0.0001	Assess impact to Runway Throughput	OK	OK	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4- HLReq -002	Controller and Flight Crew Workload shall be reduced.	-	OBJ-05.07.04-VALP-KPA0.0002	Assess workload impact of procedures for Approach Controllers & Flight Crew	NOK	NOK	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4- HLReq -003	Approach Controllers' Human Performance levels shall be maintained at Current Day levels or enhanced.	-	OBJ-05.07.04-VALP-KPA0.0003	Assess Human Performance levels (such as Situational awareness, effective communication/teamwork detection/recovery of human error)	OK	OK	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4- HLReq -004	Safety levels for the TMA shall be maintained at Current Day levels or improved.	-	OBJ-05.07.04-VALP-KPA0.0004	Assess TMA Safety levels	OK	OK	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4- HLReq -006	Hold Occupancy & Levels shall be maintained at Current Day Levels or reduced.	-	OBJ-05.07.04-VALP-KPA0.0006	Assess the impact to Hold Occupancy & Flight Levels	NOK	NOK	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4- HLReq -007	Fuel Burn and CO_2 Emissions shall be reduced.	-	OBJ-05.07.04-VALP-KPA0.0007	Assess the impact to Fuel Burn / CO_2 Emissions	OK	OK	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4- HLReq -008	The impact of Noise pollution shall be reduced	-	OBJ-05.07.04-VALP-KPA0.0008	Assess the impact of Noise pollution to the local Environment	OK	OK	*EXE-05.07.04-VP-229*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA

Table 47: Coverage Matrix

Appendix A2: Coverage Matrix Milan TMA

Requirement ID	Requirement Text	Req V&V Status	V&V Objective ID	V&V Objective Text	V&V Objective Analysis Status	V&V Objective Analysis Status per Exercise	Exercise ID	Exercise Title
5.7.4-HLReq-001	Runway Throughput shall be maintained at Current Day levels or increased	OK	574Obj_01	Assess impact to Runway Throughput	OK	OK	*EXE-05.07.04-VP-228*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4-HLReq-002	Controller and Flight Crew Workload shall be reduced	OK	574Obj_02	Assess workload impact of procedures for Approach Controllers & Flight Crew	OK	OK	*EXE-05.07.04-VP-228*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4-HLReq-003	Approach Controllers' Human Performance levels shall be maintained at Current Day levels or enhanced	OK	574Obj_03	Assess workload impact of procedures for Approach Controllers & Flight Crew	OK	OK	*EXE-05.07.04-VP-228*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4-HLReq-004	Safety levels for the TMA shall be maintained at Current Day levels or improved	OK	574Obj_04	Assess TMA Safety levels	OK	OK	*EXE-05.07.04-VP-228*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4-HLReq-005	Efficiency of Arrival & Departure Management shall be improved	OK	574Obj_05	Assess the effectiveness of Arrival and Departure Management	OK	OK	*EXE-05.07.04-VP-228*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA
5.7.4-HLReq-007	Fuel Burn and CO2 Emissions shall be reduced	OK	574Obj_07	Assess the impact to Fuel Burn	OK	OK	*EXE-05.07.04-VP-228*	Real-Time Simulation of Point Merge Procedures in a Multi-Airport TMA

