INDUSTRIAL RESEARCH

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PJ06

PJ.06-01 — OPTIMIZED TRAFFIC MANAGEMENT TO ENABLE FREE ROUTING IN HIGH AND VERY HIGH COMPLEXITY ENVIRONMENTS

This PJ.06-01 Performance Assessment Report is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 734129 under European Union's Horizon 2020 research and innovation programme.

Abstract

This PJ.06-01 Performance Assessment Report present the performance assessment results from the validation exercises at SESAR Solution level. It provides an estimation of the Solution's performance in SESAR2020 (horizon 2035, extrapolated to ECAC wide where applicable) in terms of Safety, Environment/Fuel Efficiency, Predictability and Airspace Capacity, as well as a qualitative assessment of the effect on Human Performance of ATCOs, ANS Cost Efficiency and Airspace Users Cost Efficiency. This Performance Assessment Report has been produced at the end of V3.

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1 Executive Summary

This document provides the Performance Assessment Report (PAR) for Solution PJ.06-01 —Optimized traffic management to enable Free Routing in high and very high complexity environments.

The PAR is consolidating Solution performance validation results addressing KPIs/PIs and metrics from the SESAR2020 Performance Framework [3].

Description:

Optimized traffic management to enable Free Routing in high and very high complexity environments sees airspace users being able to plan flight trajectories without reference to a fixed route network or published directs within high and very high-complexity environments so they can optimise their associated flights in line with their individual operator business needs or military requirements.

The solution provides a description of high and very high complexity cross-border Free Routing environment in upper airspace (at the 2022 timeframe - as per PCP AF#3). The scope of the solution focuses on the improvement of Aircraft-to-Aircraft Separation Provision to enable Free Routing operations in upper airspace in high and very high complexity cross-border environments (with minimum structural limits to manage airspace and demand complexity).

Note: The applicable version of the EATMA and its associated Data Set (EATMA v12 / DS19) now shows revised IOC/FOC dates for PJ.06-01: IOC 31/12/2026 – FOC 31/12/2030. Beginning of January 2027 is thus considered as targeted implementation date of the PJ.06-01 Solution. The Solution description in EATMA would need to be updated for consistency.

More Information can be found in Chapter 2!

Assessment Results Summary:

The following tables summarises the assessment outcomes per KPI (Table 1) and mandatory PI (Table 2) puts them side-by side against Validation Targets in case of KPI from PJ19 [18]. The impact of a Solution on the performances are described in Benefit Impact Mechanism. All the KPI and mandatory PI from the Benefit Mechanism were the Solution potentially impact have to be assessed via validation results, expert judgment etc.

There are three cases:

1. An assessment result of 0 with confidence level other level High, Medium or Low indicates that the Solution is expected to impact in a marginal way the KPI or mandatory PI.
2. An assessment result (positive or negative) different than 0 with confidence level High, Medium or Low indicates that the Solution is expected to impact the KPI or mandatory PI.

3. An assessment result of N/A (Not Applicable) with confidence level N/A indicates that the Solution is not expected to impact at all the KPI or mandatory PI consistently with the Benefit Mechanism.

KPI	Validation Targets – Network Level (ECAC Wide)	Performance Benefits Expectations at Network Level (ECAC Wide or Local depending on the KPI)[1]	Confidence in Results[2]
FEFF1: Fuel Efficiency – Fuel burn per flight	-27.686 Kg	-15.76 kg per ECAC flight -26.57 kg per flight concerned by the solution	Medium
CAP1: TMA Airspace Capacity – TMA throughput, in challenging airspace, per unit time.	N/A	0% (local)	N/A
CAP2: En-Route Airspace Capacity – En-route throughput, in challenging airspace, per unit time	N/A	0% (local)	Medium
CAP3: Airport Capacity – Peak Runway Throughput (Mixed mode).	N/A	0% (local)	N/A

[1] Negative impacts are indicated in red.

[2] High – the results might change by +/-10%
Medium – the results might change by +/-25%
Low – the results might change by +/-50% or greater
N/A – not applicable, i.e., the KPI cannot be influenced by the Solution

KPI	Validation Targets – Network Level (ECAC Wide)	Performance Benefits Expectations at Network Level (ECAC Wide or Local depending on the KPI)[1]	Confidence in Results[2]
PRD1: Predictability – Variance of Difference in actual & Flight Plan or RBT durations	-0.930%	Unknown	Low
PUN1: Punctuality – % Flights departing within +/- 3 minutes of scheduled departure time due to ATM and weather related delay causes	N/A	0%	N/A
CEF2: ATCO Productivity – Flights per ATCO -Hour on duty	N/A	0 No.	Medium
CEF3: Technology Cost – Cost per flight	N/A	0 EUR/flight	N/A
SAF1: Safety - Total number of fatal accidents and incidents with ATM Contribution per year	N/A	0 No.	Medium

Table 1: KPI Assessment Results Summary

[3] In Validation Targets [18] the unit for PRD1 is % Reduction in variance of block-to-block flight time.

[4] In Validation Targets [18] the unit for CEF2 is % increase in ATCO productivity.

[5] In Validation Targets [18] the unit for CEF3 is % reduction in technology cost per flight.

[6] In Validation Targets [18] the unit for SAF1 is % reduction in the total number of fatal accidents per year.

Mandatory PI	Performance Benefits Expectations at Network Level (ECAC Wide or Local depending on the KPI)[7]	Confidence in Results[8]
SAF1.X: Mid-air collision – En-Route	0%	Medium
SAF2.X: Mid-air collision – TMA	0%	N/A
SAF3.X: RWY-collision accident	0%	N/A
SAF4.X: RWY-excursion accident	0%	N/A
SAF5.X: TWY-collision accident	0%	N/A
SAF6.X: CFIT accident	0%	N/A
SAF7.X: Wake related accident	0%	N/A
SEC1: A security risk assessment has been carried out	N/A (local)	N/A
SEC2: Risk Treatment has been carried out	N/A (local)	N/A
SEC3: Residual risk after treatment meets security objective.	N/A (local)	N/A
SEC7: Personnel (safety) risk after mitigation	N/A (local)	N/A
SEC8: Capacity risk after mitigation	N/A (local)	N/A
SEC9: Economic risk after mitigation	N/A (local)	N/A
FEFF2: CO_2 Emissions.	-49.64kg -83,69kg per flight concerned by the solution	Medium
FEFF3: Reduction in average flight duration.	0.33 min/flight 0.5 min/flight concerned by the solution	Medium

[7] Negative impacts are indicated in red.

[8] High – the results might change by +/-10%
Medium – the results might change by +/-25%
Low – the results might change by +/-50% or greater
N/A – not applicable, i.e., the KPI cannot be influenced by the Solution

NOI1: Relative noise scale	N/A (local)	N/A
NOI2: Size and location of noise contours	N/A (local)	N/A
NOI4: Number of people exposed to noise levels exceeding a given threshold	N/A (local)	N/A
LAQ1: Geographic distribution of pollutant concentrations	N/A (local)	N/A
CAP3.1: Peak Departure throughput per hour (Segregated mode)	0% (local)	N/A
CAP3.2: Peak Arrival throughput per hour (segregated mode)	0% (local)	N/A
CAP4: Un-accommodated traffic reduction	0 flight/year (local)	N/A
RES1: Loss of Airport Capacity Avoided	0% (local)	N/A
RES1.1: Airport time to recover from non-nominal to nominal condition	0 min (local)	N/A
RES2: Loss of Airspace Capacity Avoided.	0% (local)	N/A
RES2.1: Airspace time to recover from non-nominal to nominal condition.	0 min (local)	N/A
RES4: Minutes of delays.	0 min (local)	N/A
RE5: Number of cancellations.	0 No. (local)	N/A
CEF1: Direct ANS Gate-to-gate cost per flight	0 EUR/flight	N/A
AUC3: Direct operating costs for an airspace user	0 EUR	N/A
AUC4: Indirect operating costs for an airspace user	0 EUR	N/A
AUC5: Overhead costs for an airspace user	0 EUR	N/A
CMC1.1: Available/Required training Duration within ARES	0%	N/A
CMC1.2: Allocated/ Optimum ARES dimension	0%	N/A
CMC1.3: Transit Time to/from airbase to ARES	0 min	N/A
CMC2.1: Fuel and Distance saved (for GAT operations)	0 kg and NM	N/A

CMC2.2: GAT planning efficiency of Available ARES	0%	N/A
HP1: Consistency of human role with respect to human capabilities and limitations	OK (local)	High
HP2: Suitability of technical system in supporting the tasks of human actors	OK (local)	High
HP3: Adequacy of team structure and team communication in supporting the human actors	OK (local)	High
HP4: Feasibility with regard to HP-related transition factors	0 (local)	N/A
FLX1: Average delay for scheduled civil/military flights with change request and non-scheduled or late flight plan request	0 min	N/A

Table 2 Mandatory PIs Assessment Summary

Additional Comments and Notes:

N/A

2 Introduction

2.1 Purpose of the document

The Performance Assessment covers the Key Performance Areas (KPAs) defined in the SESAR2020 Performance Framework [3][9]. Assessed are at least the Key Performance Indicators (KPIs) and the mandatory Performance Indicators (PIs), but also additional PIs as needed to capture the performance impacts of the Solution. It considers the guidance document on KPIs/PIs [3] for practical considerations, for example on metrics. The purpose of this document is to present the performance assessment results from the validation exercises at SESAR Solution level. The KPA performance results are used for the performance assessment at strategy level and provide inputs to the SESAR Joint Undertaking (SJU) for decisions on the SESAR2020 Programme.

In addition to the results, this document presents the assumptions and mechanisms (how the validation exercises results have been consolidated) used to achieve this performance assessment result.

This PJ.06-01 Solution Performance Assessment Report has been produced at the end of V3.

2.2 Intended readership

In general, this document provides the ATM stakeholders (e.g. airspace users, ANSPs, airspace industry) and SJU performance data for the Solution addressed.

Produced by the Solution project, the main recipient in the SESAR performance management process is PJ19, which will aggregate all the performance assessment results from the SESAR2020 solution projects PJ1-18, and provide the data to PJ20 for considering the performance data for the European ATM Master Plan. The aggregation will be done at higher levels suitable for use at Master Planning Level, such as deployment scenarios. Additionally, the consolidation process will be carried out annually, based on the SESAR Solution's available inputs.

2.3 Inputs from other projects

The document includes information from the following SESAR 1 projects:

- B.05 D72 [5]: SESAR 1 Final Performance Assessment, where are described the principles used in SESAR1 for producing the performance assessment report.

[9] *This performance assessment is consistent with the SESAR2020 Performance Framework version 2018. This framework has been updated in 2019 after consultation with Scientific Committee and SJU. The main changes are in Efficiency and Predictability performance areas with a reorganisation and redefinition of new KPIs and PIs to be aligned with the ATM Master Plan Performance Ambitions. These changes are not considered in this document.*

PJ19 will manage and provide:

- PJ19.04.01 D4.1 [3]: Performance Framework (2018), guidance on KPIs and Data collection supports.
- PJ19.04.03 D4.0.1: S2020 Common assumptions, used to aggregate results obtained during validation exercises (and captured into validation reports) into KPIs at the ECAC level, which will in turn be captured in Performance Assessment Reports and used as inputs to the CBAs produced by the Solution projects. Where are also included performance aggregation assumptions, with traffic data items.
- For guidance and support PJ19 have put in place the Community of Practice (CoP)[10] within STELLAR, gathering experts and providing best practices.

2.4 Glossary of terms

See the AIRM Glossary [1] for a comprehensive glossary of terms.

2.5 Acronyms and Terminology

Term	Definition
ACC	Area Control Center
ANS	Air Navigation Service
ANSP	Air Navigation Service Provider
AoR	Area of Responsibility
APP	Approach
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATFCM	Air Traffic Flow and Capacity Management
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management

10 https://stellar.sesarju.eu/?link=true&domainName=saas&redirectUrl=%2Fjsp%2Fproject%2Fproject.jsp%3FobjId%3Dxrn%3Aview%3Axrn%3Adatabase%3Aondb%2Ftable%2F59_anonymous%402333834.13%403834139.13

ATSU	ATS Unit
BAD	Benefits Assessment Date
BAER	Benefit Assessment Equipment Rate
CBA	Cost Benefit Analysis
CDT	Conflict Detection Tool
DB	Deployment Baseline
DOD	Detailed Operational Description
DRA	Direct Routing Airspace
E-ATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference
ER	En-Route
FIR	Flight Information Region
FOC	Full Operational Capability
FRA	Free Routing Airspace
HFE	Horizontal Flight Efficiency (PRU Performance Indicator)
HPAR	Human Performance Assessment Report
INTEROP	Interoperability Requirements
IOC	Initial Operational Capability
KEA	Key performance Environment indicator based on actual trajectory
KEP	Key performance Environment indicator based on last filed flight Plan
KPA	Key Performance Area
KPI	Key Performance Indicator
HP	Human Performance
N/A	Not Applicable
OI	Operational Improvement
OSED	Operational Service and Environment Definition
PAR	Performance Assessment Report

PCP	Pilot Common Project
PI	Performance Indicator
PRU	Performance Review Unit
QoS	Quality of Service
RBT	Reference Business / Mission Trajectory
SAC	Safety Criteria
SAR	Safety Assessment Report
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SESAR2020 Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SPR	Safety Performance Requirements
VALR	Validation Report
XFRA	Cross-border FRA

Table 3: Acronyms and terminology

3 Solution Scope

3.1 Detailed Description of the Solution

A short description of the Solution can be found in the Executive Summary!

The SESAR Solution PJ.06-01 will support traffic management optimization at local level to facilitate Free Routing in Upper En-Route airspace. It contributes to the **OI Step AOM-0505**: "*Free Routing for Flights both in cruise and vertically evolving within high and very high complexity environments in Upper En Route airspace*".

The Solution PJ.06-01 addresses the AOM-0505 OI Step only partially.

It is focused on the improvement of **Aircraft-to-Aircraft Separation Provision** to enable Free Routing operations in high and very high complexity cross-border environments (with minimum structural limits to manage airspace and demand complexity). It also links to **Coordination and Transfer** and **Free Route Airspace Design** capabilities although no specific abilities are under development in the scope of the Solution in these areas.