Appendix B: Simulation Floor Plan

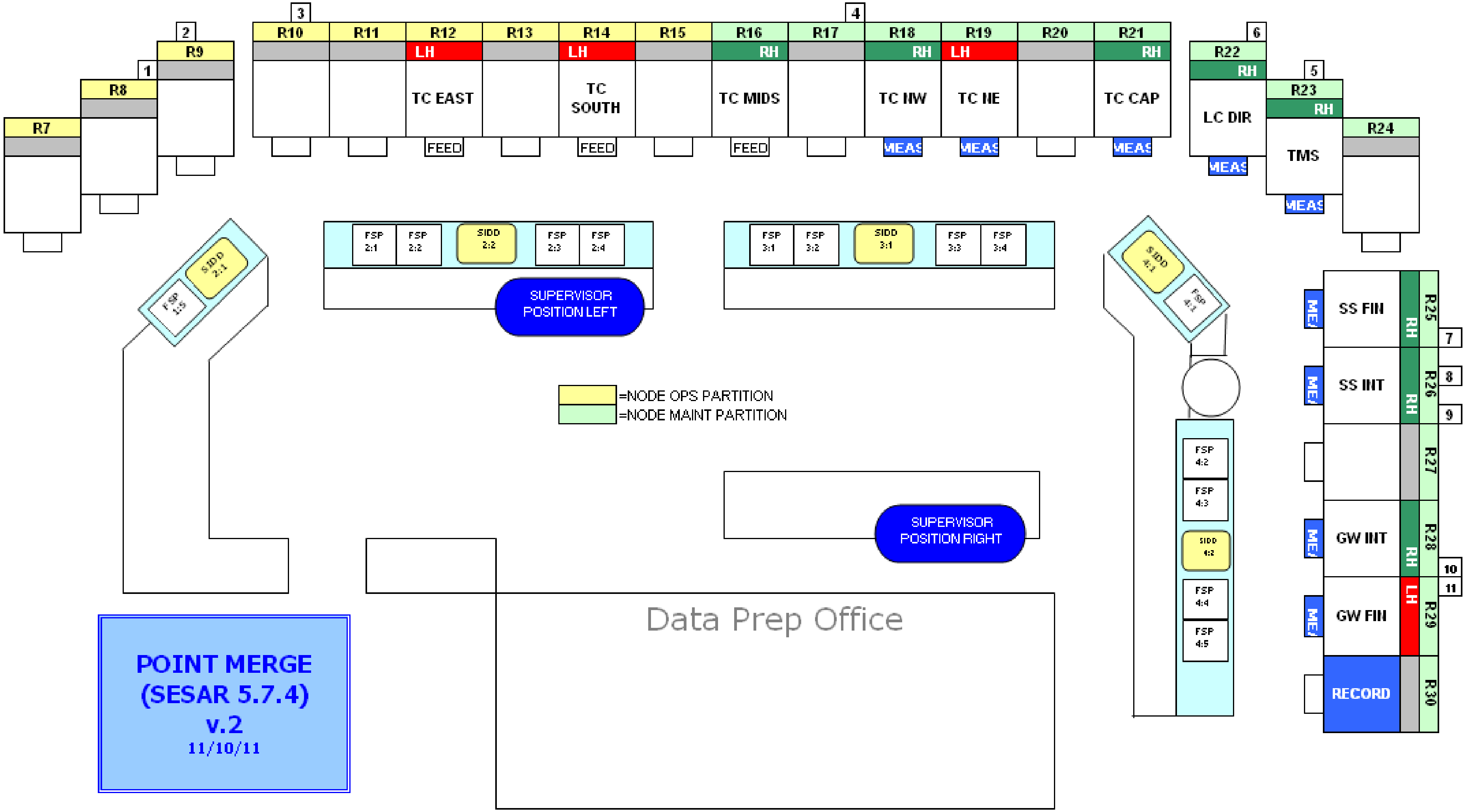


Figure 5: Simulation Floorplan

Appendix C: Airspace Designs London TMA

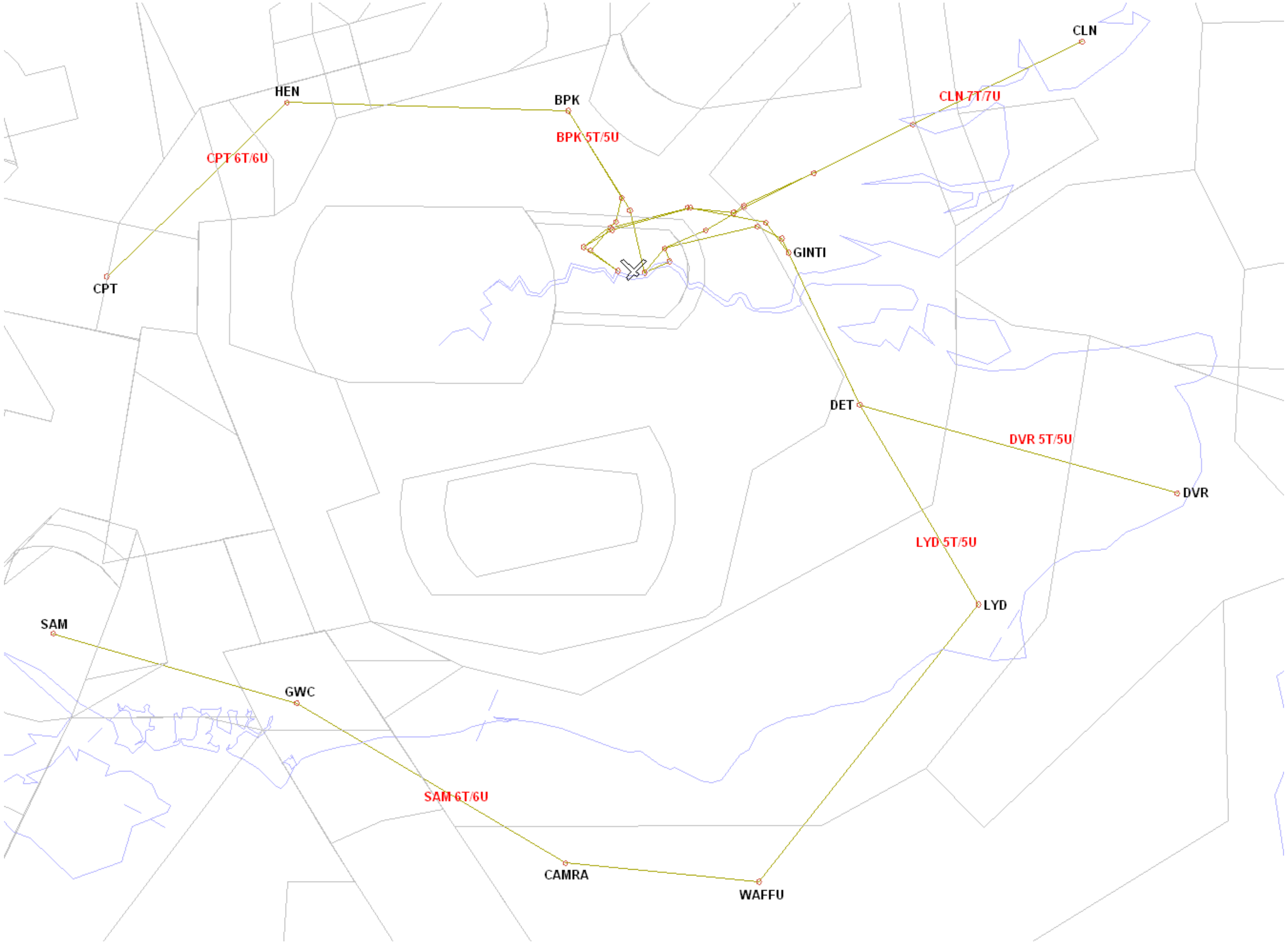


Figure 6: Baseline EGLC SIDs

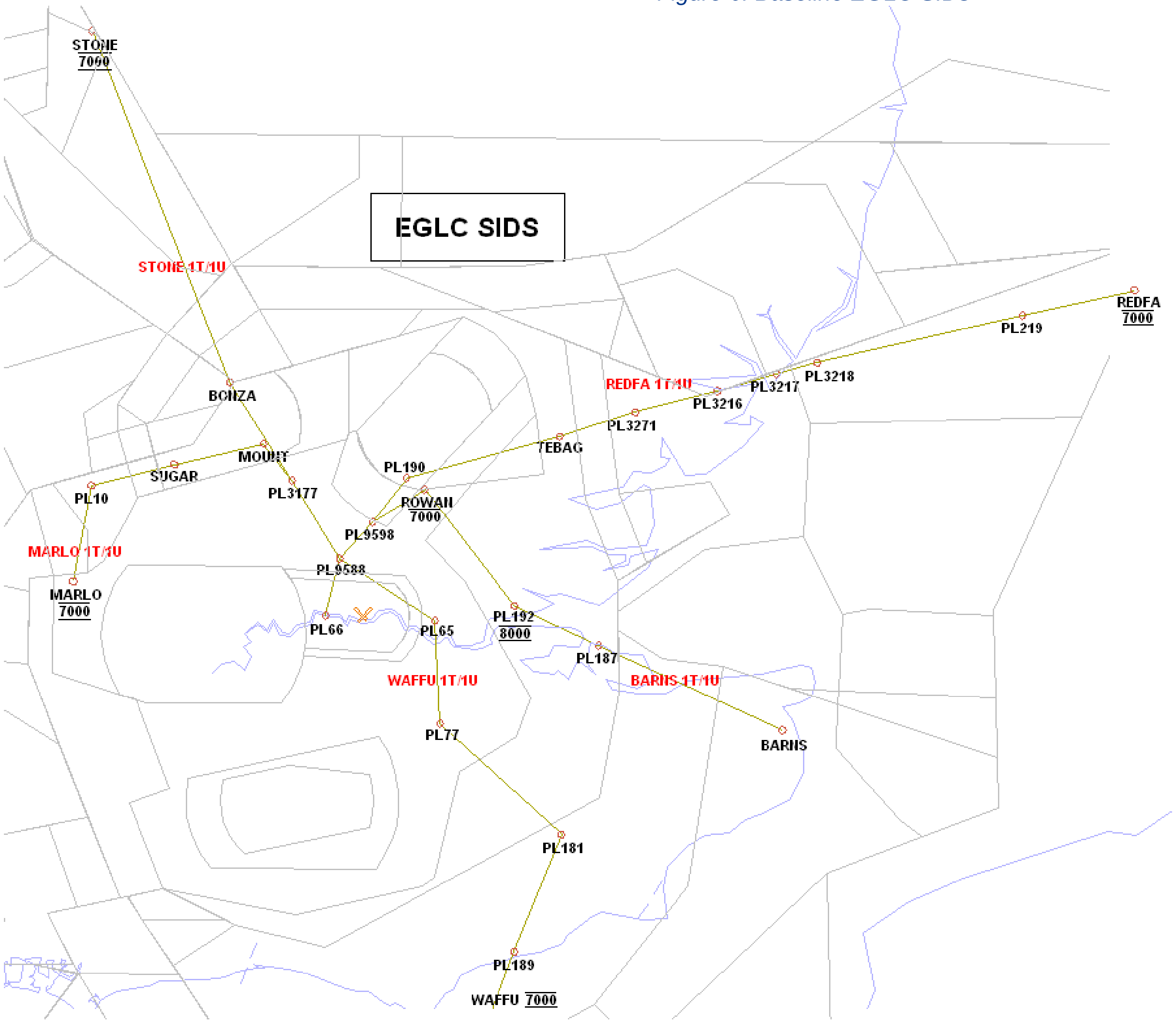


Figure 7: P-RNAV EGLC SIDs

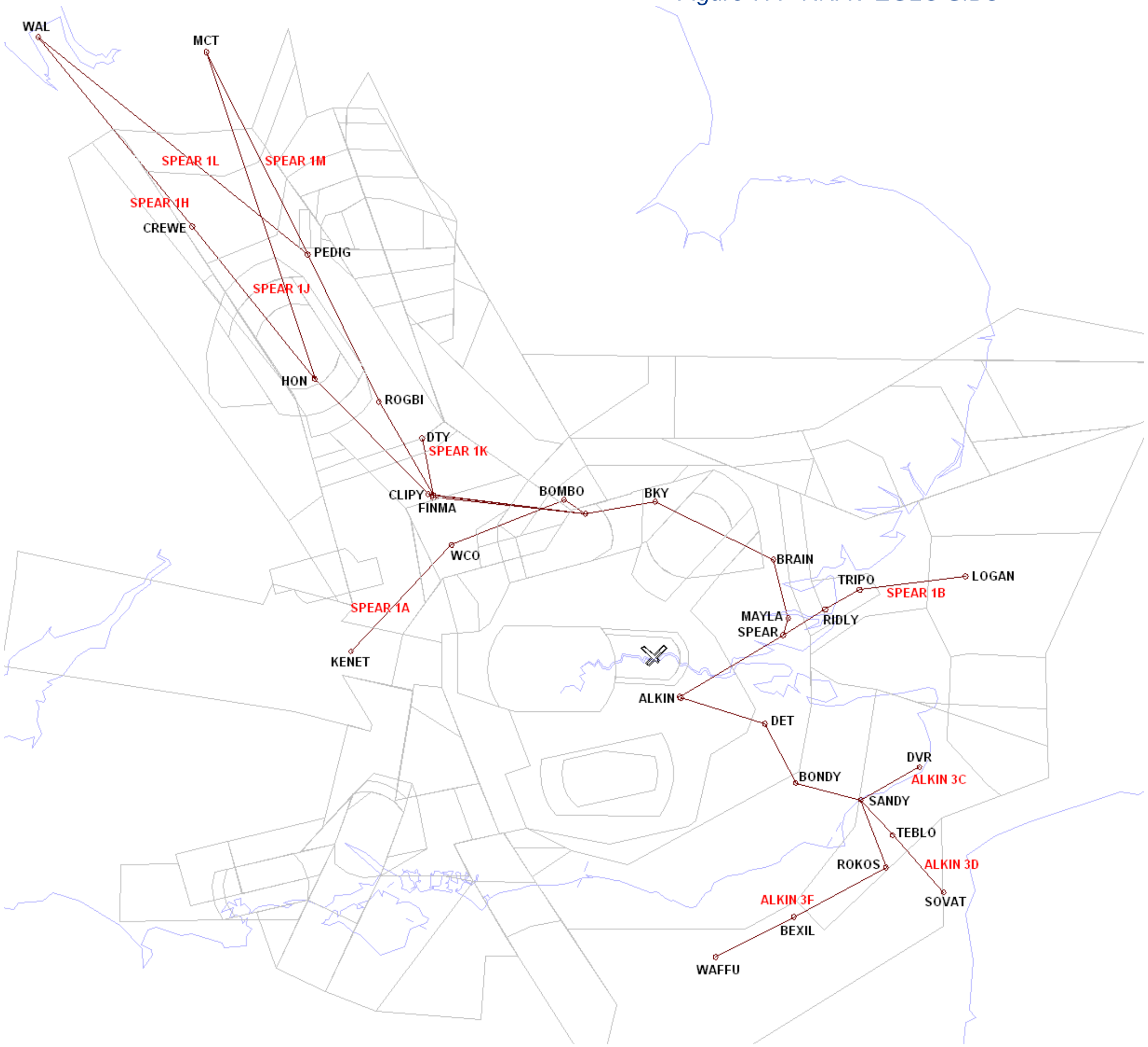


Figure 8: Baseline EGLC STARs

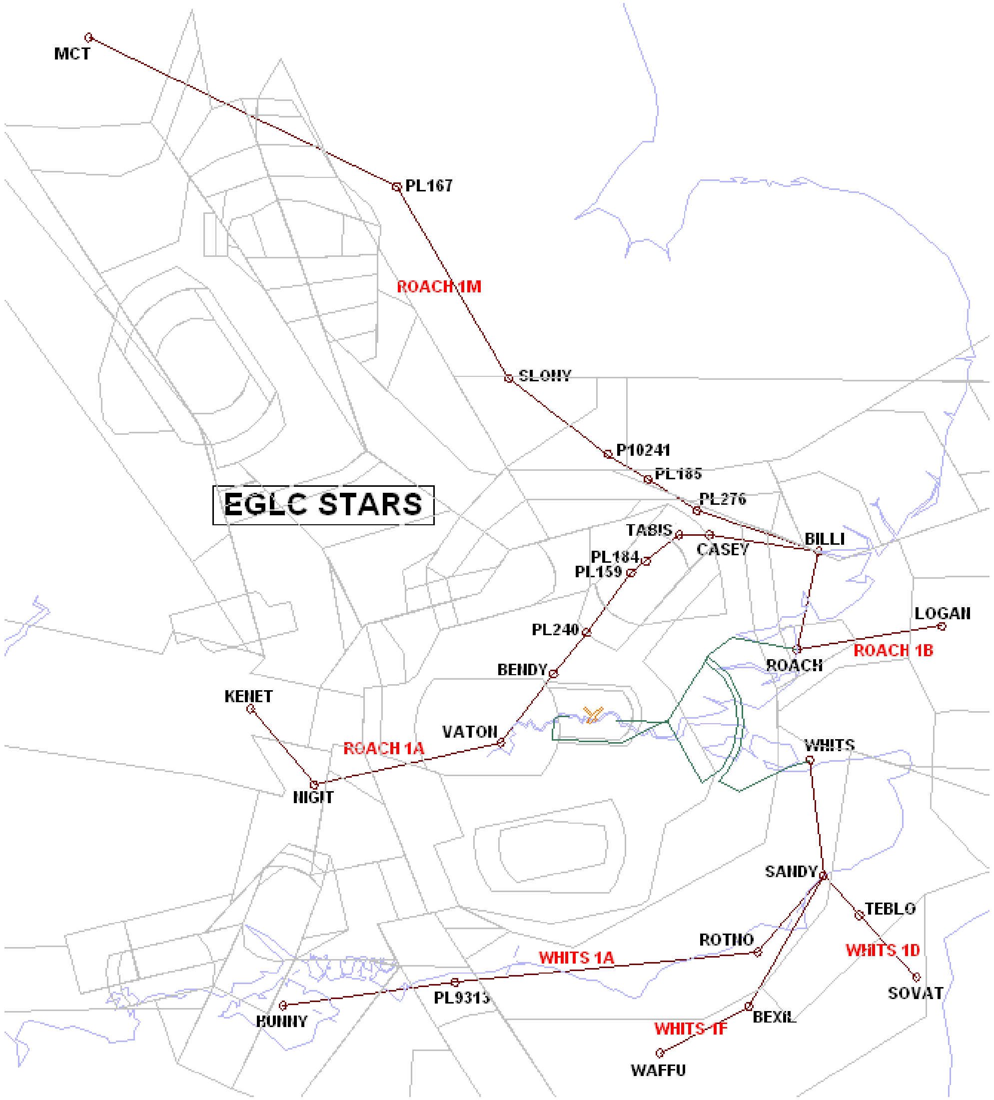


Figure 9: P-RNAV EGLC STARs

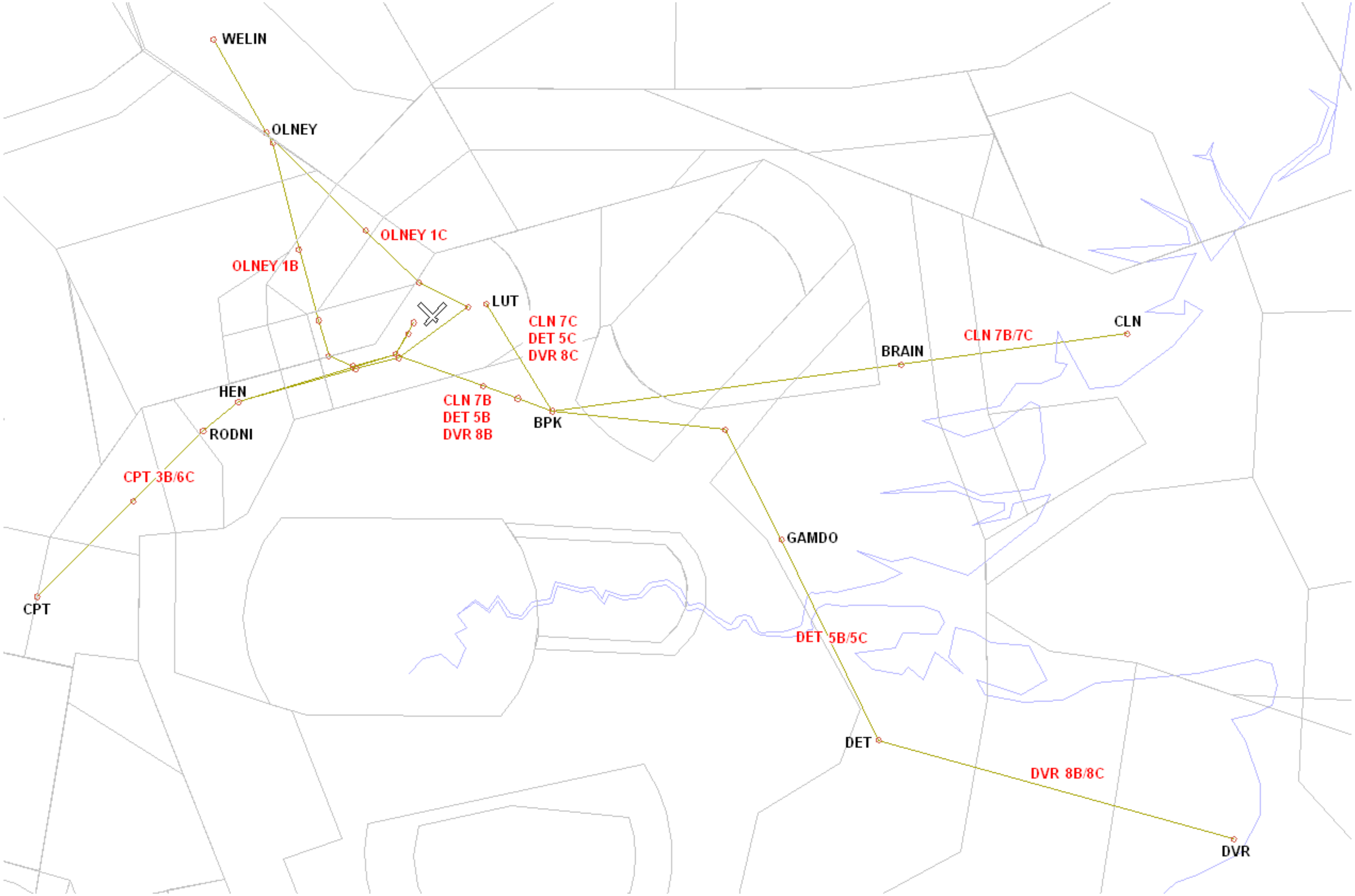

WELIN
OLNEY
OLNEY 1C
OLNEY 1B
LUT
CLN 7C
DET 5C
DVR 8C
CLN
CLN 7B/7C
BRAIN
HEN
RODNI
CLN 7B
DET 5B
DVR 8B
BPK
CPT 3B/6C
CPT
GAMDO
DET 5B/5C
DET
DVR 8B/8C
DVR