The Solution PJ.06-01 covers the "Required" Enablers, as well as some "Optional" Enablers", of the OI Step related to these ATM Capabilities: i.e.

- **Enabler ER APP ATC 78**: "*Update FDP to support 4D trajectory direct segments in free routing airspace beyond local AoR*" (Required Enabler)
- **Enabler ER ATC 91:** "*ATC System Support for Advanced Conformance Monitoring in En-route Airspace*" (Required Enabler)
- **Enabler ER ATC 157**: "*Enhanced ATC System Support to the Tactical Controller for Conflict Detection and Resolution in En-Route*" (Optional Enabler)
- **Enabler ER ATC 157b**: "*Enhanced ATC System Support the Planning Activity for Conflict Detection and Resolution in En-route*" (Optional Enabler)
- **Enabler PRO-046b**: "*ATC Procedures for Using Advanced System Assistance to Medium Term Conflict Detection and Resolution*" (Optional Enabler)

Although contributing to support the deployment of Free Routing operations beyond low and medium complexity environments, the Solution PJ.06-01 is not targeting unrestricted free routing operations, but aims at enabling safe and efficient operations in Free Routing Airspace (FRA) with minimum structural constraints as far as practicable while maintaining the required level of safety and capacity in the airspace.

Regarding cross-border aspects in the context of the Solution PJ.06-01, they could either relate to cross-FRAs, cross-ACCs/sectors or cross-FIRs aspects (e.g. Free Routing in cross-border FRA, Free Routing across adjacent local FRAs at State/FIR/ACC level).

Ability to plan flight in Free Routing Airspace (FRA) in optimised alignment with business needs is expected to improve flight effectiveness in terms of flight time (more adequate with schedule) and/or flight distance (shorter) and /or fuel and cost (more efficient). In-flight variability is also expected to be reduced thanks to less trajectory revisions (e.g. less tactical directs requested by pilots or given by ATCO to expedite the traffic).

More detailed description of the Solution can be found in the PJ.06-01 SPR-INTEROP / OSED Part I document ([45]).

3.2 Detailed Description of relationship with other Solutions

Detailed relationship with SESAR I Solutions

The Solution PJ.06-01 is complementary to the Free Route Solutions brought to a V3 maturity level in SESAR 1, i.e.:

- **Solution #32**: *Free Route through the use of Direct Routing*.
  This Solution is related to the **OI Step AOM-0500** — *Direct Routing for flights both in cruise and vertically evolving for cross ACC borders and in high complexity environments.*

- ***Solution #33****: Free Route through the use of Free Routing for Flights both in cruise and vertically evolving above a specified Flight Level.*
  This Solution is related to the **OI Step AOM-0501** — *Free Routing for Flights both in cruise and vertically evolving within low to medium complexity environments.* Due to the lower complexity addressed in Solution #33 compared to Solution PJ06.01, there was no "structurally limited FRA" concept defined in this Solution.

Together with these two SESAR I Solutions, the PJ.06-01 Solution will support the implementation of Free Routing Airspace (FRA) in upper En-Route airspace, as per PCP AF#3 (The EU Regulation No 716/2014 mandates FRA above FL310 from 1st January 2022).

These SESAR 1 Solutions covers baseline FDPS enhancement in support to Direct Route and Free Route operation (required enabler ER APP ATC 75, which is the predecessor of ER APP ATC 78) and Advanced Monitoring Aids (required enabler ER ATC 91).

From a deployment perspective in 2025-2035, the Solution PJ.06-01 does not depend on these two SESAR I Solutions:

- **Solution #32** (with IOC date end of 2016) is a possible Free Route Solution in the transition phase before Free Routing implementation in high and very high complexity environments. However, it does not need to be deployed prior to the Solution PJ.06-01. Besides, the Solutions are mutually exclusive of each other as one and only one can be deployed at the same time in the same Operational Environment.

- **Solution #33** (with IOC date end of 2020) is not directly applicable to the same operating environments than the Solution PJ.06-01. Both Solutions are therefore independent with no cross-effects in terms of their respective performance benefits.

Detailed relationship with SESAR 2020 Solutions

The Solution PJ.06-01 also links to the following SESAR Solution:

- **Solution PJ.10-02a**[11]: *Improved Performance in the Provision of Separation*.
  This Solution aims at improving the provision of separation in En-Route and TMA operational environments through improved ground trajectory prediction. This is achieved using existing information on lateral and vertical clearances that are known by the ground system, airborne information and data derived from meteorological services.

Solution PJ.10.02a covers enhanced CD/R Tools, What-if and other tools (compliant with optional enablers ER ATC 157 and ER ATC 157b), which needs to be compatible with Free Routing operating environment. However, Solution PJ.10.02a has a broader scope than the subset of CD/R functionalities V3 validated in PJ.06-01, with e.g. the use of ADS-C EPP data or MET services to predict, with better uncertainty, the present and future aircraft positions.

From a deployment perspective in 2025-2035, the Solution PJ.06-01 can be deployed prior the Solution PJ.10.02a (with IOC date end of 2029). At the timeframe of 2035, if deployed in the same operational environment, the Solution PJ.10.02a might have a positive impact on Free Routing operations (like in other En-Route operating environments) in terms Air Traffic Controllers performance, and potentially Airspace Capacity, thanks to further enhanced ATC support tools.

Other technological or operational SESAR 2020 Solutions applicable to the En-Route airspace with a targeted timeframe at or beyond the one of Solution PJ.06-01 (with IOC date end of 2026) might consider the Solution PJ.06-01 as a pre-requisite for their validation of additional benefits and description of the operational environment after PCP implementation in En-Route. However, the Solution PJ.06-01 does not need require these other technological or operational SESAR Solutions.

This is notably the case for the following SESAR Solution:

- **Solution PJ.06-02**: *Management of Performance-Based Free Routing in Lower Airspace*.
  This Solution is related to the **OI Step AOM-0506** — *Free Routing for Flights both in cruise and vertically evolving within high-complexity environments in Lower En Route airspace.*
  The Solution PJ.06-02 sees the application of FRA for airspace users beyond the PCP expectations (below FL310). It aims at improving predictability, efficiency and flexibility for a wider range of different airspace users (e.g. General Aviation, Business Aviation and the future planned RPAS use) in en-route operating environments of high complexity.
  From the ANSP perspective, it only requires updated FDP related systems (compliant with required enabler ER APP ATC 78).

From a deployment perspective, the Solutions PJ.06-01 and PJ.06-02 (with same IOC date end of 2026) are expected to be compatible and interdependent in high complexity En-Route environments.

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[11] The Solution PJ.10-02a has eventually be split into two Solutions, i.e. PJ.10-02a2 which encompasses EPP ADS-C aspects and dedicated OIs and Enablers, and PJ.10-02a1 which deals with the rest of former Solution PJ.10-02a.

Solution Number	Solution Title	Relationship	Rational for the relationship
#32	Free Route through the use of Direct Routing	Mutually exclusive	Free Route may be deployed both through the use of Direct Routing and through Free Routing Airspace. Solution #32 is a possible Free Route Solution in the transition phase before Free Routing implementation in high and very high complexity environments. However, it does not need to be deployed prior to the Solution PJ.06-01.
#33	Free Route through the use of Free Routing for Flights both in cruise and vertically evolving above a specified Flight Level	No cross effect	Solution #33 is a possible Free Route Solution low to medium complexity En-Route environments. It is not directly applicable to the same operational environments than the Solution PJ.06-01.
PJ.10-02a	Improved Performance in the Provision of Separation	Cross effect	Although they share some enhanced CD/R functionalities (enablers ER ATC 157 and ER ATC 157b), the Solution PJ.10.02a covers a broader scope of functionalities than the Solution PJ.06-01, which are expected deployed at a later stage. Both Solutions do not depend on each other to be deployed. Yet, if deployed in the same operational environment at the timeframe (e.g. by 2035), the Solution PJ.10.02a might have a positive impact on Free Routing operations (like in other En-Route operating environments).
PJ.06-02	Management of Performance-Based Free Routing in Lower Airspace	Interdependent	The Solution PJ.06-02 sees the application of FRA for airspace users beyond the PCP expectations (below FL310) in high complexity en-route environments. It is therefore complementary to the Solution PJ.06-01. Besides, both Solutions require updating FDPS to support 4D trajectory direct segments in FRA beyond local AoR (enabler

Solution Number	Solution Title	Relationship	Rational for the relationship
			ER APP ATC 78). They are therefore compatible and interdependent to achieve maximum performance requirements in En-route airspace regardless of Division FL of Free Routing Airspace across ACCs/FIRs.

Table 4: Main relationships with other Solutions

Other possible relationship with SESAR 2020 Solutions

The other SESAR 2020 Solutions that might interact with the PJ06-01 Solution (with a positive or negative effect on the benefits afforded by the Solution) if deployed in the same operating environment are as follows:

- **Solution PJ.01-01**: Extended Arrival Management with overlapping AMAN operations and interaction with DCB and CTA
  - This Solution addresses the interaction between Traffic Synchronisation and DCB, including the identification of integration needs, and CTA in high density/complexity TMAs.
  - To be future-proof, it would need to take into account Free Routing operations in upper En-Route airspace.
- **Solution PJ.07-01**: AU Processes for Trajectory Definition
  - This Solution supports the development of Airspace Users related processes for the management and update of the Shared Business Trajectory (SBT) aligned with ICAO FF-ICE increment 1 scenarios and services, giving the opportunity to the Airspace Users to be more involved in DCB processes in the future.
  - It could be a valuable solution to better accommodate individual airspace users' business needs and priorities during SBT definition in the future including in Free Routing environment.
- **Solution PJ.07-02**: AU Fleet Prioritization and Preferences
  - This Solution allows Airspace Users to recommend a priority order request to the NM and appropriate airport authorities for flights affected by delays on departure, arrival and En-route and to share preferences with other ATM stakeholders in capacity-constrained situations.
  - Such user driven prioritisation process (UDPP) could be a valuable solution to better accommodate individual airspace users' business needs in the future including in Free Routing environment.
- **Solution PJ.07-03**: Mission Trajectory Driven Processes
  - This Solution updates wing operations centre (WOC) processes for the management of the shared and reference mission trajectory (SMT/RMT).

- It could be a valuable solution to better accommodate individual airspace military users' business needs and priorities including in Free Routing environment

- **Solution PJ.08-01**: Management of Dynamic Airspace configurations
  - Dynamic airspace configuration could be a valuable solution to help managing complexity at sector level in the future including in Free Routing environment.
- **Solution PJ.08-02**: Dynamic Airspace Configuration supporting moving areas
  - Extension of dynamic airspace configuration could be a valuable solution to help managing complexity at sector level in the future including in Free Routing environment.
- **Solution PJ.09-01**: Network Prediction and Performance
  - This Solution consists of improved traffic and demand forecast based on SBT and the computation of confidence indexes, including enhanced prediction of DCB constraints and complexity issues.
  - It could be a valuable solution to improve the accuracy and credibility of the diagnosis and awareness of hotspots in the future including in Free Routing environment.
- **Solution PJ.09-02**: Integrated Local DCB Processes
  - This Solution supports the seamless integration of local network management with extended ATC planning and arrival management activities in short-term and execution phases. It represents the core functionality for the Integrated Network ATM Planning (INAP) process through an enhanced Local DCB tool set.
  - Enhanced Local DCB tool set is not necessary to enable cross- Free Routing operations in En-route airspace. However it could be a valuable solution to improve the monitoring and the assessment ATC workload/complexity at sector level and to provide input to complexity resolution tools for Extended ATC Planning (in the frame of INAP) in the future notably in Free Routing environments of high and very high complexity.
- **Solution PJ.09-03**: Collaborative Network Management Functions
  - The solution enables a real-time visualisation of the evolving AOP/NOP planning environment (such as demand pattern and capacity bottlenecks) to support airspace user and local planning activities.
  - No advanced NOP capabilities (beyond the SESAR 1 Solutions) is necessary to enable Free Routing operations in En-route cross-border environments. However collaborative 4D constraints management could be a valuable solution to better integrate AUs priorities and preferences in the future including in Free Routing environment.
- **Solution PJ.10-01a**: High Productivity Controller Team Organisation
  - This Solution supports the extension of sector team operations beyond team structures of one planning ATCO and two tactical ATCOs both in en-route and TMA in order to optimise flight profiles, minimise delays and improve ANSP cost efficiencies while taking into account intrinsic uncertainty in the trajectory.

  - To be future-proof, it would need to take into account cross-border Free Routing operations in En-Route airspace.
- **Solution PJ.10-01b**: Flight centred ATC
  - This Solution sees the provision of ground-based automated support for managing separation provision across several sectors in order to enable larger sectors to be used.
  - To be future-proof, it would need to take into account cross-border Free Routing operations in En-Route airspace. It only targets medium and low complexity en-route airspace. It is therefore not directly applicable to the same operational environments than the Solution PJ.06-01.
- **Solution PJ.10-02b**: Advanced Separation Management
  - This Solution introduces automation mechanisms and integrates additional information (ATC intent, Aircraft intent) to further improve the quality of services of separation management in En-route and TMA operational environments.
  - To be future-proof, it would need to take into account cross-border Free Routing operations in En-Route airspace.
- **Solution PJ.11-G1**: Enhanced Short Term Conflict Alert (STCA) and Non Transgression Zone (NTZ) Ground Based Safety Nets making use of DAPs information
  - This Solution takes advantage of the greater frequency of availability and updating of the data received in DAPs information in order to obtain different improvements in ground safety nets.
  - To be future-proof, it would need to take into account Free Routing operations in upper En-Route airspace.
- **Solution PJ.15-09**: Delegation of Airspace and Contingency
  - The Solution allows to delegate the airspaces between ATSUs. A seamless ATS service provision in the delegated airspace will be guaranteed, as well as the air navigation quality and safety.
  - To be future-proof, it would need to take into account Free Routing operations in upper En-Route airspace. If so, it could be a valuable solution to support seamless cross-border FRA operations.
- **Solution PJ.16-03**: Enabling rationalisation of infrastructure using virtual centre based technology
  - The Solution aims at providing, at least, geographical decoupling between ATM Data Service Provider (ADSP) (s) and some Air Traffic Service Unit (ATSU) (s), through service interfaces defined in Service Level Agreements.
  - To be future-proof, it would need to take into account cross-border Free Routing operations in En-Route airspace. If so, it could be a valuable solution to support seamless cross-border FRA operations.
- **Solution PJ.18-02a**: Trajectory Based Operations
  - This Solution supports the establishment and management of a synchronised view of the trajectory during execution phase - that is the Reference Business Trajectory (RBT).