Figure 10: Baseline EGGW SIDs

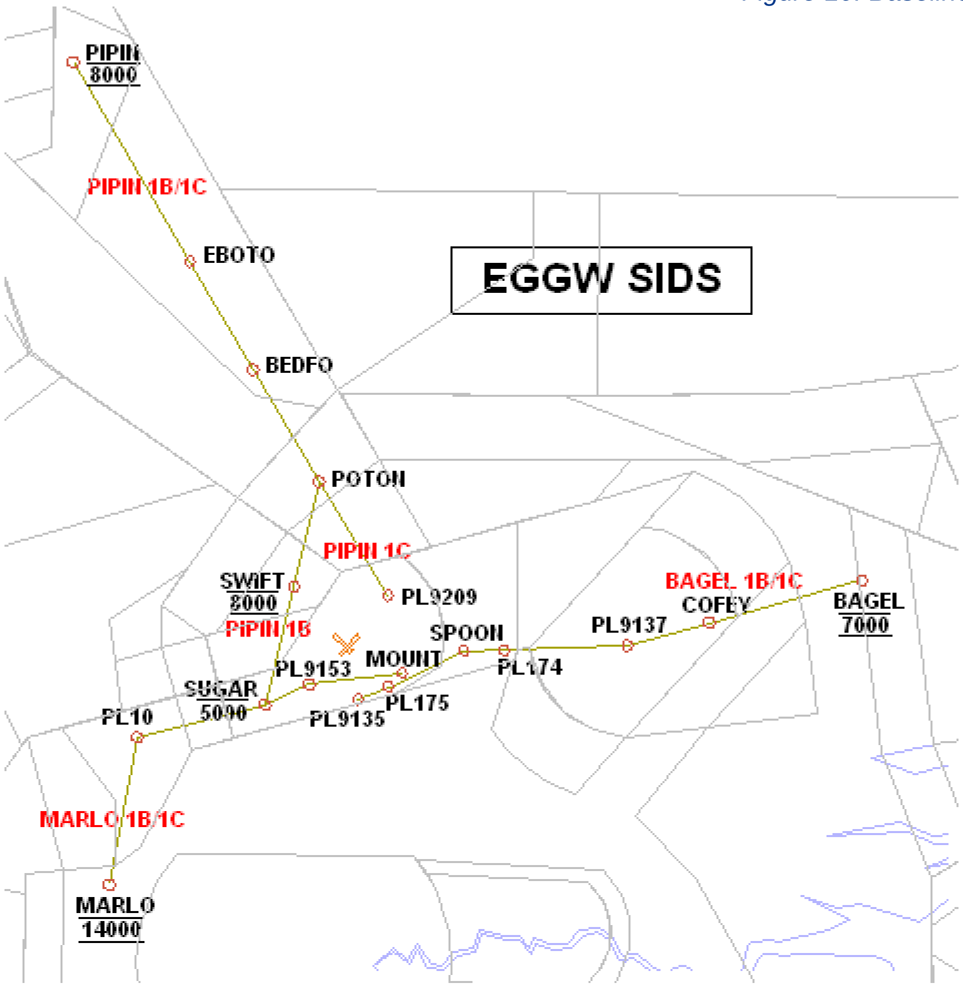


Figure 11: P-RNAV EGGW SIDs

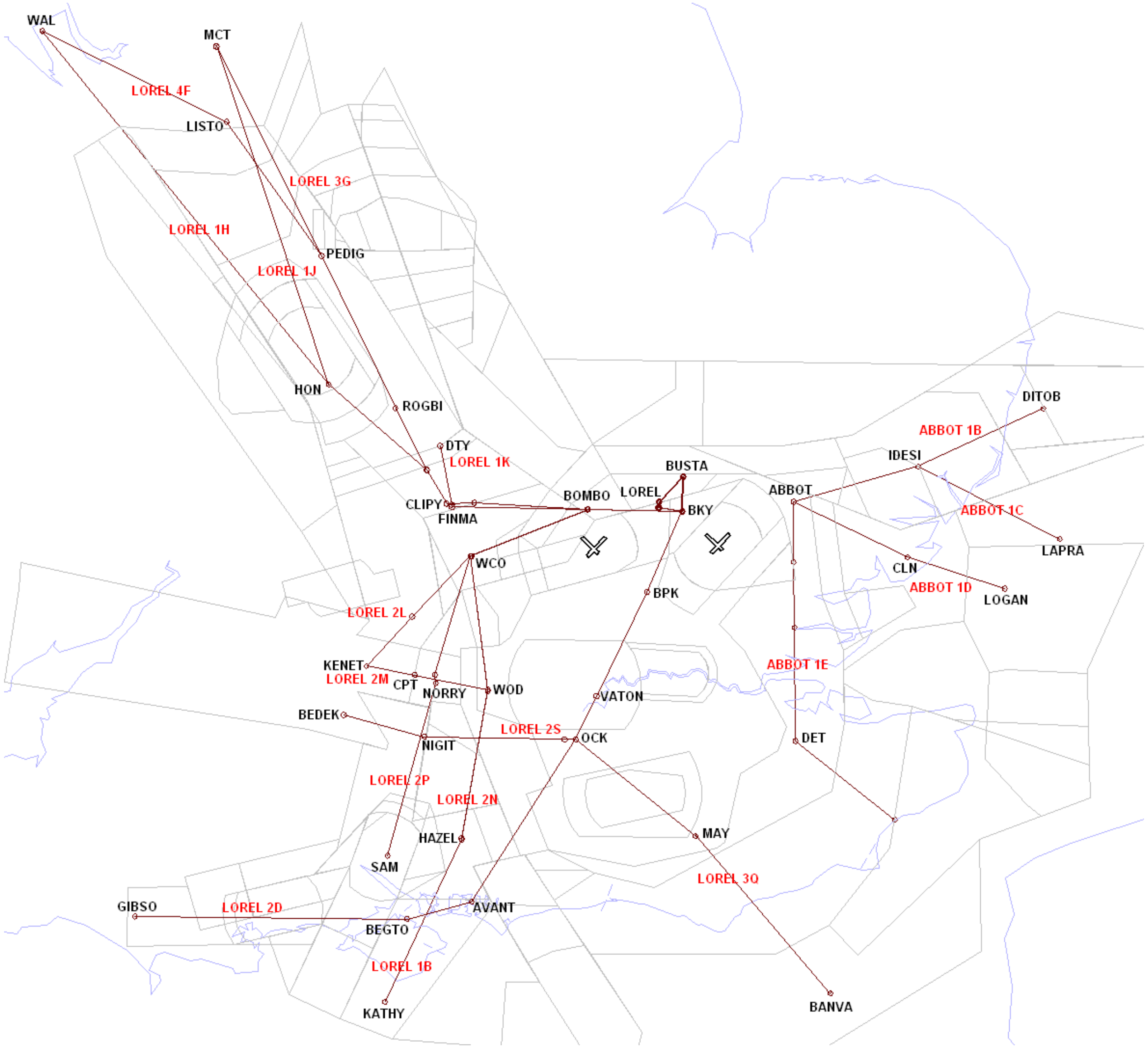


Figure 12: Baseline EGGW and EGSS STARs

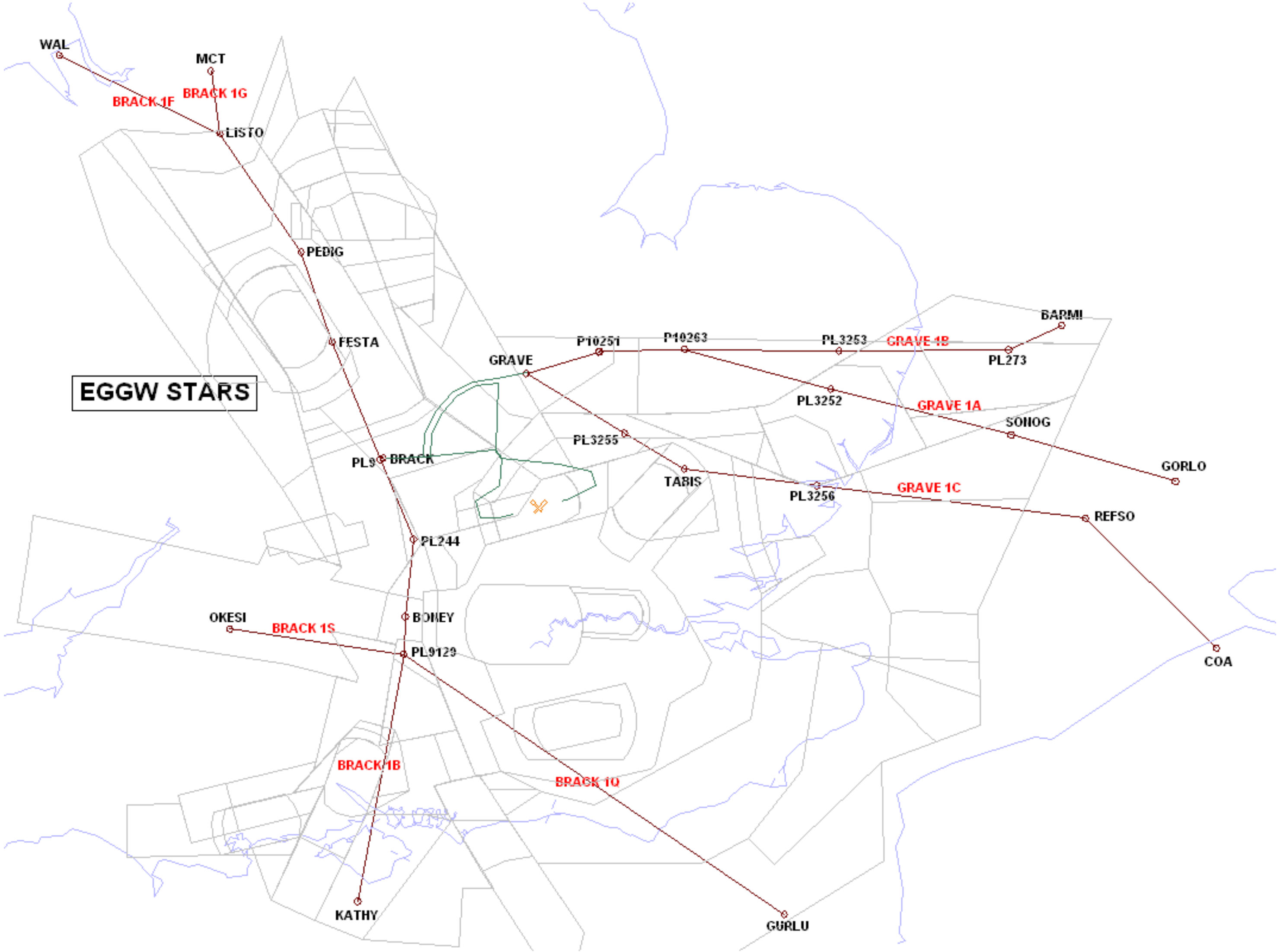


Figure 13: P-RNAV EGGW STARs

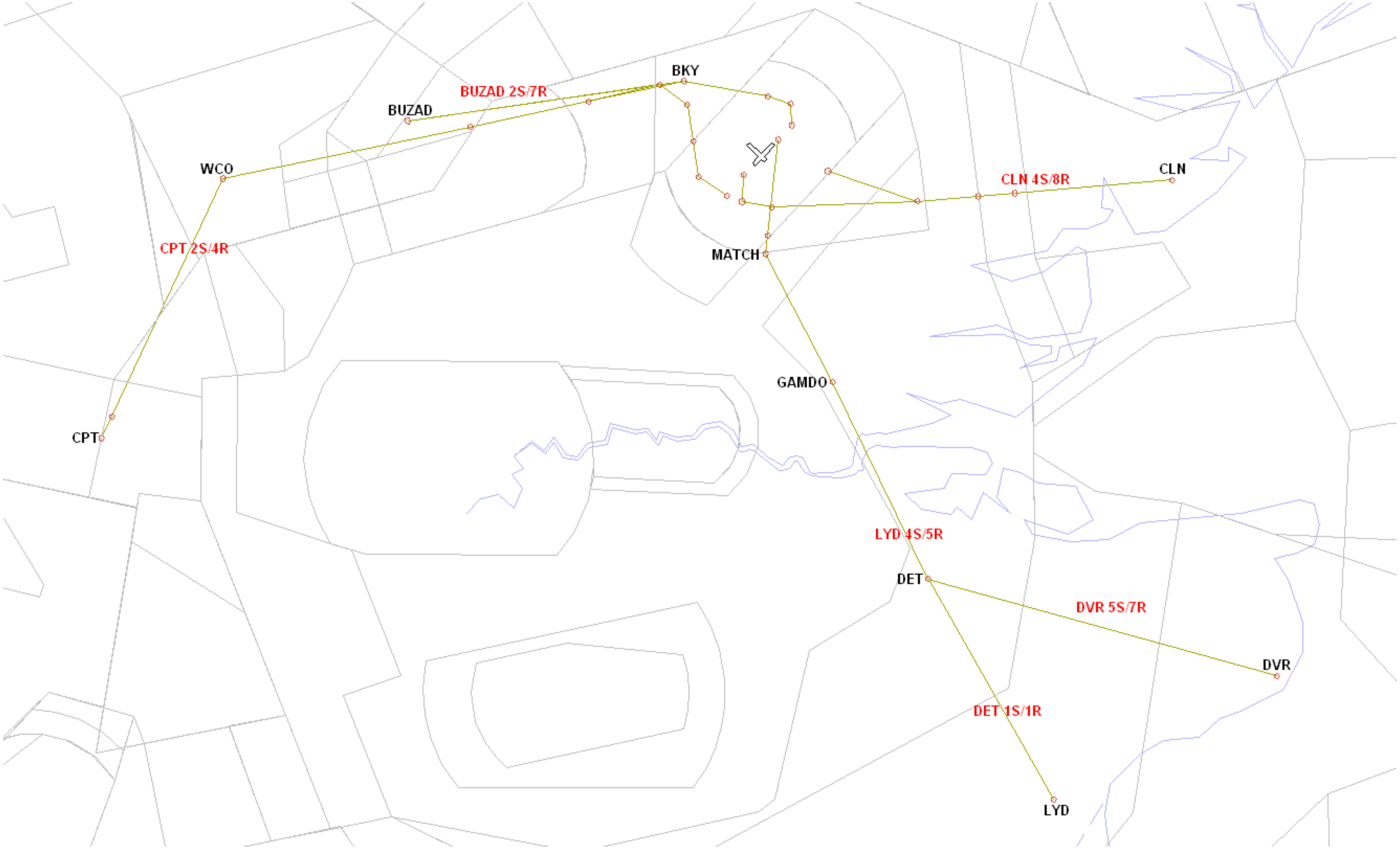


Figure 14: Baseline EGSS SIDs

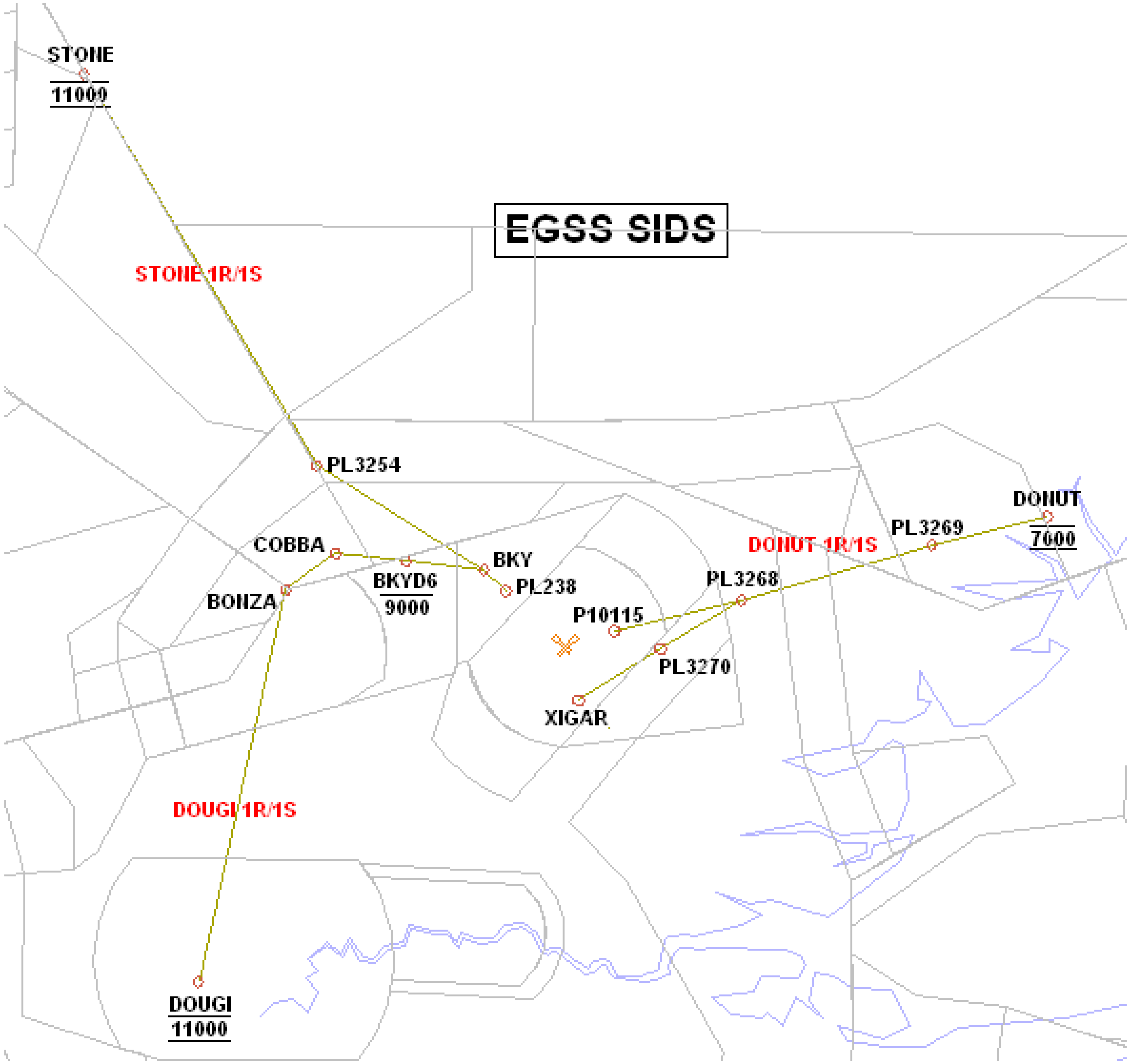