- It could be a valuable solution to better implement business trajectory in the future including in Free Routing environment.

- **Solution PJ.18-02b**: Flight Object Interoperability – (FO/IOP)
  - This Solution supports ATC-ATC interoperability taking into consideration seamless coordination, encompassing as well more complex coordination dialogues implying negotiation between controllers across ACC boundaries.
  - It could be a valuable alternative (to the use of OLDI in ATC-ATC data exchanges) to manage seamless Free Routing operations in the future.
- **Solution PJ.18-02c**: eFPL supporting SBT transition to RBT
  - This Solution address intermediate steps and building blocks for the implementation of the business trajectory concept taking into account Extended Flight Plan and ICAO FF-ICE increment 1 developments in progress, including in Free Routing environment.
  - It could be a valuable solution to better implement business trajectory in the future including in Free Routing environment.
- **Solutions under PJ.18-04b**: Meteorological (MET) information
  - This Solutions develop information services and capabilities for new or enhance meteorological (MET) information.
  - It could be a valuable solution to improve the quality, consistency and usability of the information in a full 4D trajectory in the future including in Free Routing environment.
- **Solutions under PJ.18-06a**: Air Traffic Control (ATC) Planned Trajectory Performance Improvement
  - The use of Extended Projected Profile data received by means of ADS-C communication and EFPL, as well as further aircraft and flight related information will improve the ATC Planned Trajectory Performance.
  - It could be a valuable solution to the ATC Planned Trajectory Performance in the future including in Free Routing environment.

The above SESAR 2020 Solutions aiming at improving Airspace management and Demand and Capacity Balancing (airspace), if applicable in Free Routing environments of high and very high complexity (i.e. compatible and independent from PJ.06-01), could result in greater benefit than Solution PJ.06-01 could provide on its own by enabling less structurally limited FRA.

The above SESAR 2020 Solutions aiming at improving Traffic Synchronisation, Conflict Management or Trajectory Management, if applicable to the same operational environments than the Solution PJ.06-01, could result in greater or lesser benefit for Solution PJ.06-01 depending on whether their associated ATC support tools and procedures are compatible or not with the ones associated to the Solution PJ.06-01.

Further work would be required to quantify and conclude on the potential interaction between Solution PJ.06-01 and all above Solutions. **Without firm evidence at this stage, it is proposed to consider that 'No Cross Effect' applies with between these Solutions and Solution PJ.06-01**.

4 Solution Performance Assessment

4.1 Assessment Sources and Summary of Validation Exercise Performance Results

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

Organisation	Document Title	Publishing Date
SESAR Joint Undertaking Skyguide, DSNA, ENAV, Eurocontrol, Lufthansa Systems, Sabre	SESAR 04.03-M602 Validation Report of EXE-04.03-VP-797, Edition 00.01.00	September 2016

Table 5: Pre-SESAR2020 Exercises

This SESAR I Release 5 Validation Exercise consisted in an integrated assessment of Free Route concepts (DRA/FRA, Min FL) associated to the services of Conflict Detection & Resolution, and the "Extended ATC Planning" concept. The Skyguide leg was focused on FRA scenarios with high to very high traffic complexity, thus contributing to the assessment of PJ.06-01 at V2 level.

SESAR2020 Validation Exercises of this Solution are listed below.

Exercise ID	Exercise Title	Release	Maturity	Status
EXE-06.01-V3-VALP-001	Free Routing Concept development and assessment in very high complexity cross-border environment	R9	V3	Completed
EXE-06.01-V3-VALP-002	Cross FIR analysis of Barcelona FRA and MADRID FRA integration in high complexity environment.	R9	V3	Completed

Table 6: SESAR2020 Validation Exercises

The following table provides a summary of information collected from available performance outcomes of PJ.06-01 at V2 and V3 level.

Exercise	OI Step	Exercise scenario & scope	Performance Results	Notes
EXE-04.03-VP-797	AOM-0501 / AOM-0505	This Real Time Simulation exercise involving the FOCs, Network management and ANSPs (EXE-04.03-VP-797) aimed at validating the Free Routing concept in the European core area, including minimum Flight Level and associated acceptable complexity level within the airspace. Skyguide leg – FRA scenarios with high to very high traffic complexity (AOM-0505) assuming full freedom FRA implementation at ECAC level The selected reference traffic sample was basically "high" to "very high". Due to the high variability of FRA traffic, traffic demand in FRA scenarios was evolving from "low" to "very high" in all sectors.	Skyguide leg – Safety • Different minimum Flight Levels for FRA have been assessed (FL305+ and FL365+). Evidences on the impact on safety have been demonstrated in particular by measuring the ATCOs situational awareness, the number of conflicts and the infringements of minimum distance between aircrafts. Skyguide leg – ATFCM delays • Assessment of the NM revealed a huge number of new hotspot within the considered FRA airspace. Therefore, it was decided to focus on hotspots over the simulated area. DCB measures taken to reduce these hotspots increased drastically number of regulated flights and ATFCM En-Route delay per delayed flights. Skyguide leg – Predictability • The most appropriate indicator of predictability (i.e. variance of differences between planned and real flight durations) could not be collected in a satisfactory manner. In absence of more appropriate data, expected positive effect on predictability could not be validated.	Cf. Validation Report of EXE-04.03-VP-797 ([50]) for further details

			Skyguide leg – Capacity • Different minimum Flight Levels for FRA have been assessed (FL305+ and FL365+). Evidences on the airspace capacity have been demonstrated notably by the assessment of trajectories by the NM. Skyguide leg – Human Performance: • ATCOs situation awareness & workload, traffic complexity, number of conflicts and STCA alerts show that FRA concept tested during this exercise could lead to a reduction of ATC sectors capacity.	
			FOC assessment – Fuel Efficiency • Depending on the detailed Free Route environment, average fuel savings of up to 2.53% were achieved. FOC assessment – Cost Efficiency (Airspace Users) • Depending on the detailed Free Route environment, average flight cost savings of up to 1.37% were achieved.	Cf. WP11.1 (Lufthansa Systems) contribution to the VP797 Validation Report ([51]) for further details
EXE-06.01-V3-VALP-001	AOM-0505	This validation exercise aimed at: • Designing a structurally limited Free Routing Airspace in very high complexity cross-border environment, covering 4 ACCs Areas of responsibility (AoRs):	Fuel efficiency • Horizontal Flight Efficiency (HFE concept from PRU) was improved in cross-border FRA compared to Fixed Route	Cf. PJ06-01 VALR (V3) Thread #1 ([47]) for further details

		o Geneva ACC o Zurich ACC o Milano ACC o Padova ACC • Designing cross-border FRA flight planning options in this airspace • Assessing the applicability of current processes, working methods and procedures in free routing solutions under validation and identify possible required changes/evolutions • Demonstrating improvement in Fuel Efficiency and Predictability and no negative impact in capacity, safety and Human performance	environment[12] and this efficiency is improved with the extension of cross border FRA operations. o local % of wasted route at planning level (KEP) was improved on average by 2.47% in the solution scenarios o local % of wasted route in execution phase (KEA) was improved on average by 1.12% % in the solution scenarios o average inefficient planned and flown distances was reduced respectively by to 28.8% and 18.3% in the solution scenarios • Exercise results show that XFRA implementation enables a fuel savings for AUs at planning level (amount of fuel carried out) and in executing phase. o Planned fuel consumption was reduced on average by up to 17.6 kg fuel per flight (at local level) o Actual fuel consumption was reduced on average by up to 7.86 kg fuel per flight (at local level) • Cross-border FRA implementation thus enabled a CO2/NoX emissions reduction in En-Route phase of flight	

[12] Improvements in Horizontal Flight Efficiency has been assessed using the KEP and KEA indicators measured at local FRA/ANSP level (i.e. not limited to the measured sectors, but taking into account the entry/exit points in the whole airspace).

			- An average CO_2 emissions saving up to 23.5 kg per flight (at local level) was achieved.
			
			Predictability
			
			- The airspace structure of the very high complexity FRA leaves a reduction of ~1.3% of the difference between [KEP-KEA],.but a slight degradation of the local variance of flight times
			
			Safety
			
			- Exercise results show that safety is not reduced with the implementation of structurally limited cross-border FRA concept with associated required enablers in very high complexity En-Route environment.
			  - ATCOs considered that safety was maintained during all the scenarios and there was no observed or measured Safety level reduction in solution scenarios compared to reference scenarios.
			  - With a properly designed FRA structure implementation and efficient ATC support tools, the complexity of conflict detection and resolution remained manageable by ATCOs.
			  - The ratio number of CDT alerts / number of aircraft was similar in reference and solutions scenarios. However, the more random geographical distribution of conflicts was confirmed.	

			- There was no tendency showing an increase or reduction of the number of loss of separation in solution scenario compared to reference. Capacity • Exercise results show that capacity is not reduced with the implementation of structurally limited cross-border FRA concept in very high complexity environment, with a properly designed FRA structure and the support of efficient ATC support tools adapted to free route trajectories. - In solution scenarios, the average number of ATCOs tactical action per flight was not increased (ATCOs initiatives or Flight crew requests). This average number was even slightly reduced. Human Performance • Exercise results show that Human Performances are maintained but ATCOs are more dependent on ATC support tools adapted to free routing environment and the quality of the FRA structure put in place to maintain an acceptable complexity level. ATCOs roles and responsibilities, working principles and operating methods are not strongly modified but tasks to be performed are more demanding which increases the importance of automation support and efficiency. ATC team internal and external communications are not negatively impacted (i.e. efficient and unambiguous).	

EXE-06.01-V3-VALP-002	AOM-0505	This validation exercise aimed at validating the processes and procedures to be applied in a cross-border Free Routing Airspace, in high complexity environment, supporting free routing operations across two ACCs/FIRs AORs (Areas of Responsibility). The simulated FRA covers two FIRs and 2 ACCs: • Madrid ACC • Barcelona ACC The objective was to validate ATC working methods such as: • Use of separation tools • Manage cross-fir areas • Manage plan or re-planned trajectories The objective was also to assess the impact on fuel efficiency and predictability of free routing operations while maintaining capacity and safety levels by defining a structurally limited FRA airspace permanently in high complexity.	Fuel Efficiency • The FR environment improved the KEA regarding the reference both with advanced and basic tools. o The gain achieved was a 27.2% in an advanced tools scenario, and 26.46% in the basic tools scenario. • Average fuel consumption per flight was reduced using Free Route, both with advanced and basic tools. o The gain is 109 kg fuel in an advanced tools scenario, and 121 kg fuel in the basic tools scenario, per flight at local level. • CO2 and NOX emissions were lower in Free Route both with advanced and basic tools than in the reference. o The gain of CO2 emissions (at local level) is 384 kg in an advanced tools scenario, and 359 kg in the basic tools scenario, was achieved. o The gain of NOX emissions (at local level) is 2 kg in an advanced tools scenario, and 1 kg in the basic tools scenario. Predictability o The airspace structure of the high complexity FRA resulted in a degradation of the difference [KEP-KEA]. o The use of Free Route either with advanced and basic tools, reduced the local variance of the trajectories, but the level of confidence in this result is low.	Cf. PJ06-01 VALR (V3) Thread #2 ([48]) for further details

			o The use of Free route either with advanced and basic tools, reduced the mean difference between planned and flown trajectories, i.e. between 1.6 min and 3 min on average per flight (at local level). Safety • The exercise results show that Safety is maintained within acceptable limits in FR environment. In scenarios with high tactical rerouting (military scenarios and bad weather) safety could be degraded if procedures and available rerouting waypoints are not clear. o Controllers considered that safety was maintained during all the scenarios. o Conflict detection and resolution remained manageable in all the scenarios, except in the military scenario that presented problems. o Situational awareness was lower both as EC and PC but was also considered as within acceptable limits. o There was no significant difference regarding safety between conflicts near the border of sectors of the same or different FDP centres. o Separation infringements were observed only during the military scenario. Capacity • Exercise results show that capacity is maintained if controllers are supported with the appropriate tools, sector configurations and procedures.

			o Workload of ATCOs was considered acceptable in all the scenarios, including the 2022 scenario. Human Performance • Exercise results show that the Free Route environment increases workload specially to solve conflicts, but the increase is within manageable limits if supported with the appropriate tools. The workload distribution between planner and executive controllers was more equally distributed than nowadays. Roles, responsibilities and communication among and between sectors teams were clear.	

Table 7: Summary of Validation Results

4.2 Conditions / Assumptions for Applicability

The aim of PJ06.01 solution is to enable Free Routing in **En-Route high & very high complexity environments** allowing airspace users to plan flight trajectories without reference to a fixed route network or published directs, so they can optimise their associated flights in line with their individual operator business needs or military requirements.

Applicable Operating Environments

The following Table 8 summarises the applicable operating environments.

OE	Applicable sub-OE	Special characteristics
En-Route	Very High complexity High complexity	Free Routing Airspace at and above FL305, including across multiple ACCs/FIRs/States

Table 8: Applicable Operating Environments.

The Solution PJ06-01, as other the Solutions contributing to the PCP AF#3.2: "Free Route" implementation (i.e. SESAR I Solution #32 and Solution #33), will contribute at paving the way towards the large-scale implementation of Free Routing operations including across ACC/FIR borders in European airspace above FL305.

SESAR 2020 Sub-OEs	En-route - Low Complexity	En-route - Medium Complexity	En-route - High Complexity	En-route - Very High Complexity
Aggregated Traffic Complexity Score	<2	[2;6(	[6;10)	>10
SESAR Free Route Solutions	Solution #33 (Free Routing)	Solution #33 (Free Routing)	Solution #32 (Direct Routing) **Solution PJ.06-01 (Free Routing above FL305)** Solution PJ.06-02 (Free Routing below FL305)	Solution #32 (Direct Routing) **Solution PJ.06-01 (Free Routing)**

Figure 1 – Sub-OEs coverage in relation with PCP #AF3.2: Free Route

The applicability area of the PJ.06-01 Solution at ECAC level potentially include all ACCs of high & very high complexity (i.e. En-route and En-route/Terminal Airspace OEs) outside oceanic airspace with aggregated traffic complexity scores at or greater than 6) where FRA will be deployed as per PCP. The En-Route ACCs of low & medium complexity are assumed to be covered by the SESAR Solution #33.

Note: The Solution PJ.06-01 applicability area could also include some medium complex ACCs affected by peak of traffic complexity in daily operations, but this was not considered in this Performance Assessment Report.

Below the list of ATS Units providing Area Control Services in ECAC continental airspace with an upper vertical limit of the controlled airspace above FL305 with aggregated traffic scores at or above 6 in 2017, and PJ20 forecast of complexity scores in 2025, 2030 and 2035[13].

Code of ATC Operational Unit	Type of ATC Operational Unit	Name of ATC Operational Unit Providing ATC Services	ANSP/Controlling Authority Name	Lower Vertical Limit of the Controlled Airspace by ATC Operational Unit	Upper Vertical Limit of the Controlled Airspace by ATC Operational Unit	Area Control Service	Category of Operating Environment (OE) in SESAR 2020	The Aggregated Traffic Complexity Score in 2017 (or in 2016)	The Aggregated Traffic Complexity Score in 2025	The Aggregated Traffic Complexity Score in 2030	The Aggregated Traffic Complexity Score in 2035
EDYYUAC	UACC	Maastricht UAC	MUAC	FL 245	FL 660	Y	En-route OE	16,85	16,98	17,10	17,17
LSAGACC	ACC	Geneva ACC	Skyguide	2000 FT AGL	FL 660	Y	En-route OE	14,31	14,53	14,64	14,71
EGTTACC	ACC	London Area Control (Swanwick)	NATS (Continental)	FL 245	FL 660	Y	En-route OE	13,34	13,56	13,70	13,80
EDUUUAC	UACC	Karlsruhe UAC	DFS	FL 235	FL 660	Y	En-route OE	13,29	13,50	13,62	13,71
LSAZACC	ACC	Zurich ACC	Skyguide	2000 FT AGL	FL 660	Y	En-route OE	11,50	11,68	11,79	11,85
LFEEACC	ACC	Reims ACC	DSNA	3000 FT ASFC	FL 660	Y	En-route OE	9,80	10,02	10,14	10,21
LFFFALL	ACC	Paris ACC	DSNA	1500 FT AMSL	FL 660	Y	En-route/Terminal Airspace OE	9,70	9,89	10,00	10,08
LIPPACC	ACC	Padova ACC	ENAV	4500 FT AMSL	FL 660	Y	En-route OE	9,00	9,22	9,36	9,46
LOVVACC	ACC	Wien ACC	Austro Control	1000 FT AGL	FL 660	Y	En-route OE	8,22	8,41	8,54	8,65
LJLAACC	ACC	Ljubljana ACC	Slovenia Control	FL 245	FL 660	Y	En-route OE	7,93	8,14	8,29	8,40
LIMMACC	ACC	Milano ACC	ENAV	2000 FT AMSL	FL 660	Y	En-route/Terminal Airspace OE	7,90	8,06	8,18	8,27
LKAAACC	ACC	Praha ACC	ANS CR	FL 125	FL 660	Y	En-route OE	7,75	8,00	8,13	8,23
LFBBALL	ACC	Bordeaux ACC	DSNA	3000 FT ASFC	FL 660	Y	En-route OE	7,40	7,60	7,70	7,78
LFRRACC	ACC	Brest ACC	DSNA	3000 FT ASFC	FL 660	Y	En-route OE	7,10	7,30	7,40	7,48
LZBBACC	ACC	Bratislava ACC	LPS	8000 FT AMSL	FL 660	Y	En-route OE	7,06	7,34	7,47	7,58
LHCCACC	ACC	Budapest ACC	Hungarocontrol	9500 FT ALT	FL 660	Y	En-route OE	7,03	7,25	7,39	7,50
EGPXALL	ACC	Scottish Control (Prestwick)	NATS (Continental)	3000 FT ALT	FL 660	Y	En-route/Terminal Airspace OE	7,02	7,26	7,37	7,46
EDMMACC	ACC	München ACC	DFS	FL 0	FL 315	Y	En-route/Terminal Airspace OE	6,82	7,07	7,19	7,28
LQSBACC	ACC	Sarajevo ACC	BHDCA	9500 FT AMSL	FL 325	Y	En-route/Terminal Airspace OE	6,46	6,47	6,47	6,47
LFMMACC	ACC	Marseille ACC	DSNA	3000 FT ASFC	FL 660	Y	En-route OE	6,30	6,55	6,66	6,75
LDZOACC	ACC	Zagreb ACC	Croatia Control	1000 FT AGL	FL 660	Y	En-route OE	6,12	6,35	6,51	6,64

Table 9: Applicable ATC Operational Units (in 2017, 2025, 2030 and 2035)

Note 1: The latest PJ20 **forecast of ACC complexity scores appears to be very conservative with almost no change in complexity scores in the 20 years to come**. Would this PJ20 forecast be revisited, the solution benefits estimated in this Performance Assessment Report would need to be updated.

Note 2: The above table includes two mixed (En-route/Terminal Airspace) OE of high complexity with an upper vertical limit just above FL305, i.e. München ACC (up to FL315) and Sarajevo ACC (up to FL325). As it might not be worthwhile to deploy the Solution PJ.06-01 for a few upper FLs inside the ATSU AoR, these two ACCs have not been considered in this Performance Assessment Report.

[13] Source PJ20 En-route & Terminal Airspace OEs_April 2019 Version.xslsx

Benefits Assessment Date

For the performance extrapolation, the Benefits Assessment Dates (BAD) considered in the performance assessment are the FOC date of the single OI Step the Solution PJ.06-01 is contributing to, i.e. 2030, and the SESAR 2020 FOC date, i.e. 2035. At these timeframes, the Solution is assumed to be fully deployed in all targeted En-Route ACCs (as described in section 0).

The following Table 10 summarises the essential deployment details (used in the Performance Assessment Report).

BAD	Specific geographical and/or stakeholder deployment
31-12-2030	FOC of AOM-0505 and basic Solution PJ.06-01 (i.e. FOC of latest required Enabler ER APP ATC 78) Deployment of basic PJ.06-01 Solution in all ACCs of High and Very High Complexity with Upper Vertical Limit of the Controlled Airspace by ATC Operational Unit above FL305
31-12-2035	SESAR 2020 FOC and full Solution PJ.06-01 (i.e. FOC of latest optional Enabler ER ATC 157b) Deployment of full PJ.06-01 Solution in all ACCs of High and Very High Complexity with Upper Vertical Limit of the Controlled Airspace by ATC Operational Unit above FL305

Table 10: Deployment details.

The Solution PJ.06-01 does not required any specific Airspace Users equipage to provide the expected benefits in Free Routing Airspace.

Equipage details and how equipage influences benefits in the ramp-up phase is given in Table 11.

Min flight equipage rate	Opt flight equipage rate	BAER	AUs that need to equip	Start of flight equipage	End of flight equipage
Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable

Table 11: Influence of Equipage on benefits.

PJ19 Common Assumptions

The following PJ19 common assumptions ([44]) are used in this Performance Assessment Report for the ECAC wide extrapolation of benefits measured at ACC level.

ID	Domain	Value	Unit	Item	Source[14]
F-0001	ALL	5280	kg	avg fuel burn per flight	Master Plan 2018
F-0005	ENR	66,0	%	En-route fuel consumption contribution	PRU fuel efficiency figure and Airspace User meeting with B4.1
T-0010	ALL	1,5	h	Average ECAC flight time	(1 hour 30 minutes or 90 minutes) (Values based on flights in the ESRA08 area) EUROCONTROL Performance Review Report (PRR 2013), May 2014
T-0011	ALL	49,00	min^2	B2B variability (variance)	from B.4.1 Step1 Validation Targets

Besides, the following aggregation assumptions (from [44] or directly provided by PJ.19.04.02) are used for the extrapolation of benefits in 2030 and 2035, respectively.

ID	Sub-OE	Year	Value	Unit	Comment
ER-VHC-2035	Very High Complexity ER	2035	31,3%	%	contribution to total En-Route traffic from the specific sub-OE
ER-HC-2035	High Complexity ER	2035	28,0%	%	contribution to total En-Route traffic from the specific sub-OE
ER-VHC-2030	Very High Complexity ER	2030	28,4%	%	contribution to total En-Route traffic from the specific sub-OE
ER-HC-2030	High Complexity ER	2030	31,4%	%	contribution to total En-Route traffic from the specific sub-OE

Other PJ06-01 Assumptions

Other specific performance assumptions used in this Performance Assessment Report are as follows.

ID	Sub-OE	Value	Unit	Item (description)	Source
PJ06.01_ER_SPEED_001	ENR	7.4	NM/Min	Distance flown per minute in En-Route	Master Plan 2019 campanion excel sheet Speed_Enroute_KmPerHr (row 197 of excel file) In 2035 825 km/hr = 13.75 km/min

[14] Source D4_0_30-PJ19-SESAR2020_Common_Assumptions_2019_annex1 (1_1).xlsx.

ID	Sub-OE	Value	Unit	Item (description)	Source
PJ06_01_ER_FUEL_001	ENR	49	Kg fuel/min	Average fuel consumption in ECAC En-Route airspace	SESAR Deployment Manager currently uses SDM currently uses 0.049 tons/min See also ICAO (2007) - "Global Aviation Plan", ICAO, Doc 9750 AN/963, 3rd Ed. 2007 (Attachment 1, App-H08) http://www.icao.int/publications/Documents/9750_3ed_en.pdf Average fuel burn per minute of flight = 49 kg
PJ06_01_ER_ACC_001	ENR	88	%	Average % of flight time in ACC in En-Route	Source Eurocontrol/NM (cf. PJ.06-01 CBA)
PJ06_01_ER_ACC_002	ENR	70	%	Average % of flight time in ACC in En-Route above FL305	Rough estimate assuming 80% of flight time in ER above FL305 (88%*80%=70%)

4.3 Safety

The PJ.06-01 Solution aims at being Safety neutral in En-Route High and Very High Complexity operating environments.

According to the applicable version of EATMA, no specific Safety performance targets are allocated to Solution PJ.06-01:

- Safety Performance Area – Mid-Air Collision En-Route (SAF1.1): no targets defined.

Considering the potential negative impact of Free Routing operations on Safety (and Human Performance of ATCOs) if not supported with adequate ATM capabilities, it was nevertheless essential to demonstrate that the Solution PJ.06-01 contributes to not adversely affect the Safety KPA in En-Route High and Very High Complexity operating environments, which has done through the safety assessment and validation activities conducted at V3 level.

4.3.1 Safety Criteria and Performance Mechanism

As indicated above, the PJ.06-01 Solution aims at not degrading the level of safety. Based on this target, and in accordance with SESAR Safety Reference Material, the PJ.06-01 Safety Assessment Report has identified several Safety Criteria using the Mid Air Collision Accident Incident Models. These criteria are expressed in terms of proxies and reflect the need to maintain the efficiency of each high-level barrier from the Mid Air Collision model.

Below the **Safety Criteria (SAC)** defined for the Solution PJ06-01:

SAC#1 The number of "Planned tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high complexity Free Routing Environment.

SAC#2 The number of "ATC induced tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high complexity Free Routing Environment.

SAC#3 The number of "ATC induced pre-tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high complexity Free Routing Environment.

SAC#4 The number of “crew/aircraft induced tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high complexity Free Routing Environment.

SAC#5 The number of "imminent infringements" shall not increase in En Route sectors in cross border, permanent or temporary high complexity Free Routing Environment.

SAC#6 The number of “imminent collisions” shall not increase in En Route sectors in cross border, permanent or temporary high complexity Free Routing Environment.

More justification about these safety criteria can be found in the PJ06.01 Safety Plan ([52]).

In addition to these Safety Criteria, the following figure presents the PJ06.01 Performance Mechanism with a focus on Safety KPA.

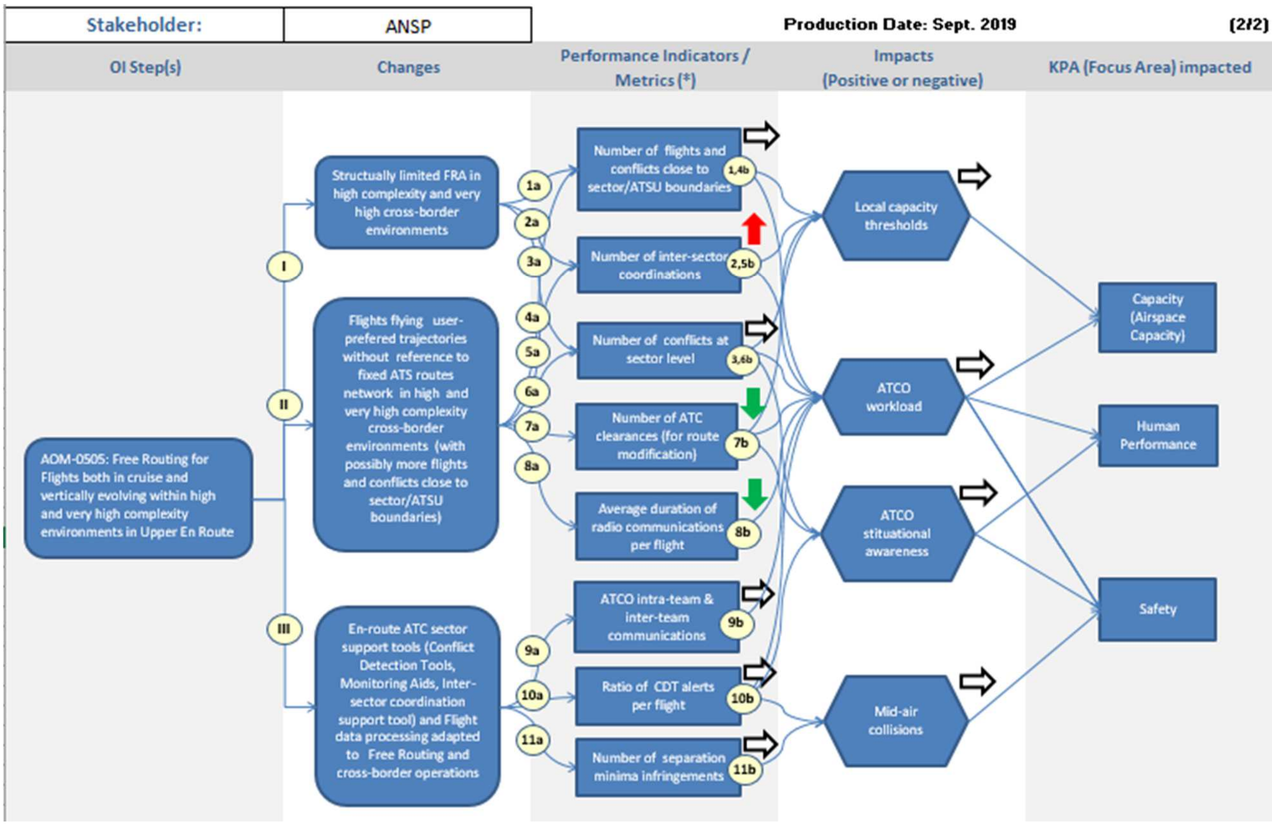


Figure 2: Benefit mechanisms – Stakeholder: ANSP – Safety KPA

A description of the **benefit and impact mechanisms describing how the Solution does not affect safety performance in En-Route high & very high complexity environments** and justifying the SAC can be found in Appendix A of the PJ.06-01 SPR-INTEROP / OSED Part I document ([45]).