Figure 15: P-RNAV EGSS SIDs

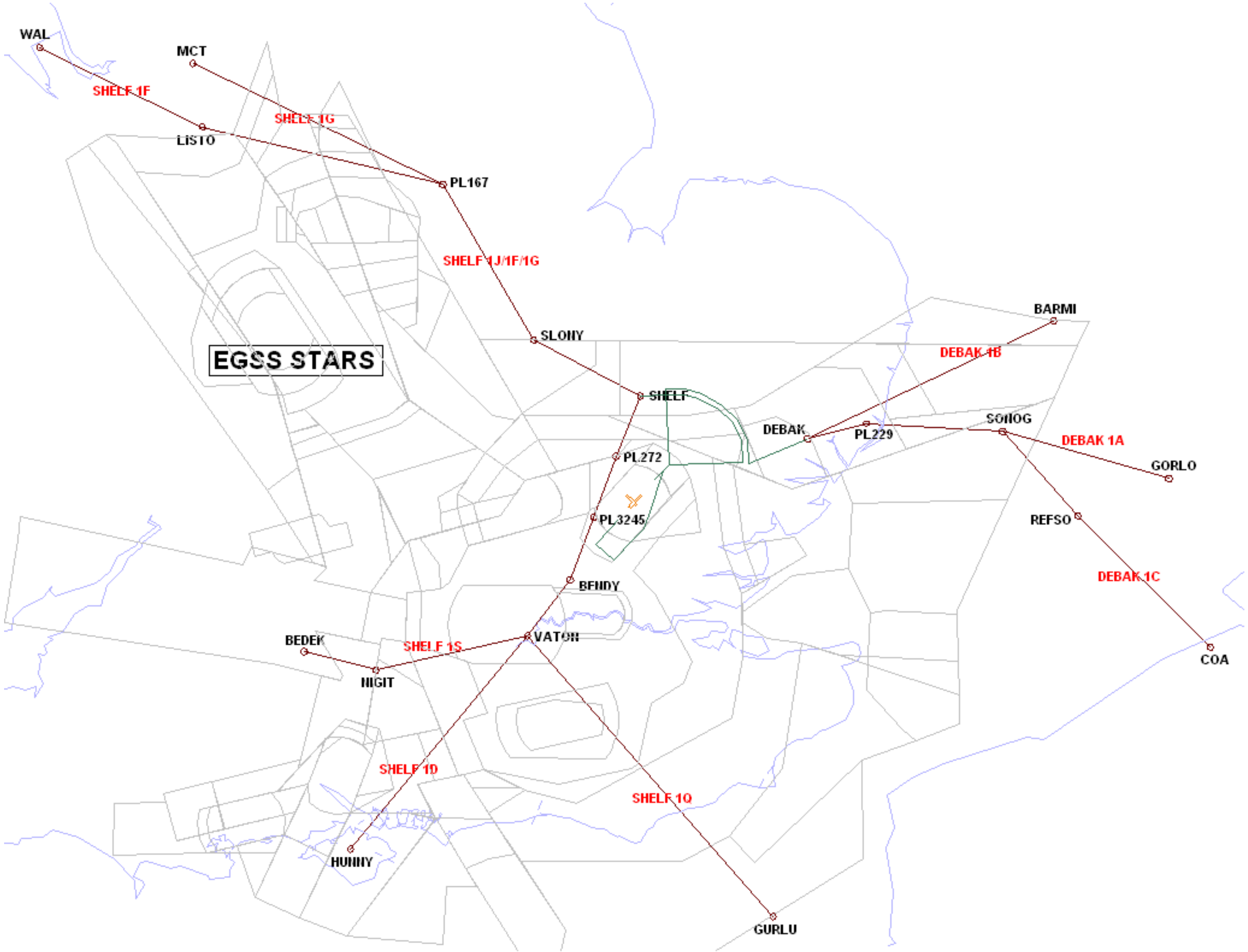


Figure 16: P-RNAV EGSS STARs

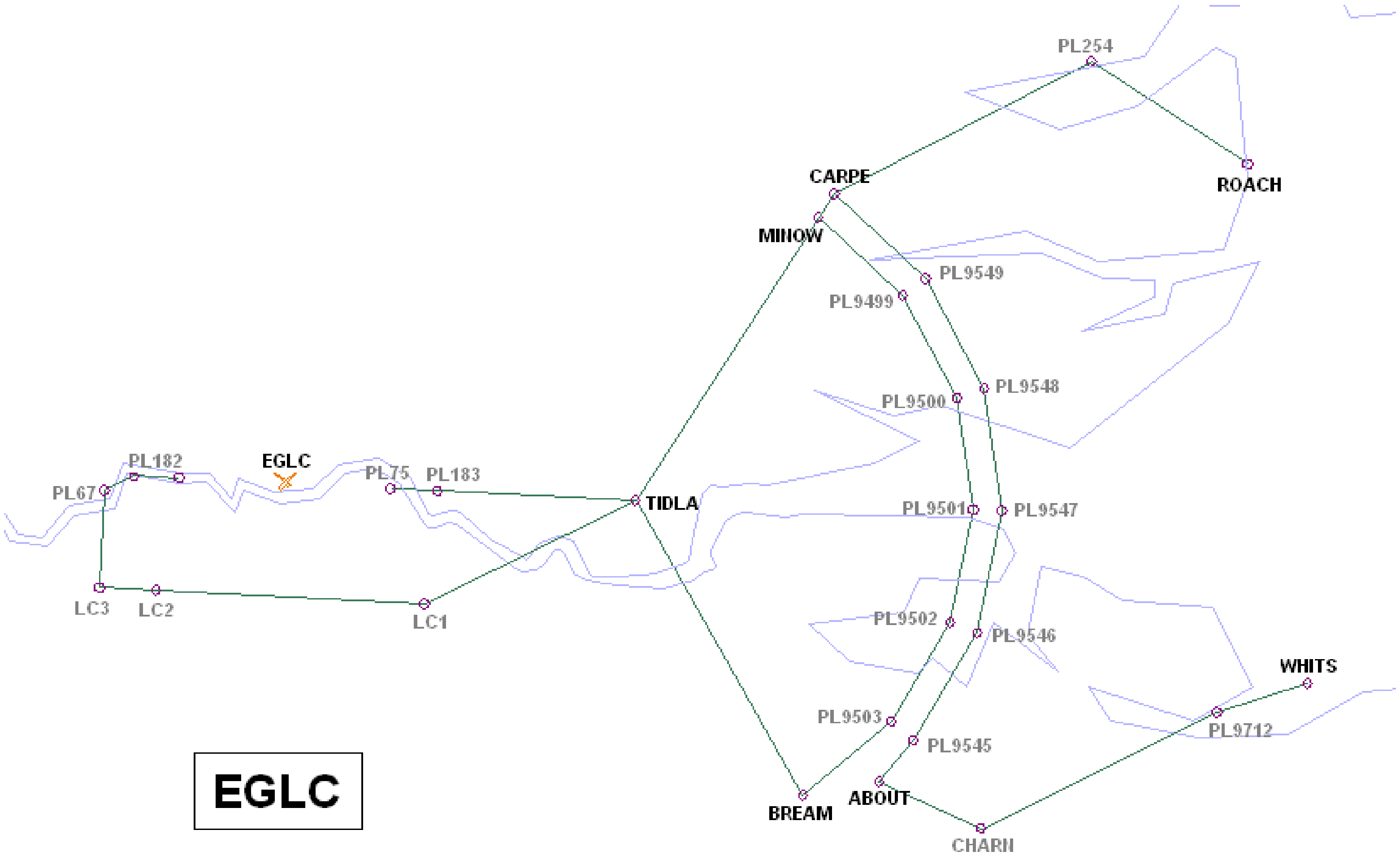


Figure 17: P-RNAV EGLC Transitions

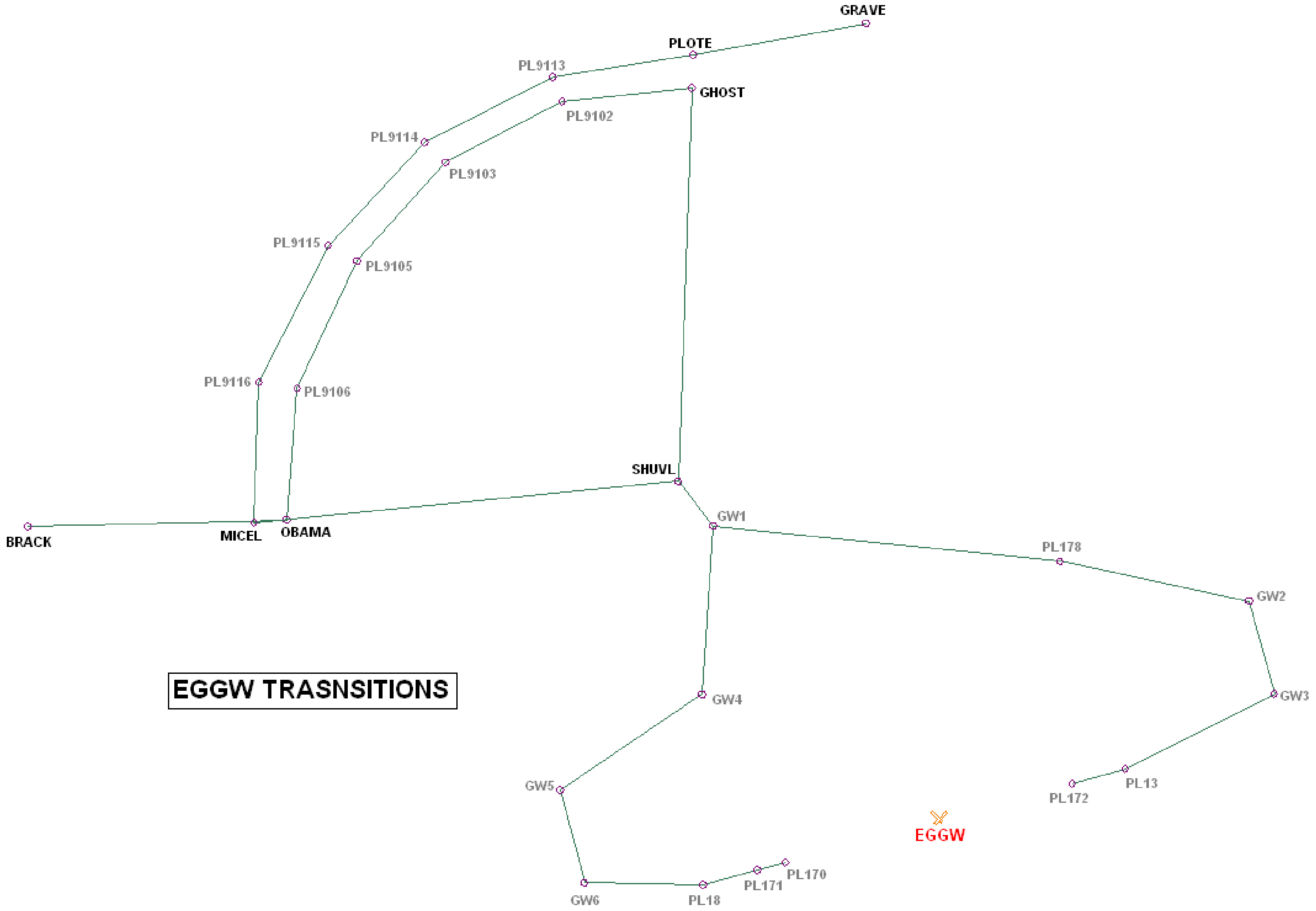


Figure 18: P-RNAV EGGW Transitions

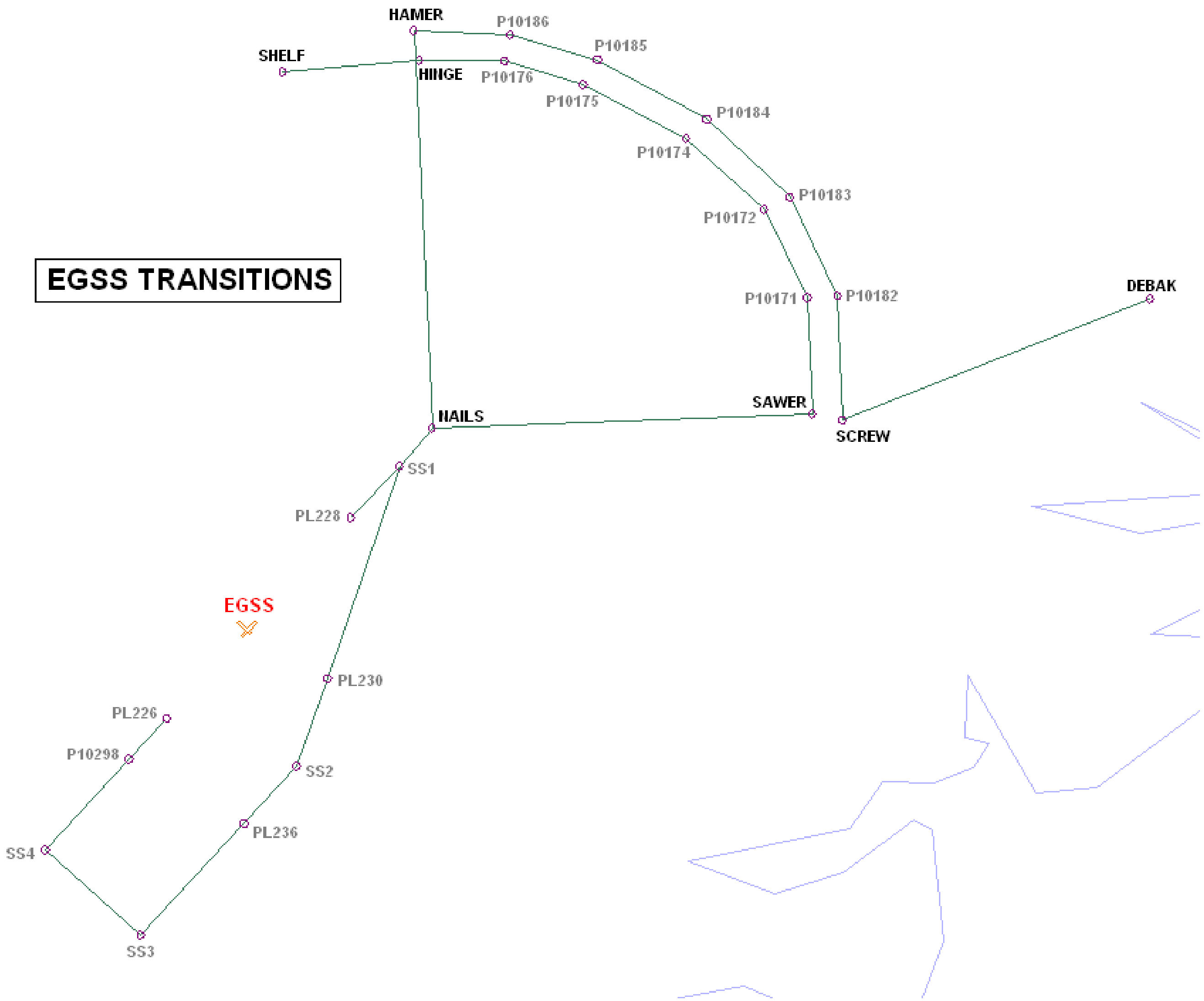


Figure 19: P-RNAV EGGW Transitions

Appendix D: Radar Track Plots London TMA