4.3.2 Data collection and Assessment

In accordance with the SESAR Safety Reference Material, the impact of safety of the PJ.06-01 solution has been assessed considering a two-fold approach:

- A **success approach** which is concerned with the safety of the solution operations in the absence of failure within the end-to-end solution system;
- A **conventional failure approach** which is concerned with the safety of the solution operations in the event of failures within the end-to-end solution system.

This safety assessment includes two levels:

- An assessment at operational level defining Success and Failure Safety Objectives
- An assesment at SPR-level, defining Success and Failure Safety Requirements at SPR level

The safety assessment and in particular the SPR-level Safety Requirements has then been reviewed and validated through several safety workshop involving operational, technical and validation experts which provide assurance that these safety requirements are capable of being satisfied in a typical implementation and that the implementation of these safety requirements will allow to achieve the Safety Criteria.

More justification about these safety assessment and associated validation can be found in the PJ.06-01 Safety Assessment Report included in the PJ.06-01 SPR-INTEROP / OSED Part II document ([53]).

No formal traceability between Safety Objectives or Safety Requirements and Validation Objectives has been established. However, Safety was also addressed during the V3 validation exercises through a specific validation objective and related success criteria. The metrics used to assess these criteria include the following ones:

- Number of flights
- Number of CDTs alerts
- Number of STCA warnings
- Number of separation minima infringements
- Aircraft-aircraft conflicts location
- Ratio Number of aircraft-aircraft interference (potential conflict) / number of aircraft
- Debriefing / Questionnaires for subjective assessment by ATCOs (situation awareness, workload…)

More details about these validation objective/success criteria and metrics can be found in the PJ.06-01 VALP for V3 ([46]).

The results of the V3 validation activities reported in the PJ.06-01 consolidated VALR ([49]) show that all these safety-related success criteria are successfully achieved.

OBJ-06.01-V3-VALP-021 Safety **To assess the impact on safety of solution under validation implementation in high / very high complexity environment**				
Success Criterion ID	**Success Criterion**	**Success Criterion Status EXE-001**	**Success Criterion Status EXE-002**	**Validation Objective Status**
CRT-06.01-V3-VALP-021-001	Solution under validation operations in High/very high complexity environment remain safe in all conditions (normal and abnormal conditions).	OK	OK	OK
CRT-06.01-V3-VALP-021-002	In solution under validation in High/very high complexity environment, the Safety level is at least maintained compared to reference scenarios (similar traffic volumes)	OK	OK	
CRT-06.01-V3-VALP-021-003	In solution under validation in High/very high complexity environment, the Safety level is at least maintained when managing traffic volumes/complexity expected at horizon 2022	OK	OK	

CRT-06.01-V3-VALP-021-004	In solution under validation in High/very high complexity environment, in a considered sector/AoR the ratio number of CDTs alerts / number of aircraft is not increased.	OK	N/A (not addressed)	
CRT-06.01-V3-VALP-021-005	In solution under validation in High/very high complexity environment, conflict detection and resolution remain manageable (i.e. conflict complexity: geometries, location, interacting surrounding traffic)	OK	POK (OK in all scenarios, except in military scenario)	
CRT-06.01-V3-VALP-021-006	In solution under validation in High/very high complexity environment, airspace design and procedures are developed in a coordinated way in order to maintain complexity increase in manageable limits (strategic de-confliction of flows, transfer conditions and management of conflicts close to sectors boundaries)	OK	POK (ATCOs indicated areas of improve-ment)	
CRT-06.01-V3-VALP-021-007 [15]	In solution under validation in High/very complexity environment, the ratio number of STCA warning / number of aircraft is not increased	N/A	N/A	

Table 12: PJ06-01 Validation Results Overview – Safety KPA

4.3.3 Extrapolation to ECAC wide

Considering that there is no expected contribution to Safety from the PJ.06-01 Solution and that the solution has been demonstrated to be safe, no extrapolation at network (ECAC wide) level of safety benefits was performed and it is considered that the PJ.06-01 Solution will have a neutral safety impact at ECAC level.

4.3.4 Discussion of Assessment Result

The outcomes of the safety assessment conducted at SPR level and the V3 validation exercises results give confidence that **the PJ.06-01 Solution contributes to not adversely affect the Safety KPA with the implementation of structurally limited cross-border FRA in En-Route High and Very High Complexity operating environments**.

4.3.5 Additional Comments and Notes

N/A

[15] STCA warnings were not enabled in both exercise platforms. Separation infringements were analysed instead in the post processing (separation infringements were detected only in military scenario).

4.4 Environment / Fuel Efficiency

The PJ.06-01 Solution is contributing to the Environment/ Fuel Efficiency KPA in En-Route High and Very High Complexity operating environments.

Often fuel efficiency is improved through a reduction of flight (or taxi time). This flight time benefit is also assessed, in this section, as it is additional input for the business case for Airspace Users.

4.4.1 Performance Mechanism

Ability to plan flight in FRA in optimised alignment with business needs is expected to improve flight effectiveness in terms of flight time (more adequate with schedule) and/or flight distance (shorter) and /or fuel and cost (more efficient). Fuel efficiency is thus expected to be improved thanks to uploading less fuel (including fuel to carry fuel), as a result of shorter planned routes and a better adherence to flight plan as filed in the execution phase.

It should nevertheless be noted that Airspace Users' expectation regarding the Free Routing concept is not necessarily to fly more fuel optimum tracks, but more generally to be provided with significant opportunities to optimise their flights in line with individual operator business needs and/or military needs.

The following figure presents the PJ06.01 Performance Mechanism with a focus on Environment/Fuel Efficiency KPA.

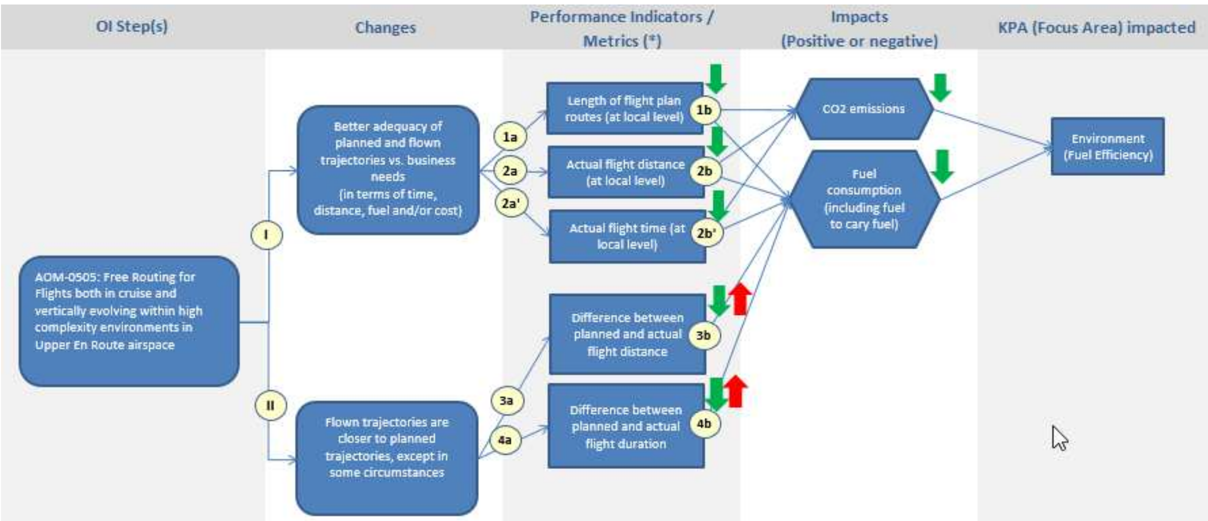


Figure 3: Benefit mechanisms – Stakeholder: ANSPs – Environment /Fuel Efficiency KPA

A description of the **benefit and impact mechanisms describing how the Solution PJ.06-01 is expected to improve environment / fuel efficiency performance** is provided in Appendix A of the PJ.06-01 SPR-INTEROP / OSED Part I document ([45]).

4.4.2 Assessment Data (Exercises and Expectations)

4.4.2.1 General

The contribution of PJ.06-01 to the Environment/Fuel Efficiency KPA was assessed during the V3 validation exercises through a specific validation objective and related success criteria. The metrics planned to be used to assess these criteria included the following ones:

- Difference between Planned and actual Flight duration (local assessment and report on gate-to-gate trajectory)
- Difference between Planned and actual Flight distance (local assessment and report on gate-to-gate trajectory)
- Fixed route / Free routing difference between Planned and actual Flight Distance (planned/planned (gate to gate) and Flown/Flown (Local assessment))
- Number of flights
- Fuel consumption / burn (based on planned and actual trajectories)
- CO2 emission (based on planned and actual trajectories)
- Total amount of actual fuel burn divided by the number of flights (FEFF1)
- Total amount of planned fuel burn divided by the number of flights (FEFF1.1)
- Amount of fuel burn x 3.15 (CO2 emission index) divided by the number of flights (FEFF2)
- Average actual flight duration measured in the Reference Scenario – Average flight duration measured in the Solution Scenario (FEFF3)
- Average actual flight length measured in the Reference Scenario – Average flight duration measured in the Solution Scenario (FEFF A)

More details about these validation objective/success criteria and metrics can be found in the PJ.06-01 VALP for V3 ([46]).

The results of the V3 validation activities reported in the PJ.06-01 consolidated VALR ([49]) show that all these flight efficiency-related success criteria are successfully achieved.

OBJ-06.01-V3-VALP-001 Fuel Efficiency **To assess the increase in fuel efficiency by implementing Solution under validation (SUV) in high/very high complexity environment**				
Success Criterion ID	**Success Criterion**	**Success Criterion Status EXE-001**	**Success Criterion Status EXE-002**	**Validation Objective Status**
CRT-06.01-V3-VALP-001-001	Solution under validation in high/very high complexity environment allows Airspace User's to plan shorter trajectories	OK	OK	OK
CRT-06.01-V3-VALP-001-002	Solution under validation increases fuel saving / flight by 10,389 kg in very High complexity En-Route operational environment	OK	N/A	OK

OBJ-06.01-V3-VALP-001 Fuel Efficiency To assess the increase in fuel efficiency by implementing Solution under validation (SUV) in high/very high complexity environment				
CRT-06.01-V3-VALP-001-003	Solution under validation increases fuel saving / flight by 2,968 kg in High complexity En-Route operational environment	N/A	OK	OK
CRT-06.01-V3-VALP-001-004	The planning of minimum cost tracks in solution under validation of high/very high complexity lead to fuel consumption gains in execution phase	OK	OK	OK
CRT-06.01-V3-VALP-001-005	The planning of minimum cost tracks in solution under validation of high/very high complexity lead to CO2/NOX emissions reduction in execution phase	OK	OK	OK

Table 13: PJ06-01 Validation Results Overview – Environment / Fuel Efficiency KPA

The fuel efficiency assessment at local level (using the metrics listed above) lead to false results and conclusions. Indeed the new flight planning options locally offered to airspace users lead to an increase average distance and duration of flights at local level, but contribute to a reduction of the entire ADEP/ADES flight distance / duration. This is in particular true for completely new connections attracting traffic and creating new flows.

In order to mitigate this risk, in coordination with CBA and Performance assessment activities, it was decided not to use SESAR KPIs but the calculation method of the Horizontal Flight Efficiency defined by the Eurocontrol / PRU which is compliant with IR691/2010 and IR390/2013. This method is based on two Key performance Environment indicators:

- **Key performance Environment indicator based on last filed flight Plan (KEP)**
- **Key performance Environment indicator based on actual trajectory (KEA).**

This method allows to consider the additional distances, so the rate of inefficiency along the flight dimension and along the measured area used during the exercise, and obtain consistent values. The calculation is based on the measurement of the flown distance (in the measured area) and the achieved distance which is the projection of the flown trajectory on the great circle from ADEP to ADES (corresponding to the optimal trajectory for an airspace user in terms of distance). The achieved distance represents the real progression of the flight on the great circle. Comparing the flown and achieved distances allows to measure the inefficient distance flown within the considered area.

This inefficient distance is linked to two parameters:

- o The network outside the measured area leading to the fact that entry/Exit points in the area are offset with respect to the Great circle. (This is usually called "interface" factor).
- o The local deviations of trajectories compared to the direct trajectory from Entry point to Exit point. These deviations are linked:

- To the offered flight planning options within the measured area, and
- To the ATC actions applied during the execution phase of the flights. (This is also called "extension" factor).

Exact methodology can be found here: https://ansperformance.eu/methodology/horizontal-flight-efficiency-pi/

4.4.2.2 EXE-06.01-V3-VALP-001 in En-Route – Very High Complexity sub OE

In the frame of this exercise, the objective was to demonstrate a reduction of inefficiency at flight planning level and during the execution. The same measurement area has been used for Reference and Solution scenarios, corresponding to Skyguide AoR (Geneva + Zurich ACCs) slightly amended due to the new and improved connectivity with neighbouring centres (only a few nautical miles more taken into account around a few Entry/Exit points), in order to properly assess the gain brought by all connections.