The following radar plots provide a cumulative picture of all matched scenarios run during the RTS for the London TMA (including non-nominal scenarios)

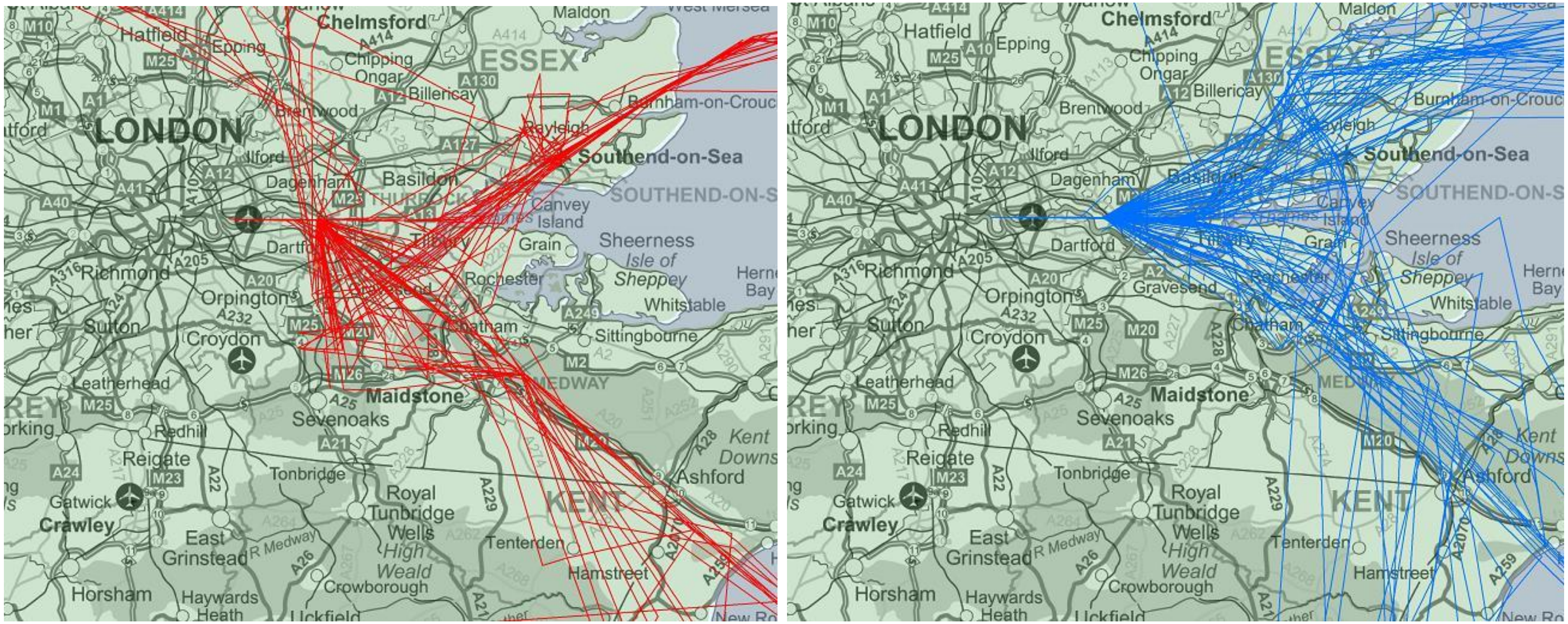


Figure 20: EGLC Arrivals: Current Airspace (Red) & P-RNAV Airspace (Blue)

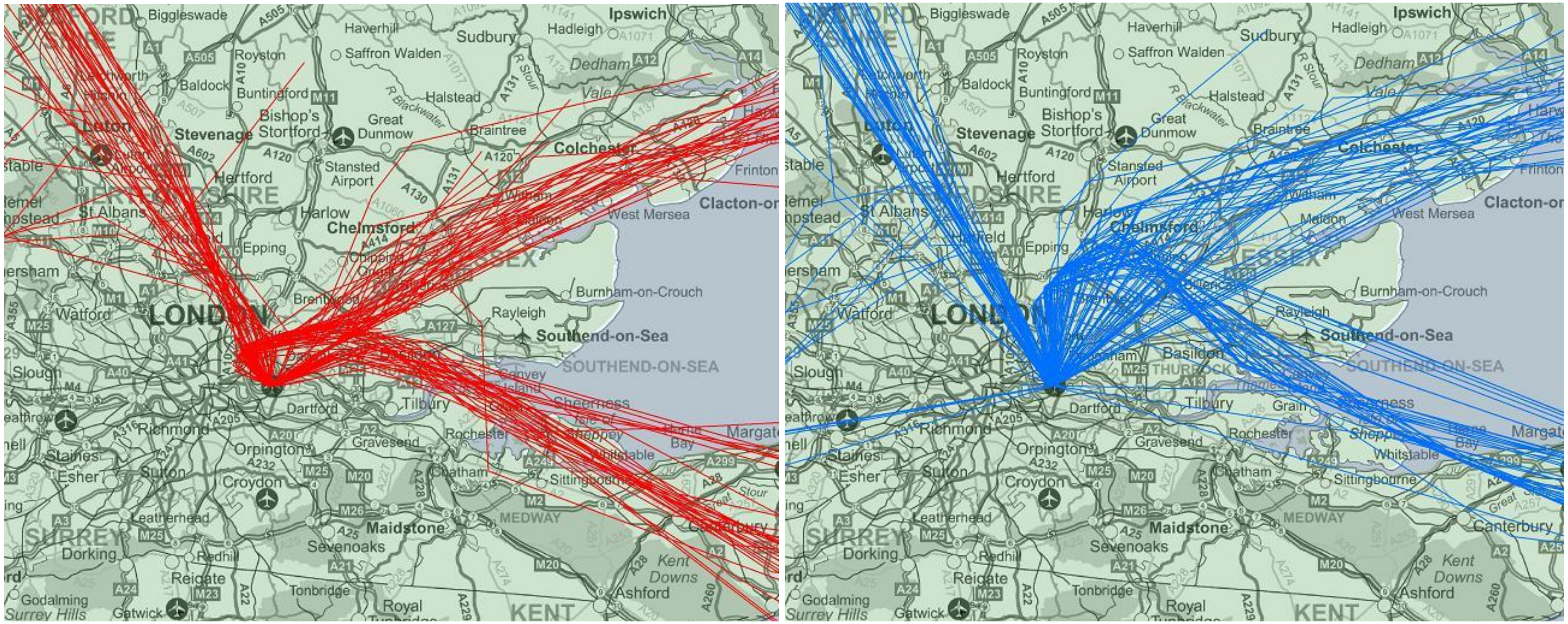


Figure 21: EGLC Departures: Current Airspace (Red) & P-RNAV Airspace (Blue)