Below the Validation Results from EXE-06.01-V3-VALP-001 exercise related to Environment/Fuel Efficiency benefits.

<table>
<tr><th>Success Criterion ID</th><th>Success Criterion</th><th>Validation Results</th></tr>
<tr><td>CRT-06.01-V3-VALP-001-001</td><td>Solution under validation in high complexity environment allows Airspace User's to plan shorter trajectories</td><td>
The results show that the horizontal flight efficiency is improved in cross-border FRA compared to Fixed Route environment and this efficiency is further improved with the extension of cross border FRA operations.
This improvement is demonstrated through a reduction of the local inefficiency (local % of wasted route at planning level (KEP indicator) and in execution phase (KEA indicator)):
<table>
<tr><th>VALIDATIONS</th><th>KEP (planned)</th><th>KEA (Flown)</th><th>KEP improvement REF > SOL</th><th>KEA improvement REF > SOL</th></tr>
<tr><td>Reference - FRN</td><td>7,81%</td><td>5,55%</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Solution 1 - XFRA 2 cells</td><td>5,42%</td><td>4,49%</td><td>2,39%</td><td>1,06%</td></tr>
<tr><td>Solution 2 - XFRA 1 cell</td><td>5,26%</td><td>4,37%</td><td>2,55%</td><td>1,18%</td></tr>
</table>
Note: The figures related to the Reference scenarios are fully coherent with PRU statistics related to operations in Skyguide area of responsibility. The confidence in the results is thus high.
These KEP & KEA values correspond to the following results in terms of inefficient distances planned and flown within the measured area:
<table>
<tr><th>VALIDATIONS</th><th>Planned inefficient Distance</th><th>Flown inefficient Distance</th><th>Planned inefficient distance reduction SOL vs REF</th><th>Flown inefficient distance reduction SOL vs REF</th></tr>
<tr><td>Reference - FRN</td><td>8.32 NM</td><td>5.79 NM</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Solution 1 - XFRA 2 cells</td><td>6.02 NM</td><td>4.79 NM</td><td>2.30 NM</td><td>1.00 NM</td></tr>
<tr><td>Solution 2 - XFRA 1 cell</td><td>5.83 NM</td><td>4.67 NM</td><td>2.49 NM</td><td>1.11 NM</td></tr>
</table>
It is demonstrated that with XFRA implementation, the inefficient planned distance is reduced, AUs can plan shorter trajectories. This has a beneficial impact on fuel carried out.
</td></tr>
</table>

<table>
<tr><td></td><td></td><td>It is also demonstrated that flown inefficient distance in execution phase is reduced in XFRA compared to Fixed Route Network (Reference scenario).</td></tr>
<tr><td>CRT-06.01-V3-VALP-001-002</td><td>Solution under validation increases fuel saving / flight by 2,968 kg in high complexity En-Route operational environment</td><td>The conversion factors applied at European level (average speed of 6,94NM/Min) lead to the following results in the measured area in terms of average flight time inefficiency reduction in the solution scenarios, compared to reference scenarios, in flight planning and execution phases:
<table>
<tr><th>VALIDATIONS</th><th>Planned inefficient Flight time reduction SOL vs REF</th><th>Flown inefficient Flight time reduction SOL vs REF</th></tr>
<tr><td>Solution 1 - XFRA 2 cells</td><td>19.91 sec</td><td>8.63 sec</td></tr>
<tr><td>Solution 2 - XFRA 1 cell</td><td>21.56 sec</td><td>9.62 sec</td></tr>
</table>
Taking into account the retained conversion factor related to fuel consumption (49 kg/min), here are the gains in the measured area in terms of fuel consumption reduction in the solution scenarios, compared to reference scenarios, in flight planning and execution phases:
<table>
<tr><th>VALIDATIONS</th><th>Planned fuel consumption reduction SOL vs REF</th><th>Fuel consumption reduction in flight execution phase SOL vs REF</th></tr>
<tr><td>Solution 1 - XFRA 2 cells</td><td>16.26 kg</td><td>7.04 kg</td></tr>
<tr><td>Solution 2 - XFRA 1 cell</td><td>17.60 kg</td><td>7.86 kg</td></tr>
</table>
It is demonstrated that XFRA implementation enables a fuel saving for AUs in very High complexity En-Route operational environment.

The fuel saving first takes place in planning phase allows to reduce the amount of fuel carried out what also leads to a fuel consumption during the execution of flight.</td></tr>
<tr><td>CRT-06.01-V3-VALP-001-004</td><td>The planning of minimum cost tracks in solution under validation of high/very high complexity lead to fuel consumption gains in execution phase</td><td>The traffic scenarios used during the solution runs were based on minimum cost tracks calculated by Eurocontrol. The trajectories of all flights in execution phase during the selected time slots of the reference scenarios (not only those crossing the selected simulated area in the traffic samples selected as reference) have been recalculated. This has allowed to see the impact of minimum cost tracks planning and brought realism as some flights crossing the simulated area in reference scenarios were not crossing it in the solution scenarios, while new ones were crossing it.

In the solution scenarios using these minimum cost tracks, a fuel consumption reduction has been demonstrated in the simulated area with the implementation of cross-border FRA, compared to reference scenarios.</td></tr>
</table>

<table>
<tr>
<td>CRT-06.01-V3-VALP-001-005</td>
<td>The planning of minimum cost tracks in solution under validation of high complexity lead to CO2/NOX emissions reduction in execution phase</td>
<td>Using the retained conversion factor CO2/Fuel (3.5 kg C=2/kg fuel) here are the results in the measured area in terms of Co2/NoX emissions reduction in solution scenarios, compared to reference scenarios:

<table>
<tr><th>VALIDATIONS</th><th>Planned reduction of CO2/NoX emissions SOL vs REF</th><th>Flown reduction of CO2/NoX emissions SOL vs REF</th></tr>
<tr><td>Solution 1 - XFRA 2 cells</td><td>51.22 kg</td><td>22.19 kg</td></tr>
<tr><td>Solution 2 - XFRA 1 cell</td><td>55.45 kg</td><td>24.76 kg</td></tr>
</table>

It is demonstrated that cross-border FRA implementation enables a Co2/NoX emissions reduction.</td>
</tr>
</table>

Table 14: EXE-06.01-V3-VALP-001 Validation Results – Environment / Fuel Efficiency KPA

4.4.2.3 EXE-06.01-V3-VALP-002 in En-Route – High Complexity sub OE

Below the Validation Results from EXE-06.01-V3-VALP-002 exercise related to Environment/Fuel Efficiency benefits.

<table>
<tr><th>Success Criterion ID</th><th>Success Criterion</th><th>Validation Results</th></tr>
<tr>
<td>CRT-06.01-V3-VALP-001-001</td>
<td>Solution under validation in high complexity environment allows Airspace User's to plan shorter trajectories</td>
<td>The structurally limited FR environment improves the local % of planned wasted route (KEP indicator) regarding the reference scenario both with advanced and basic tools.

<table>
<tr><td></td><td colspan="8">Advanced tools</td><td colspan="3">Basic tools</td><td colspan="5">Reference</td></tr>
<tr><td>Run</td><td>1.1</td><td>1.2</td><td>3.2</td><td>5.2</td><td>6.2</td><td>7.1</td><td>9.1</td><td>ALL</td><td>2.1</td><td>6.1</td><td>ALL</td><td>3.1</td><td>4.1</td><td>5.1</td><td>8.1</td><td>ALL</td></tr>
<tr><td></td><td>2.3</td><td>0.4</td><td>0.7</td><td>2.1</td><td>1.1</td><td>2.5</td><td>3.5</td><td>1.8</td><td>0.5</td><td>0.4</td><td>1.5</td><td>3.9</td><td>5.2</td><td>4.2</td><td>4.3</td><td>4.4</td></tr>
</table>
Table 20: KEP

The gain is around a 60%. This high improvement could be related to the fact that the airspace was designed with the minimum possible limitations, and most of the effort was concentrated inside and near the area under simulation. The result should thus be considered as optimistic.

The FR environment also improves the local % of flown wasted fown route (KEA indicator) regarding the reference both with advanced and basic tools. The gain is a 27.2% in an advanced tools scenario, and a 26.46% in the basic tools scenario.

<table>
<tr><td></td><td colspan="8">Advanced tools</td><td colspan="3">Basic tools</td><td colspan="5">Reference</td></tr>
<tr><td>Run</td><td>1.1</td><td>1.2</td><td>3.2</td><td>5.2</td><td>6.2</td><td>7.1</td><td>9.1</td><td>ALL</td><td>2.1</td><td>6.1</td><td>ALL</td><td>3.1</td><td>4.1</td><td>5.1</td><td>8.1</td><td>ALL</td></tr>
<tr><td></td><td>3.09</td><td>1.99</td><td>2.36</td><td>2.56</td><td>2.26</td><td>4.00</td><td>3.02</td><td>2.75</td><td>2,27</td><td>3,29</td><td>2,78</td><td>4,70</td><td>4,78</td><td>2,04</td><td>3,59</td><td>3,78</td></tr>
</table>
Table 16: KEA %</td>
</tr>
</table>

<table>
<tr><td></td><td></td><td>This corresponds to about 1% KEA improvement between the Reference scenario and Solution scenarios (1,00% with Basic tools and 1,03% with Advanced tools). The reference KEA is very similar to the one reported by Spain in 2017, thus the confidence in results are high.</td></tr>
<tr><td>CRT-06.01-V3-VALP-001-003</td><td>Solution under validation increases fuel saving / flight by 2,968 kg in high complexity En-Route operational environment</td><td>
The average fuel consumption per flight is reduced in reduced using Free Route, both with advanced and basic tools.
Due to some recording problems, the trajectories that flight only in Barcelona ACC have not been computed. The data from run 5.2 has been disregarded because the outcome data is not aligned with the rest of the runs.
<table>
<tr><td></td><td colspan="8">Advanced tools</td><td colspan="3">Basic tools</td><td colspan="5">Reference</td></tr>
<tr><td>Run</td><td>1.1</td><td>1.2</td><td>3.2</td><td>5.2</td><td>6.2</td><td>7.1</td><td>9.1</td><td>ALL</td><td>2.1</td><td>6.1</td><td>ALL</td><td>3.1</td><td>4.1</td><td>5.1</td><td>8.1</td><td>ALL</td></tr>
<tr><td></td><td>1510</td><td>1653</td><td>1431</td><td>N/A</td><td>1616</td><td>1443</td><td>1576</td><td>1538</td><td>1519</td><td>1532</td><td>1526</td><td>1708</td><td>1741</td><td>1659</td><td>1479</td><td>1647</td></tr>
</table>
Table 17: average fuel consumption (kg)
The average fuel consumption per flight is reduced by 6% using structurally limited Free Route, both with advanced and basic ATC support tools. The gains are higher than expected. This could be due to the fact the only flights that cross Madrid ACC are measured and the free route trajectories are more beneficial in this area. Benefits could be lower in the not measured flights, the ones that cross only Barcelona or the other Spanish ACCs.
</td></tr>
<tr><td>CRT-06.01-V3-VALP-001-004</td><td>The planning of minimum cost tracks in solution under validation of high/very high complexity lead to fuel consumption gains in execution phase</td><td>Due to the configuration of the exercise with two ACCs belonging to the same country, there was no difference in the navigation taxes.</td></tr>
<tr><td>CRT-06.01-V3-VALP-001-005</td><td>The planning of minimum cost tracks in solution under validation of high complexity lead to CO2/NOX emissions reduction in execution phase</td><td>
CO2 and NOX emissions are around 7.5% lower in structurally limited Free Route both with advanced and basic tools than in the reference scenario.
<table>
<tr><td></td><td colspan="8">Advanced tools</td><td colspan="3">Basic tools</td><td colspan="5">Reference</td></tr>
<tr><td>Run</td><td>1.1</td><td>1.2</td><td>3.2</td><td>5.2</td><td>6.2</td><td>7.1</td><td>9.1</td><td>ALL</td><td>2.1</td><td>6.1</td><td>ALL</td><td>3.1</td><td>4.1</td><td>5.1</td><td>8.1</td><td>ALL</td></tr>
<tr><td>CO2</td><td>4618</td><td>5224</td><td>4363</td><td>N/A</td><td>5106</td><td>4565</td><td>4955</td><td>4805</td><td>4818</td><td>4841</td><td>4830</td><td>5242</td><td>5340</td><td>5501</td><td>4674</td><td>5189</td></tr>
<tr><td>NOX</td><td>21</td><td>26</td><td>21</td><td>N/A</td><td>25</td><td>21</td><td>27</td><td>23.5</td><td>25</td><td>24</td><td>24.5</td><td>27</td><td>26</td><td>28</td><td>21</td><td>25.5</td></tr>
</table>
</td></tr>
</table>

Table 15: EXE-06.01-V3-VALP-002 Validation Results – Environment / Fuel Efficiency KPA

4.4.3 Extrapolation to ECAC wide

Initial estimation of FEFF benefits (expert-based judgement before V3 validation exercises)

In absence of V3 validation results during the PAGAR 2018 campaign, expert based judgment was used to estimate the solution benefits and experts estimated **between 1 minutes to 1.5 minutes the flight time reduction in En-Route**.

This expert-based average flight time reduction was then translated into Flight Efficiency (FEFF1) benefits ECAC wide using SESAR2020 Common and other assumptions as detailed below.

- Average flight duration is (SESAR2020 Common Assumption T-0010ALL) 90 minutes.
- Reduction of 1 to 1.5 minutes is 1.1% to 1.7% fuel reduction in En Route.
- En route represents (SESAR2020 Common Assumption F-0005ENR) 66% of the average ECAC fuel burn.

Fuel reduction (in %) in Very high and High Complexity = (F-0005ENR 66%) x 1.1% to (SESAR2020 Common Assumption F-0005ENR 66%) x 1.7% = -0.72% to -1.11%

Fuel reduction (in kg) in Very high and High Complexity = (SESAR2020 Common Assumption F-0001 ALL 4800kg) x -0.74% to (SESAR2020 Common Assumption F-0001 ALL 4800kg) x -1.11% = 34.56kg to 53.28kg

- Solution applies to High and Very High Complexity En-Route Airspace, which represents (SESAR2020 Common Assumption ENR-VH + ENR-H) 57.61% of the traffic (see below excerpt from the SESAR2020 Common Assumption)

- Expert assumption for Year 2035 was that 80 to 100% of the En-Route airspace will be FRA and 90% of the flights will fly FRA (Note: the Solution only applies to upper levels in En-Route, however this estimate did not consider this granularity).

Nb of flights impacted = 72.0% to 90.0% x (SESAR2020 Common Assumption M-0015ALL 37839) =27,244 to 34,055 flights/day

ECAC Fuel reduction in kg (FEFF1) = 72% x-34.56 to 90% x-53.28kg = -24.88 kg to -47.88 kg on average per ECAC flight

ECAC Fuel reduction in % (FEFF1) = 72% x-0.72% to 90% x-1.11% = -0.52% to -0.99%

This initial expert-based estimation was revised after the V3 validation activities.

Final assessment of FEFF benefits (based on V3 validation results)

The V3 validation results for both En-Route High and Very High Complexity environments allowed refining the solution benefit estimates using an ad-hoc and thorough performance model of PJ06-01 implementation.

The goal of this modelling was to estimate the fuel efficiency gained thanks to the solution implementation in En-Route HC & VHC environments. For representativeness purposes and extrapolation at ECAC level, the modelling was done at ACC level.

The model is composed of the following elements:

- Input sheets which gather all the data considered as given and reliable in the model, which are either historical data (2017) or forecasted data (2030/2035) from PJ19/PJ20.
- Assumptions sheets which gather all the assumptions used to make the performance assessment which are either from the common assumptions issued by PJ19 or additional assumptions for the PJ06-01 solution, for example validation results are considered as assumptions.
- Calculation sheets which enable the modelling of the FEFF performance and are based on both Inputs and Assumption sheets.

The model is presented in the following figure:

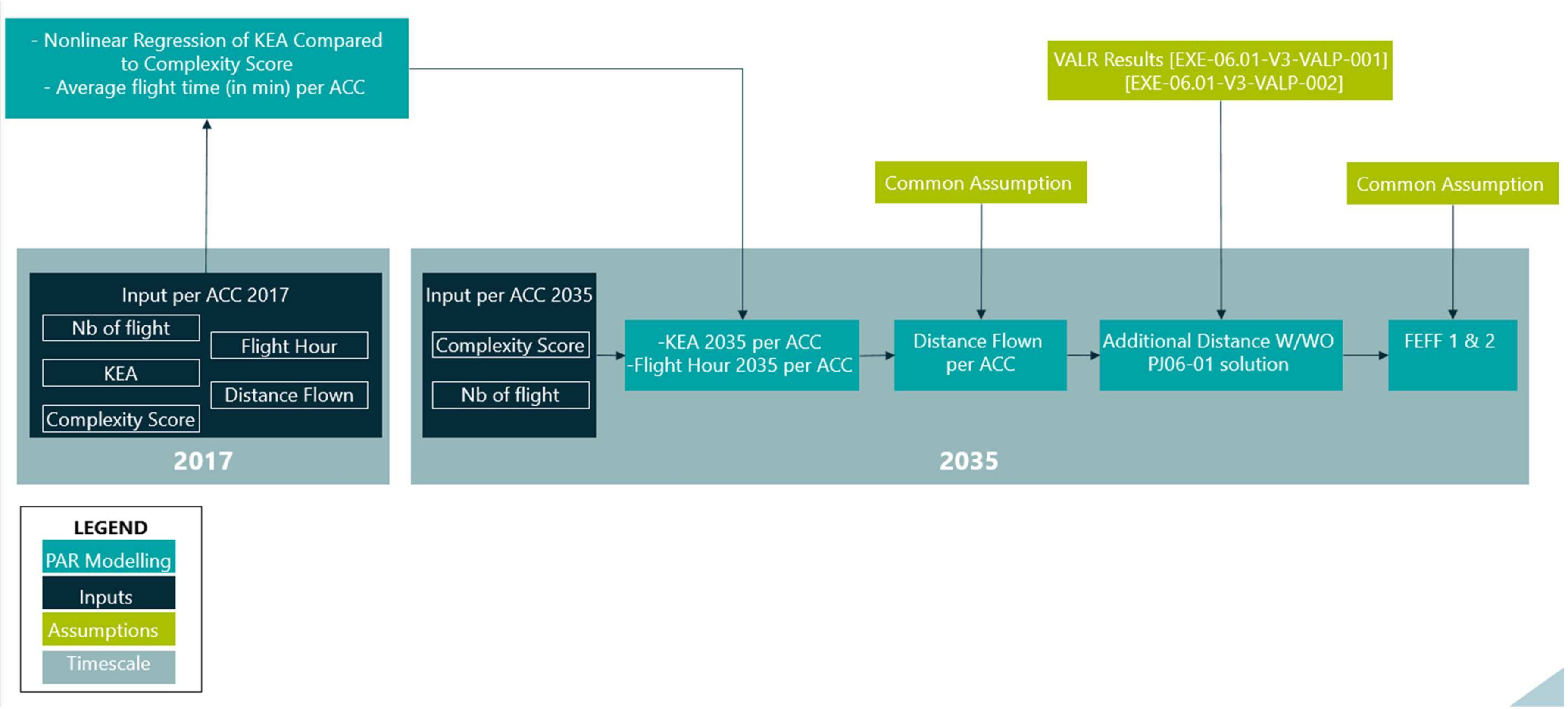


Figure 4: FEFF benefit extrapolation model

KEA reference scenario forecast in 2030/2035

The V3 validation exercise results provided a quantification of the horizontal flight efficiency benefits in terms of % of KEA improvement brought by the solution. In order to estimate the FEFF 1, 2 & 3 benefits in 2030/2035, the KEA baseline needed to be forecasted.

An econometric model estimates the statistical relationship between the variables. In other words, it models, based on historical data, the interdependence of the chosen output and several explanatory variables. For an econometric model to be relevant, the explanatory variables need to be independent, to avoid autocorrelations phenomena.

The correlation coefficients that are a measure of the correlation (relationship) between two variables (explanatory, and of interest) was used in a preliminary analysis (based on historical data from Eurocontrol PRU) to identify the main relationships between the variables before the calibration of the econometric models. The results of this analysis have underlined that there is a correlation between the Complexity Score and the KEA and that the equation presented below can be used to forecast KEA evolution based on the Complexity Score per ACC:

$$KEA = pr1 + pr2 * Cos(2 * \pi * pr3 * Compl.Score) + pr4 * Sin(2 * \pi * pr3 * Compl.Score)$$

With the following value for each estimator:

Parameter	Value	Standard Error
pr1	40,380	4002,546
pr2	-38,755	4002,772
pr3	-0,005	0,180
pr4	1,240	51,189

Tableau 1: Parameters of the Econometric model CS & KEA

The statistical test on the model parameters are presented in the table below:

Statistical Element	Values
Observations	107,000
DDL	103,000
R^2	0,525

Tableau 2: Observation, DDL and R^2 of the Model

The trigonometric relationship determined between the Complexity Score and the KEA is illustrated in the following figure.

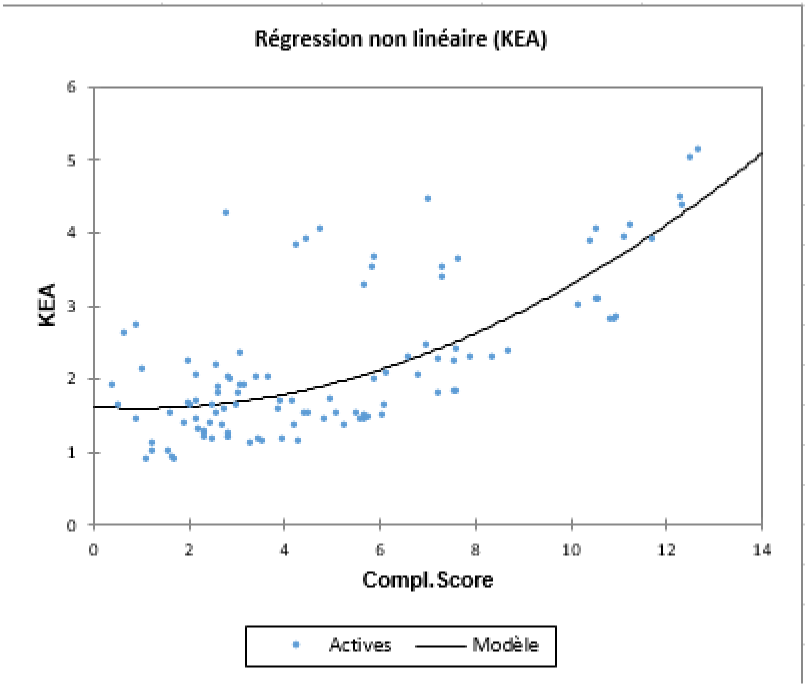


Figure 5: Nonlinear Regression of Complexity Score and KEA

Based on PJ20 forecasts of Complexity Scores per ACC in 2030/2035[16] and the validation of the econometric model the KEA per ACC in 2030/2035 has been forecasted. All things being equal, the results of this forecast represent the KEA per ACC without PJ06-01 implementation.

KEA solution scenario forecast in 2030/2035

As presented in section 4.4.2.2 and 4.4.2.3, the validation exercise results differ depending on the complexity score of the environment. Therefore the KEA forecast per ACC in 2030/2035 with the effect of PJ.06-01 has taken into account the following rules:

- Low and Medium Complexity : No KEA improvement
- High Complexity: KEA improvement based on EXE-06.01-V3-VALP-002 validation results (i.e. 27.25%)
- Very High Complexity: KEA improvement of based on EXE-06.01-V3-VALP-001 validation results (i.e. 20.18%)

Distance gained estimation in 2030/2035

The KEA indicator represents the difference between the shortest route of the great circle within the ACC and the distance flown as follows:

[16] Source PJ20 En-route & Terminal Airspace OEs_April 2019 Version.xslsx

$$KEA = \frac{(Additional)}{Achieved}$$

$$KEA = \frac{(Flown - Achieved)}{Achieved}$$

In order to transform the KEA performance gains into fuel consumption gains, the additional distance gains had to be forecasted.

As EUROCONTROL provided the annual flight hour results and annual IFR movements per ACC in 2017, the 2017 average flight duration was computed at an ACC level.

The performance model assumes that the average fight duration per ACC is stable over the BAD period. In other words, it is considered that the traffic growth will not impact the characteristics of the traffic within each ACC (i.e.: no significant variation of traffic partners) or if it varies it is compensated between flights.

This assumption provides an average minutes flown per ACC, which is then applied to PJ20 traffic forecast per ACC to estimate the 2030/2035 annual flight hours per ACC.

This assumption combined with the average distance flown per minute in En-Route (assumption PJ06_01_ER_SPEED_001) and the PJ20 traffic forecast in number of IFR movements per ACC in 2030/2035 allowed the estimation of the annual distance flown per ACC in 2030/2035.

At this stage, the modelling provided both forecasts for:

- The KEA with/without PJ06-01 solution implementation per ACC in 2030/2035.
- The estimated annual distance flown per ACC in 2030/2035.

As presented in the equations below, the KEA indicator depends on the additional and achieved distances:

$$KEA = \frac{(Additional\ distance\ )}{Achieved\ distance}$$

$$KEA = \frac{(Flown - Achieved)}{Achieved}$$

$$KEA = \frac{Flown}{Achived} - 1$$

$$1 + KEA = \frac{Flown}{Achieved}$$

$$\frac{Flown}{(1 + KEA)} = Achieved$$

Therefore, the forecast of both the KEA and the annual distance flown per ACC allowed the estimation of the achieved, and then of the annual additional distance per ACC. The distance gained from the solution implementation is the difference between the additional and achieved distance with/without the solution implementation.

For example, an ACC XX that has the following criteria:

- *KEA without PJ06-01 implementation:5.05%*
- *KEA with PJ06-01 implementation: 4.03%*
- *Traffic forecast: 933 989 IFR Flights in 2035*
- *Average flight duration within the ACC in 2017: 7.69 minutes*

Calculation of the achieved distance and additional distance without the solution implementation:

$$Achieved = \frac{Flown}{(1 + KEA)}$$
$$Achieved_{\ w/o} = \frac{(933\,989 * 7.69)}{(1 + 5.05)}$$
$$Achieved_{\ w/o} = \frac{(7\,182\,375)}{(1 + 5.05\%)}$$
$$Achieved_{\ w/o} = 6\,837\,102$$
$$Additionnal_{\ w/o} = \left(7\,182\,375 - 6\,837\,102\right)$$
$$Additionnal_{\ w/o} = 345\,273\ NM$$

Calculation of the achieved distance and additional distance without the solution implementation:

$$Achived = \frac{Flown}{(1 + KEA)}$$
$$Achived_{\ w/o} = \frac{(933\,989 * 7.69)}{(1 + 4.03\%)}$$
$$Achived_{\ w/o} = \frac{(7\,182\,375)}{(1 + 4.03\%)}$$
$$Achived_{\ w/o} = 6\,904\,139$$
$$Additionnal_{\ w/o} = \left(7\,182\,375 - 6\,904\,139\right)$$
$$Additionnal_{\ w/o} = 278\,236\ NM$$

Therefore, the solution implementation allows an annual gain of 67 037 NM (=345 273-278 236) in this ACC in 2035.

FEFF Forecast per ACC

The conversion of distance gain into fuel consumption gain relied on the following additional assumptions:

- PJ06_01_ER_SPEED_001: Distance flown per minute in En-Route
- PJ06_01_ER_FUEL_001: Average fuel consumption in ECAC En-Route airspace

The distance gained thanks to the solution implementation is transformed in minutes of flight and then in kg of fuel per ACC. *For example, ACC XX gain of 67 036.21 NM converts into 53 308 269 minutes and 2 607 329 324 Kg of fuel annual savings.*

As the FEFF performance is monitored in terms of kg of fuel per flight, the total annual gain per ACC was divided by the forecasted number of IFR movements. *For example, ACC XX gained 2 607 329 324 Kg of fuel in 2035 which represents and average of 3.51 kg per ACC flight.*

However, this measurement is only representative of the time flown in the ACC, therefore the average flight duration in ECAC (SESAR 2020 common assumption T-0010 = 90 minutes) was used to extrapolate the average fuel gain per ECAC-like flight. *For example, ACC XX gained 3.51 of fuel per ACC flight and the averaged flight time in this ACC XXX is 7.69. Therefore,*

$$Kg\ of\ fuel\ gained\ by\ ECAC\ flight = \frac{3.51}{7.69} * 90 = 41.08\ kg$$

However, the results so far assumes that 100% of the 90 min of flight are accountable for the solution, which is not correct as only the flights hours in En-Route (and above FL305) are to be considered. Therefore, to be more representative of the targeted operational environment, the average fuel gain per ECAC-like flight needed to be weighted by the ratio of flight hours in En-Route (assumption PJ06_01_ER_ACC_001=88%) or above FL305 (assumption PJ06_01_ER_ACC_002=70%). *For example, ACC XX potential gain of 41.08 kg of fuel per ECAC-like flight is actually 36.15 kg of fuel per ECAC-like flight in En-Route, and .only 28,75 kg of fuel per ECAC-like flight above FL305, that can be afforded by the solution.*

The aggregated FFEFF1 results of the performance model are presented in the following table (average results at ECAC level taking into all concerned ACCs in 2030/2035).