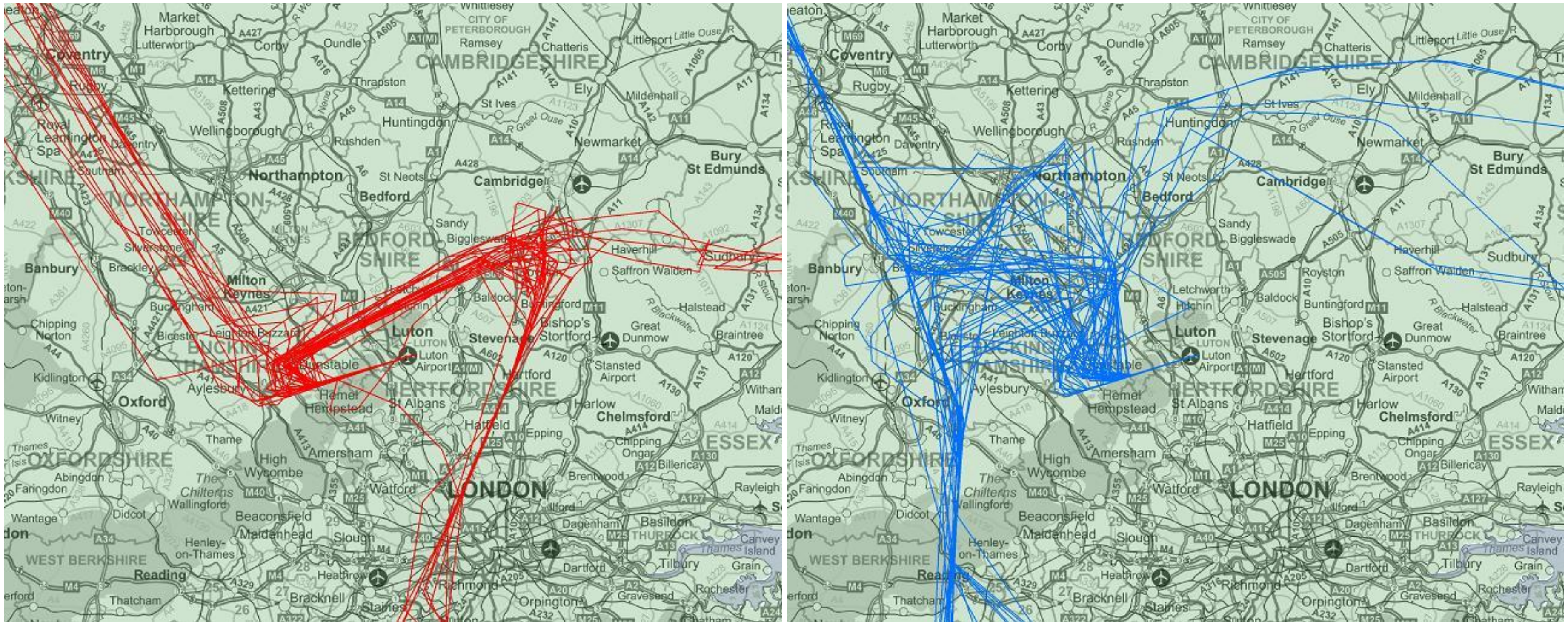


Figure 22: EGGW Arrivals: Current Airspace (Red) & P-RNAV Airspace (Blue)

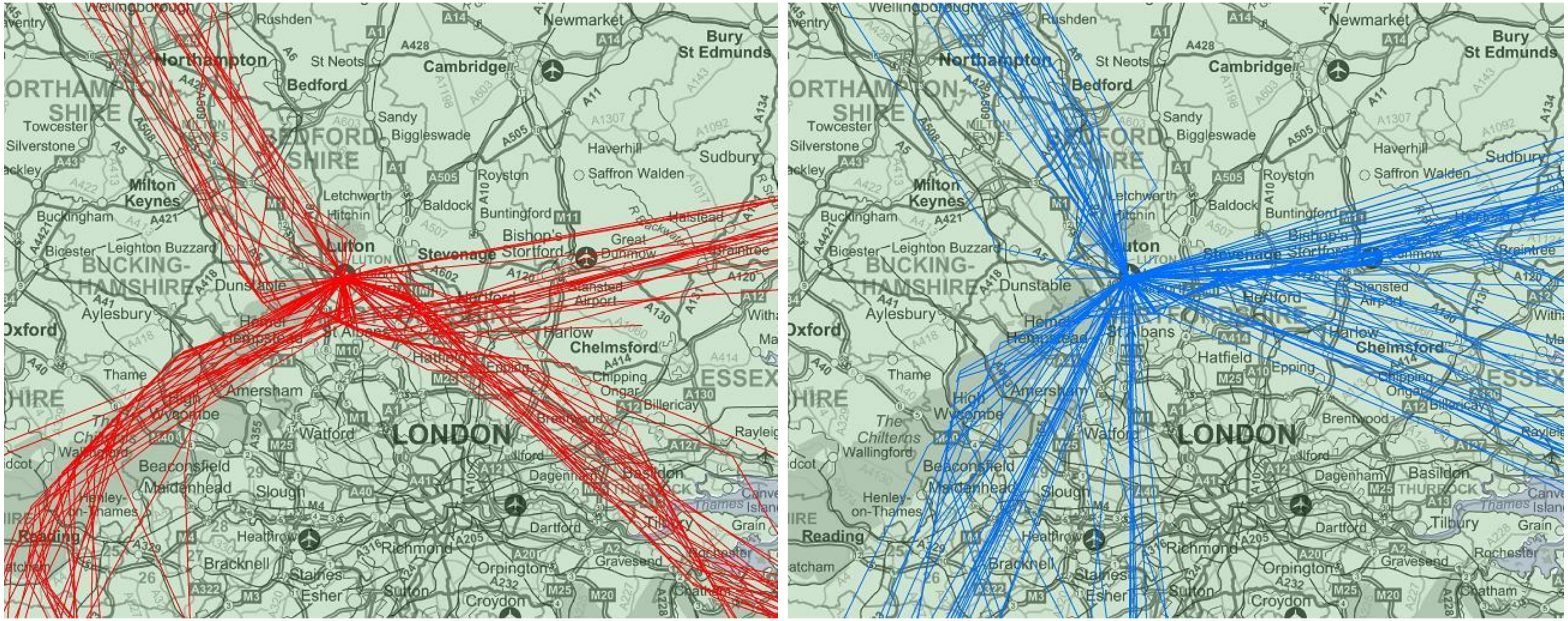


Figure 23: *EGGW Departures: Current Airspace (Red) & P-RNAV Airspace (Blue)*

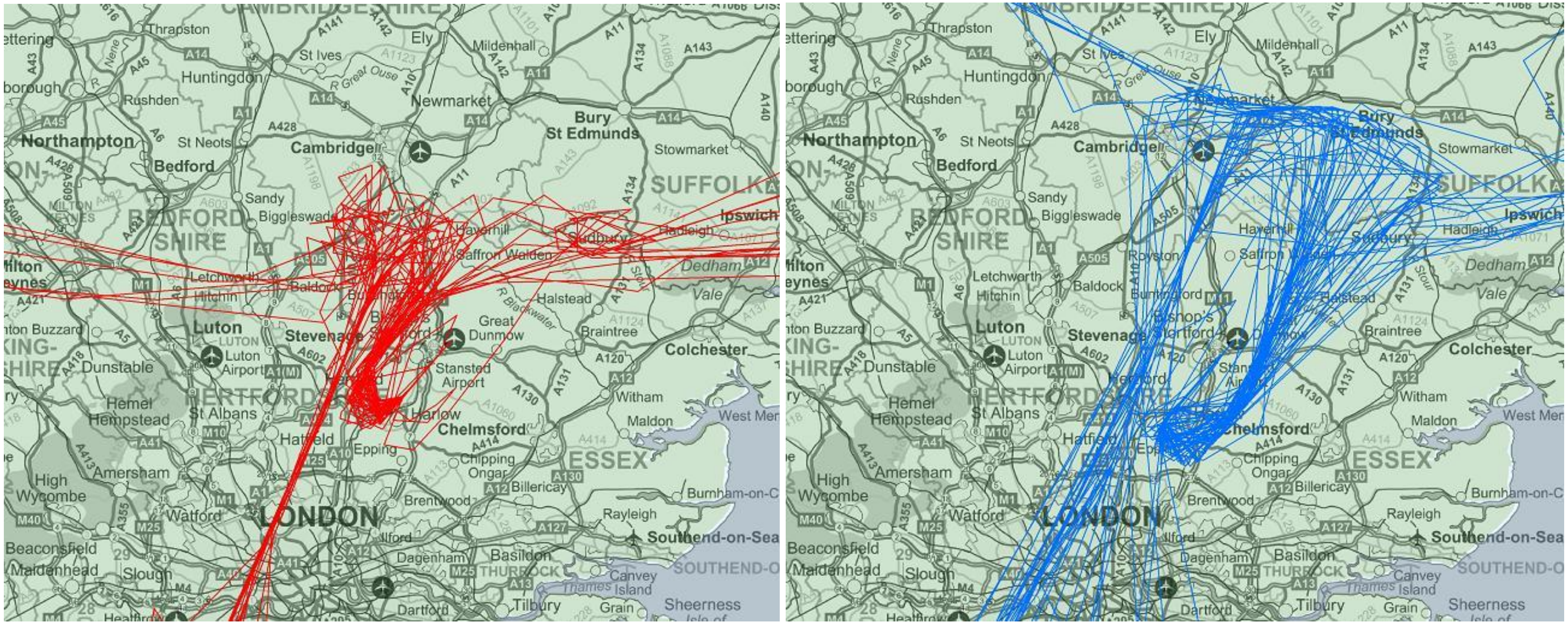


Figure 24: EGSS Arrivals: Current Airspace (Red) & P-RNAV Airspace (Blue)

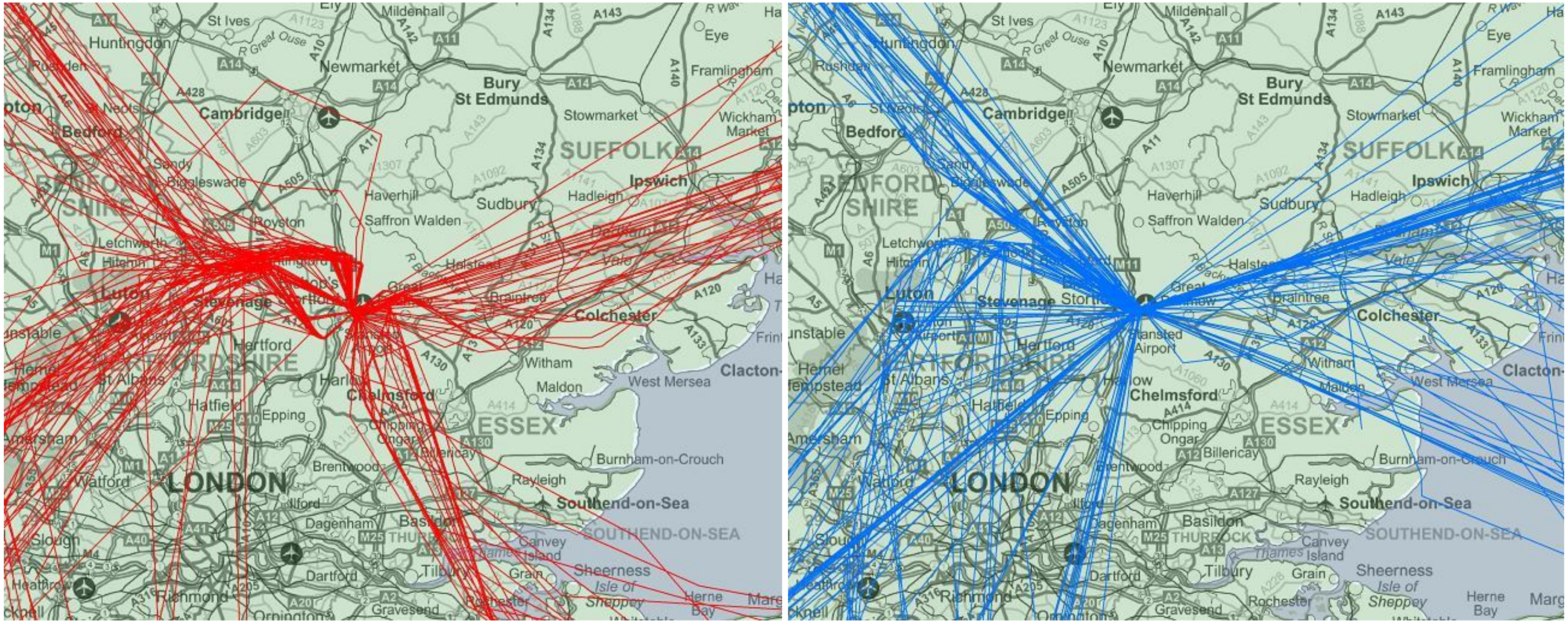


Figure 25: EGSS Departures: Current Airspace (Red) & P-RNAV Airspace (Blue)

Appendix E: Simulation Timetable London TMA

RunID	RTSA_ID	Date	Traffic Sample	Organisation	Wind Profile	Direction Operations	Non-nominal scenario	Match
ND1R1	111	13/11/11	6431_GAMAN	PMS	Nil	Easterly	P-RNAV Specific	n/a
ND1R2	112	13/11/11	6400_GAMAN	PMS	Nil	Easterly	P-RNAV Specific	n/a
ND1R3	113	13/11/11	6431_GAMAN	PMS	Nil	Westerly	P-RNAV Specific	n/a
ND2R1	121	14/11/11	6431_PAMAN	PMS	Nil	Easterly	P-RNAV Specific	n/a
ND2R2	122	14/11/11	6400_PAMAN	PMS	Nil	Easterly	P-RNAV Specific	n/a
ND2R3	123	14/11/11	6431_PAMAN	PMS	Nil	Westerly	P-RNAV Specific	n/a
ND2R4	124	14/11/11	6400_PAMAN	PMS	Nil	Westerly	P-RNAV Specific	n/a
ND3R1	131	15/11/11	6400_GAMAN	PMS	Light Easterly	Easterly	P-RNAV Specific	n/a
ND3R2	132	15/11/11	6400_GAMAN	PMS	Light Westerly	Westerly	P-RNAV Specific	n/a
ND3R3	133	15/11/11	6400_PAMAN	PMS	Medium Easterly	Easterly	P-RNAV Specific	n/a
ND3R4	134	15/11/11	6400_PAMAN	PMS	Medium North Westerly	Westerly	P-RNAV Specific	n/a
ND4R1	141	17/11/11	6431_GAMAN	PMS	Medium Easterly	Easterly	P-RNAV Specific	n/a
ND4R2	142	17/11/11	6431_GAMAN	PMS	Light South Westerly	Westerly	P-RNAV Specific	n/a
ND4R3	143	17/11/11	6431_PAMAN	PMS	Nil	Easterly	P-RNAV Specific	n/a
DD1R1	211	10/12/11	6431_GAMAN	Current	Light Easterly	Easterly	P-RNAV vs Baseline	1
DD1R2	212	10/12/11	6431_PAMAN	Current	Medium South Easterly	Easterly	P-RNAV vs Baseline	2
DD1R3	213	10/12/11	6431_GAMAN	PMS	Light Easterly	Easterly	P-RNAV vs Baseline	1
DD1R4	214	10/12/11	6431_PAMAN	PMS	Medium South Easterly	Easterly	P-RNAV vs Baseline	2
DD2R1	221	11/12/11	6400_GAMAN	PMS	Light North Easterly	Easterly	P-RNAV vs Baseline	3
DD2R2	222	11/12/11	6400_PAMAN	PMS	Nil	Easterly	P-RNAV vs Baseline	4
DD2R3	223	11/12/11	6400_GAMAN	Current	Light North Easterly	Easterly	P-RNAV vs Baseline	3
DD2R4	224	11/12/11	6400_PAMAN	Current	Nil	Easterly	P-RNAV vs Baseline	4
DD3R1	231	12/12/11	6431_GAMAN	Current	Nil	Westerly	P-RNAV vs Baseline	5
DD3R2	232	12/12/11	6431_PAMAN	Current	Nil	Westerly	P-RNAV vs Baseline	6
DD3R3	233	12/12/11	6431_GAMAN	PMS	Nil	Westerly	P-RNAV vs Baseline	5
DD3R4	234	12/12/11	6431_PAMAN	PMS	Nil	Westerly	P-RNAV vs Baseline	6
DD4R1	241	13/12/11	6400_GAMAN	PMS	Nil	Westerly	P-RNAV vs Baseline	7
DD4R2	242	13/12/11	6400_PAMAN	PMS	Nil	Westerly	P-RNAV vs Baseline	8
DD4R3	243	13/12/11	6400_GAMAN	Current	Nil	Westerly	P-RNAV vs Baseline	7

RunID	RTSA_ID	Date	Traffic Sample	Organisation	Wind Profile	Direction Operations	Non-nominal scenario	Match
DD4R4	244	13/12/11	6400_PAMAN	Current	Nil	Westerly	P-RNAV vs Baseline	8
DD5R1	251	14/12/11	6431_GAMAN	PMS	Strong Easterly	Easterly	P-RNAV Specific	n/a
DD5R2	252	14/12/11	6431_GAMAN	PMS	Light Westerly	Westerly	P-RNAV Specific	n/a
DD5R3	253	14/12/11	6400_GAMAN	PMS	Strong Westerly	Westerly	P-RNAV Specific	n/a

Appendix F: Airspace Design Milan TMA

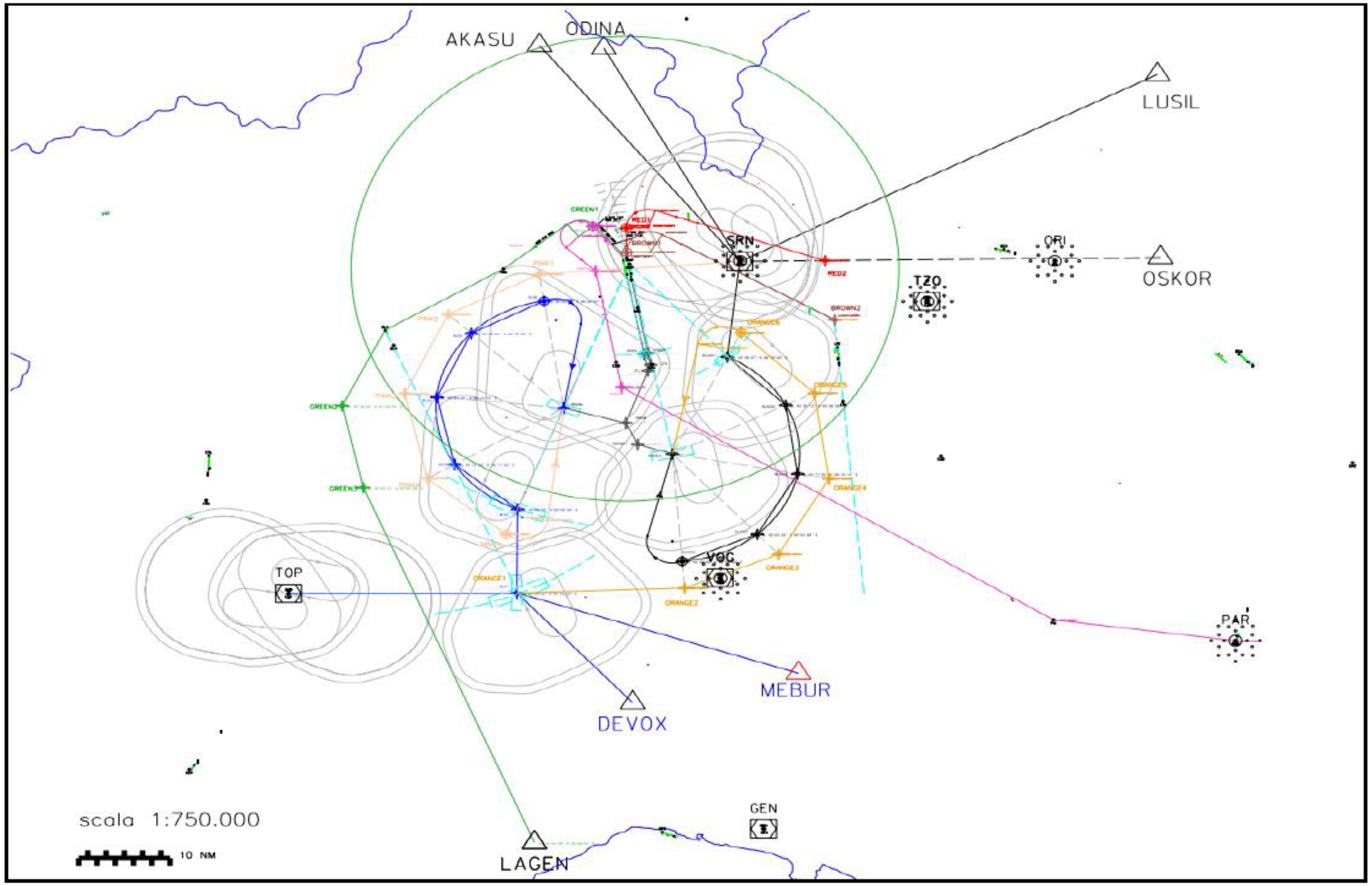


Figure 26: Milan Procedure Design (SIDs and STARs)

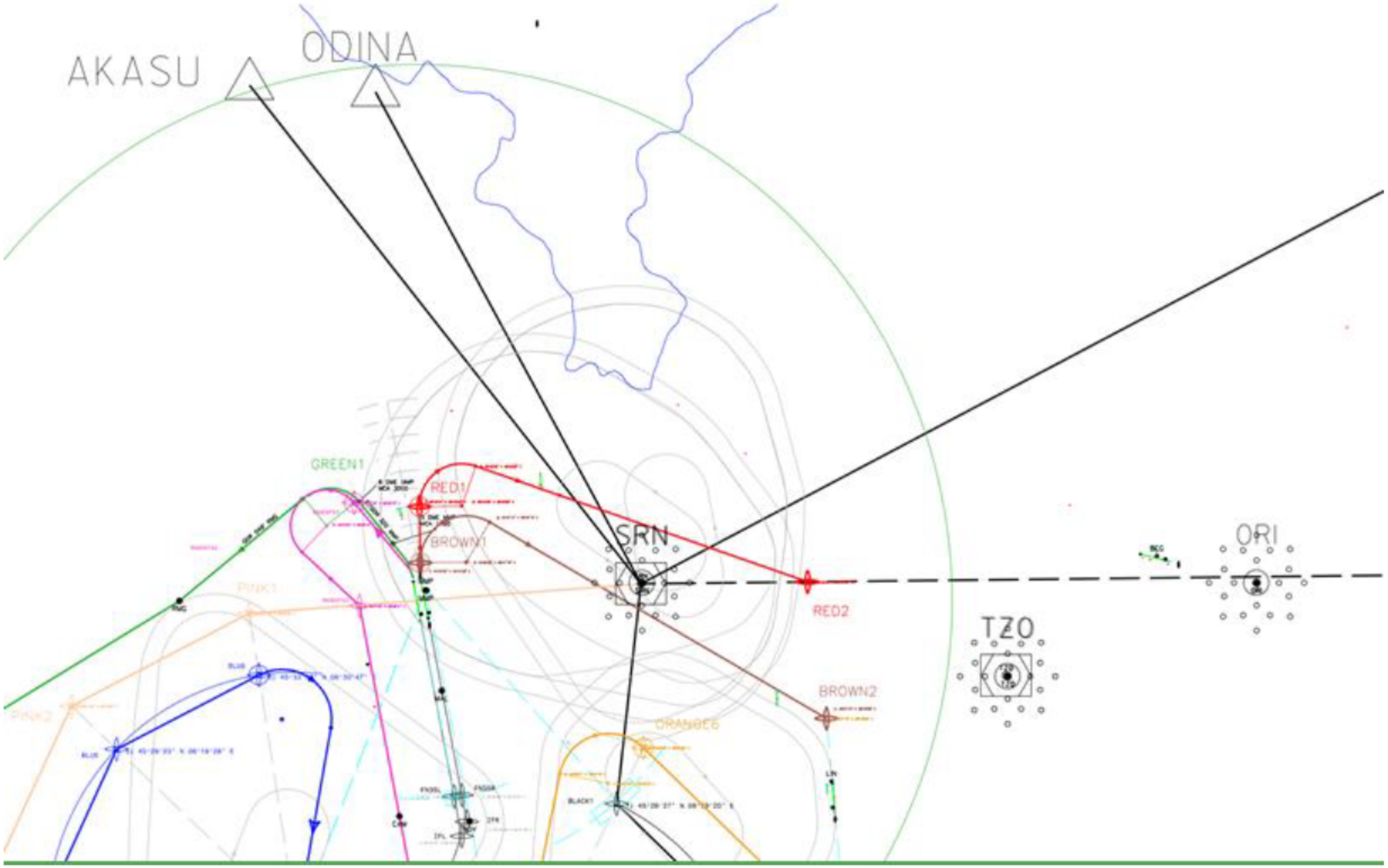


Figure 27: Milan Procedure Design (SIDs detail)

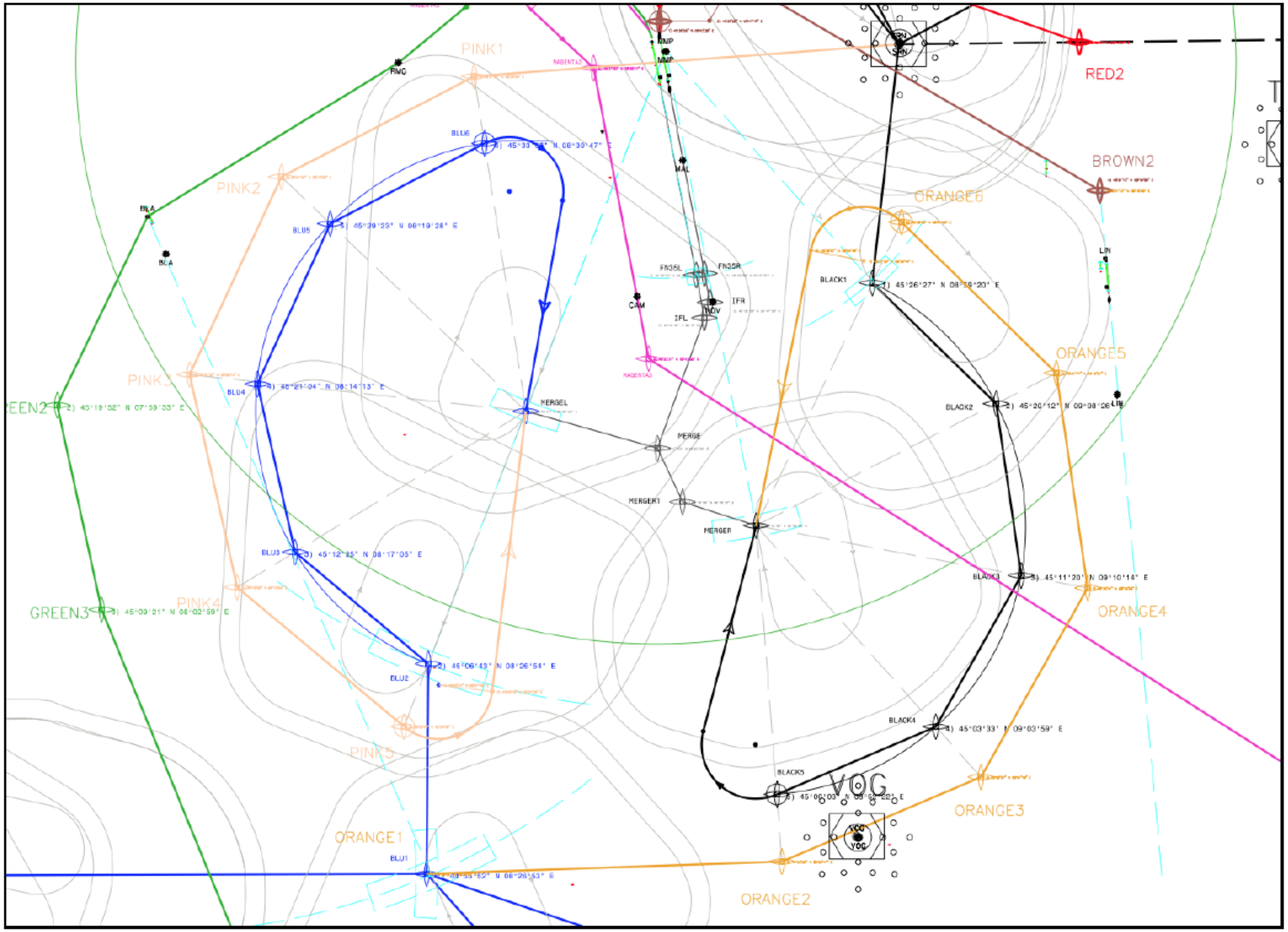


Figure 28: Milan Procedure Design (STARs detail)

STARs

NAME	CODE	GO TO FL	SPEED KT	POINT 1	POINT 2	SPEED KT	POINT 3	POINT 4	POINT 5	POINT 6	POINT 7	MERGER
ODINA 1Z	ODI 1Z	150/200	250	ODINA	SRN		BLAK1	BLAK2	BLAK3	BLAK4	BLAK5	
					MERGER	220	MERGER1	MERGE	IF L/R 35	FN L/R 35		
AKASU 1Z	AKA 1Z	150/200	250	AKASU	SRN		BLAK1	BLAK2	BLAK3	BLAK4	BLAK5	
					MERGER	220	MERGER1	MERGE	IF L/R 35	FN L/R 35		
LUSIL 1Z	LUS 1Z	150/200	250	LUSIL	SRN		BLAK1	BLAK2	BLAK3	BLAK4	BLAK5	
					MERGER	220	MERGER1	MERGE	IF L/R 35	FN L/R 35		
OSKOR 1Z	OSK 1Z	150/200	250	OSKOR	SRN		BLAK1	BLAK2	BLAK3	BLAK4	BLAK5	
					MERGER	220	MERGER1	MERGE	IF L/R 35	FN L/R 35		
NAME	**CODE**	**GO TO FL**	**SPEED KT**	**POINT 1**	**POINT 2**	**SPEED KT**	**POINT 3**	**POINT 4**	**POINT 5**	**POINT 6**	**POINT 7**	**MERGEL**
TOP 1Z	TOP 1Z	150/200	250	TOP	BLU1		BLU2	BLU3	BLU4	BLU5	BLU6	
					MERGEL	220	MERGEL1	MERGE	IF L/R 35	FN L/R 35		
DEVOX 1Z	NED 1Z	150/200	250	DEVOX	BLU1		BLU2	BLU3	BLU4	BLU5	BLU6	
					MERGEL	220	MERGEL1	MERGE	IF L/R 35	FN L/R 35		
MEBUR 1Z	TOP 1Z	150/200	250	MEBUR	BLU1		BLU2	BLU3	BLU4	BLU5	BLU6	
					MERGEL	220	MERGEL1	MERGE	IF L/R 35	FN L/R 35		

REFERENCE WAYPOINTS

NAME	LATITUDE	LONGITUDE	NAME	LATITUDE	LONGITUDE
BLACK1	45°26'27"	08°59'20"	OSKOR	45°38'57"	10°07'00"
BLACK2	45°20'12"	09°08'26"	LUSIL	46°02'35"	10°07'00"
BLACK3	45°11'20"	09°10'14"	ODINA	46°06'16"	08°39'54"
BLACK4	45°03'33"	09°03'59"	AKASU	46°06'35"	08°29'44"
BLACK5 (FLY OVER)	45°00'03"	08°52'22"	ORI	45°38'38"	09°50'30"
BLACK5 (centro virata)	45°02'37"	08°50'50"	MERGER	45°13'55"	08°50'50"
BLACK5 (fine virata)	45°03'18"	08°47'00"	MERGER1	45°15'08"	08°45'27"
BLU1	44°55'52"	08°26'53"	MERGE	45°17'53"	08°43'36"
BLU2	45°06'43"	08°26'54"	MERGEL	45°19'47"	08°33'56"
BLU3	45°12'25"	08°17'05"	IFR	45°26'55"	08°47'01"
BLU4	45°21'04"	08°14'13"	FN35R	45°25'26"	08°47'25"
BLU 5	45°29'23"	08°19'28"	IFL	45°26'50"	08°46'24"
BLU 6 (FLY OVER)	45°33'35"	08°30'47"	FN35L	45°24'37"	08°47'00"
BLU6 (centro virata)	45°31'07"	08°32'38"	MEBUR	44°45'35"	09°10'18"
BLU6 (fine virata)	45°30'39"	08°36'33"	DEVOX	44°41'46"	08°44'49"
			TOP	44°55'31"	07°51'42"

Table 48: Path description: STARs (1/2)

STARs

NAME	CODE	GO TO FL	SPEED KT	POINT 1	POINT 2	SPEED KT	POINT 3	POINT 4	POINT 5	POINT 6	POINT 7	MERGER
ODINA 1Y	ODI 1Y		250	ODINA	SRN		PINK1	PINK2	PINK 3	PINK 4	PINK 5	
					MERGEL	220	MERGEL1	MERGE	IF L/R 35	FN L/R 35		
AKASU 1Y	AKA 1Y		250	AKASU	SRN		PINK1	PINK2	PINK 3	PINK 4	PINK 5	
					MERGER	220	MERGEL1	MERGE	IF L/R 35	FN L/R 35		
LUSIL 1Y	LUS 1Y		250	LUSIL	SRN		PINK1	PINK2	PINK 3	PINK 4	PINK 5	
					MERGER	220	MERGEL1	MERGE	IF L/R 35	FN L/R 35		
OSKOR 1Y	OSK 1Y		250	OSKOR	SRN		PINK1	PINK2	PINK 3	PINK 4	PINK 5	
					MERGER	220	MERGEL1	MERGE	IF L/R 35	FN L/R 35		
NAME	**CODE**	**GO TO FL**	**SPEED KT**	**POINT 1**	**POINT 2**	**SPEED KT**	**POINT 3**	**POINT 4**	**POINT 5**	**POINT 6**	**POINT 7**	**MERGEL**
TOP 1Y	TOP 1Y		250	TOP	ORANGE1		ORANGE 2	ORANGE 3	ORANGE 4	ORANGE 5	ORANGE 6	
					MERGEL	220	MERGER1	MERGE	IF L/R 35	FN L/R 35		
DEVOX 1Y	NED 1Y		250	DEVOX	ORANGE1		ORANGE 2	ORANGE 3	ORANGE 4	ORANGE 5	ORANGE 6	
					MERGEL	220	MERGER1	MERGE	IF L/R 35	FN L/R 35		
MEBUR 1Y	TOP 1Y		250	MEBUR	ORANGE1		ORANGE 2	ORANGE 3	ORANGE 4	ORANGE 5	ORANGE 6	
					MERGEL	220	MERGER1	MERGE	IF L/R 35	FN L/R 35		

REFERENCE WAYPOINTS

NAME	LATITUDE	LONGITUDE	NAME	LATITUDE	LONGITUDE
PINK1	45°37'02"	08°29'59"			
PINK2	45°31'46"	08°15'50"			
PINK3	45°21'32"	08°09'14"			
PINK4	45°10'35"	08°12'53"			
PINK5 (FLY OVER)	45°03'28"	08°25'09"			
PINK 5 (centro virata)	45°05'37"	08°27'40"			
PINK 5 (fine virata)	45°05'18"	08°31'35"			
ORANGE1	44°55'52"	08°26'53"			
ORANGE 2	44°56'35"	08°52'47"			
ORANGE 3	45°00'57"	09°07'16"			
ORANGE 4	45°10'41"	09°15'06"			
ORANGE 5	45°21'47"	09°12'51"			
ORANGE 6 (FLY OVER)	45°29'35"	09°01'29"			
ORANGE 6 (centro virata)	45°27'35"	08°58'43"			
ORANGE 6 (fine virata)	45°28'07"	08°54'49"			

Table 49: Path description: STARs (2/2)

SIDs												
NAME	CODE			POINT 1	POINT 2	POINT 3	POINT 4	POINT 5	POINT 6	POINT 7	MERGER	
PAR	PAR 5Z			MAGENTA1	MAGENTA2	MAGENTA3	PIA	PAR				
				IAS 230KT		IAS 250KT						
OSKOR	OSK 5Z			MAGENTA1	MAGENTA2	MAGENTA4	PIA	PAR				
				IAS 230KT								
LIN	LIN 5Z			BROWN1	BROWN 2							
				IAS 230KT	IAS 250KT							
LAGEN	LAG 5Z			GREEN1	RMG	BLA	GREEN2	GREEN3	LAGEN			
				IAS 230KT	IAS 250KT							

REFERENCE WAYPOINTS					
NAME	LATITUDE	LONGITUDE	NAME	LATITUDE	LONGITUDE
MAGENTA1 (FLY OVER)	45°43'16"	08°38'19"	PIA	44°52'18"	09°49'36"
MAGENTA1 (centro virata)	45°41'58"	08°36'07"	PAR	44°49'20"	10°17'36"
MAGENTA1 (fine virata virata)	45°40'29"	08°34'10"	RMG	45°37'42"	08°24'24"
MAGENTA2	45°37'30"	08°38'47"	BLA	45°29'39"	08°06'02"
MAGENTA3	45°22'31"	08°42'56"			
GREEN1(FLY OVER)	45°43'16"	08°38'19"	LAGEN	44°23'39"	08°29'53"
GREEN1(centro virata)	45°41'58"	08°36'07"	OSKOR	45°38'57"	10°07'00"
GREEN1(fine virata virata)	45°43'31"	08°34'17"			
GREEN2	45°19'52"	07°59'33"			
GREEN3	45°09'21"	08°02'59"			
BROWN1 (FLY OVER)	45°39'55"	08°43'38"			
BROWN1 (centro virata)	45°39'58"	08°47'19"			
BROWN1 (fine virata virata)	45°42'12"	08°49'10"			
BROWN2	45°43'04"	09°16'05"			
RED 1(FLY OVER)	45°39'55"	08°43'33"			
RED1 (centro virata)	45°43'06"	08°46'56"			
RED1 (fine virata virata)	45°45'20"	08°48'02"			
RED2	45°38'51"	09°14'37"			

Table 50: Path description: SIDs

HOLDING PROCEDURES					
NAME	**BIRING/DISTANCES**	**MHA/MHL**	**TURN**	**INBOUND TRACK (TRUE)**	**REMARKS**
SRN			L	169°	IAS MAX 230
BLACK1	RDL138/16NM MMP		R	318°	IAS MAX 230
MERGER	RDL169/25NM MMP		R	349°	IAS MAX 230
BLU1	RDL156/37NM BLA		R	336°	IAS MAX 230
BLU2	RDL201/34NM TOP		R	021°	AWAY FROM STATION IAS MAX 230
MERGEL	RDL201/20NM TOP		R	021°	AWAY FROM STATION IAS MAX 230

Table 51: Path description: Holdings

-Appendix G: Operational Sectors

Arrivals and Departures

ANE (+ANW)
This sector is in charge of pre-sequencing the traffic from NORD/NORD EST, managing the departures from LIMC, the departure from LIML and LIME towards nord, managing the arrivals to LIML and to LIME incoming from nord. ANE routes the traffic with destination LIMC to BLK01-STARBLK01 and authorizes to descend to FL110 or QL. Finally ANE assign the traffic to MAR for descending.

ANW
This sector gets ANE's competencies in case of high traffic and manages the departures from LIMC, LIML, LSZA in accordance with the standards commonly used by Milan ACC.

ASW
This sector is in charge of pre-sequencing the traffic from SUD and OVEST and routes the traffic with destination LIMC to BLU02-STARBLU.

MAR
This sector receives the traffic from ANE and ASW is in charge of managing the traffic inside PMS. MAR authorizes the traffic to go towards MERRE or MERLE points in accordance with the described operational standards.

MAP
This sector receives the traffic from MAR and authorizes to descend to 3000ft, towards the approaching procedure, and verifies by checking the aircraft speed the proper safety distance between aircraft during approaching and landing.

LAR/ADE
This sector manages the traffic in accordance with the standards commonly used by Milan ACC.

The simulator configuration and the used frequency are as follows:

- MAP FREQ. 119.200;
- MAR FREQ. 124.800;
- ASW FREQ. 124.200;
- ANW FREQ. 134.200;
- ANE FREQ. 131.250;
- LAR FREQ. 125.500;

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