Results	**2030 Aggregated Results at ECAC Level for FEFF 1 (in kg fuel per flight)**		**2035 Aggregated Results at ECAC Level for FEFF 1 (in kg fuel per flight)**	
All flights in High Complexity ACCs	-29,61 (in en-route)	-23,69 (above FL305 only)	-29,03 (in en-route)	-23,22 (above FL305 only))
All flights in Very High Complexity ACCs	-36,67 (in en-route)	-29,34 (above FL305 only)	-36,94 (in en-route)	-29,56 (above FL305 only)
All flights in ACCs concerned by PJ 06-01[17]	-32,97 (in en-route)	-26,38 (above FL305 only)	-33,21 (in en-route)	**-26,57 (above FL305 only)**

[17] *Weighted sum of the benefits in ER HC and VHC ACCs using for the % of traffic in each sub-OE in 2030/2035 (e.g. SESAR2020 Common assumptions ER-VHC-2035=31.33%, ER-HC-2035=27.98%).*

All flights in ECAC airspace[18]	-19,72 (in en-route)	-15,77 (above FL305 only)	-19,70 (in en-route)	**-15,76 (above FL305 only)**

Tableau 3: Expected FEFF performance benefits based on VALR results

In summary

Below the absolute expected performance of the Solution PJ.06-01 (and its contribution to the SESAR2020 VT starting point).

KPIs / PIs	Unit	Calculation	Mandatory	Benefit in SESAR1 (if applicable)	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
FEFF1 Actual Average fuel burn per flight	Kg fuel per movement	Total amount of actual fuel burn divided by the number of movements	YES	*-10.75kg (=30kg * 0.224%) for AOM-0500/Solution #32* *-10.37kg (=30kg *-0.216%) for AOM-0501/Solution # 33*	*-26.57kg per flight concerned by the solution* *-15.76kg per ECAC flight*	*From 3.15% (above FL305) to 3.94% (in ER as a whole)*
FEFF2 Actual Average CO_2 Emission per flight	Kg CO_2 per flight	Amount of fuel burn x 3.15 (CO_2 emission index) divided by the number of flights	YES	*Not defined*	*-83,69kg per flight concerned by the solution* *-49.64kg per ECAC flight*	N/A
FEFF3 Reduction in average flight duration	Minutes per flight	Average actual flight duration measured in the Reference Scenario – Average flight duration measured in the Solution Scenario	YES	*-0.86% route extension for AOM-0500/ Solution #32* *-0.94% route extension for AOM-0500/ Solution #33*	*≈ -0.5 min per flight concerned by the solution* *≈ -0.3 min per ECAC flight*	N/A

Note: The above benefits are only takes into account benefits that can be afforded by the solution above FL305 in En-Route HC & VHC sub-OEs based on the very conservative forecast of ACC complexity scores developed by PJ20 (refer to Table 9 for details).

Table 16 is showing the impact on flight phases (provided when it is possible).

[18] *Ratio taking into account only % of traffic concerned by the solution at ECAC level (e.g. 59.31% =31.33%+27.98% in 2035).*

	Taxi out	TMA departure	En-route	TMA arrival	Taxi in
FEFF1 Actual Average fuel burn per flight	N/A	N/A	≈ -0,45% (=-15.76kg / 5280kg x 66%)	N/A	N/A
FEFF2 Actual Average CO_2 Emission per flight	N/A	N/A	≈ -0,45%	N/A	N/A
FEFF3 Reduction in average flight duration	N/A	N/A	≈ -0,45%	N/A	N/A

Table 16: Fuel burn reduction per flight phase.

4.4.4 Discussion of Assessment Result

The SESAR 2020 Validation Targets [43] allocated to the Solution is a reduction of the actual average fuel burn per flight (FEFF1) by 27.69 kg/flight (5.54% contribution to SESAR2020 VT starting point) decomposed into 17.72 kg/flight (64%) in En-Route Very high complexity sub-OE and 9.97 kg/flight (36%) in En-Route high complexity sub-OE.

The outcomes of the Performance Assessment based on the V3 validation exercises results give confidence that the PJ.06-01 Solution positively contributes to the Environment / Fuel Efficiency KPA through the implementation of structurally limited cross-border FRA in En-Route High and Very High Complexity operating environments. Although the direct benefit of the Solution PJ.06-01 (measured above FL305 in high and very high complexity sub-OEs) is smaller than the initial performance expectations translated into the Validation Targets, **the Solution PJ.06-01 is expected to deliver significant Environment / Fuel Efficiency benefits in en-route airspace at the 2035 timeframe**.

4.4.5 Additional Comments and Notes

N/A

4.5 Environment / Noise and Local Air Quality

The PJ06-01 Solution does not impact the Environment / Noise and Local Air Quality KPA.

4.6 Airspace Capacity (Throughput / Airspace Volume & Time)

The PJ.06-01 Solution aims at being Airspace Capacity neutral in En-Route airspace where the Solution applies, as well as in TMA airspace below Free Routing Airspace.

According to the applicable version of EATMA, no specific Capacity performance targets is allocated to Solution PJ.06-01:

- Airspace Capacity Focus Area – En-Route Capacity (CAP2): 0% increase in peak hour en-route throughput (0% contribution to the SESAR2020 Validation Target starting point);

Considering the potential negative impact of Free Routing operations on Airspace Capacity (and Human Performance of ATCOs) if not supported with adequate ATM capabilities, it was necessary to demonstrate that the Solution PJ.06-01 contributes to not adversely affect the Airspace Capacity KPA in En-route airspace of high and very high complexity, which has done through the validation activities conducted at V3 level.

4.6.1 Performance Mechanism

Airspace Capacity is not expected to be enhanced purely by the application of Free Routing operations In En-Route airspace. By offering more flight planning options, Free Routing can reduce bottlenecks introduced by airspace / ATS route network design in the ATM system with more flexibility to plan for AUs, but Air Traffic Controllers' workload could increase without appropriate automation support due to reduced predictability of conflicts and possibly increased need for ATC-ATC coordination.

To counterbalance the possible negative effect of free routing on ATCO's performance, Air Traffic Control will have to be performed using appropriate ATC sector support tools (Conflict Detection Tools, Monitoring Aids, Inter-sector coordination support tool) adapted to Free Routing cross-border operations.

The potentially high variability of the traffic demand could also lead to an increase of the traffic complexity at ACC/sector level, thus potentially entailing new requirements to cope with peaks of demand/complexity, particularly in case of Free Routing operations in high complexity cross-border environment. To accommodate the variability of the traffic demand, more or less structurally limited cross-border FRA will have to be defined to allow Free Routing operations, while maintaining capacity in the airspace.

The following figures presents the PJ06.01 Performance Mechanism with a focus on capacity aspects.

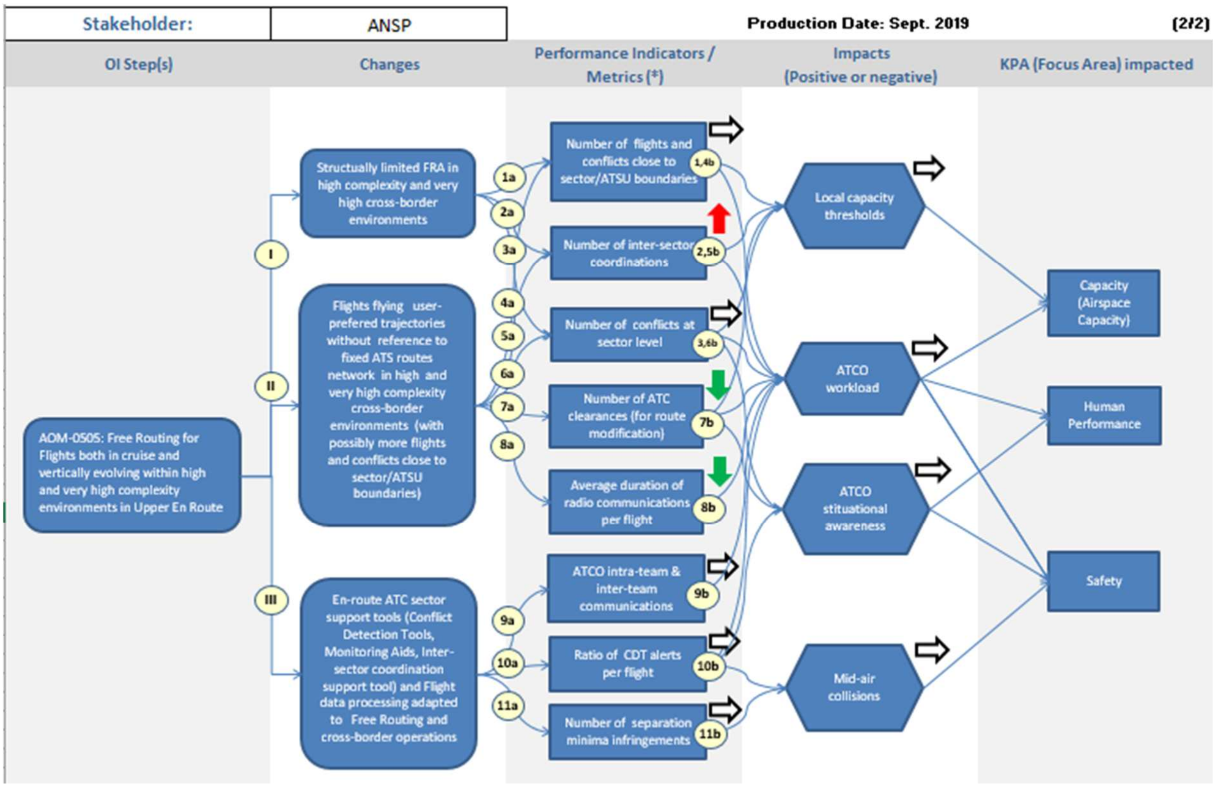


Figure 6: Benefit mechanisms – Stakeholder: ANSP – Airspace Capacity KPA

A description of the **benefit and impact mechanisms describing how the Solution PJ.06-01 does not affect airspace capacity performance in En-Route high & very high complexity environments** is provided in Appendix A of the PJ.06-01 SPR-INTEROP / OSED Part I document ([45]).

4.6.2 Assessment Data (Exercises and Expectations)

The impact of PJ.06-01 on Airspace Capacity KPA was assessed during the V3 validation exercises through specific validation objective and related success criteria. The metrics used to assess these criteria include the following ones:

- Number of assumed flights per measured sector
- Occupancy charts (volume/time)
- Number of clearances
- Debriefing / Questionnaires for subjective assessment by ATCOs (situation awareness, workload…)

More details about these validation objective/success criteria and metrics can be found in the PJ.06-01 VALP for V3 ([46]).

The results of the V3 validation activities reported in the PJ.06-01 consolidated VALR ([49]) show that all these capacity-related success criteria are successfully achieved.

OBJ-06.01-V3-VALP-031 Capacity **To assess the impact on airspace capacity of solution under validation implementation in high and very high complexity environment**				
Success Criterion ID	**Success Criterion**	**Success Criterion Status EXE-001**	**Success Criterion Status EXE-002**	**Validation Objective Status**
CRT-06.01-V3-VALP-031-001	Airspace capacity is at least maintained with the implementation of solution under validation in High/Very High complexity environment (no reduction of capacity compared to reference scenarios)	OK	OK	OK
CRT-06.01-V3-VALP-031-002	Solution under validation airspace capacity in high/very high complexity environment allows to manage the expected traffic level/complexity at horizon 2022	OK	OK	
CRT-06.01-V3-VALP-031-003	In solution under validation in high/very high complexity environment the number of ATCOs tactical actions per flight is not increased (ATCOs initiatives or Flight crew requests)	OK	N/A (not addressed)	

Table 17: PJ06-01 Validation Results Overview – Airspace Capacity KPA

Below the consolidated validation results of the Solution's performance in SESAR2020 (horizon 2035, compared to 2012).

KPIs / PIs	**Unit**	**Calculation**	**Mandatory**	**Benefit in SESAR1 (if applicable)**	**Absolute expected performance benefit in SESAR2020**	**% expected performance benefit in SESAR2020**
CAP1 TMA throughput, in challenging airspace, per unit time	Relative change of movements (% and number of movement)	Not Applicable	YES	*Not Applicable*	*Not Applicable*	*Not Applicable*
CAP2 En-route throughput, in challenging airspace, per unit time	Relative change of movements (% and number of movement)	% and also total number of movements, per volume of En-Route airspace per hour for specific traffic mix and density, for High and Medium Complexity TMAs.airspace at peak demand hours.	YES	*No benefits obtained in SESAR1 for this Solution*	*0% increase in peak hour throughput*	*0%*

Airspace capacity, in the context of the SESAR Performance Framework [3], focuses on the capability of a challenging volume of airspace to handle an increasing number of movements per unit time – through changes to the operational concept and technology. The aggregation is at local level.

4.6.3 Extrapolation to ECAC wide

N/A

4.6.4 Discussion of Assessment Result

The outcomes of the V3 validation activities give confidence that **the PJ.06-01 Solution contributes to not adversely affect the Airspace Capacity Focus Area with the implementation of structurally limited cross-border FRA in En-Route High and Very High Complexity operating environments**.

4.6.5 Additional Comments and Notes

N/A

4.7 Airport Capacity (Runway Throughput Flights/Hour)

The PJ06-01 Solution does not impact the Airport Capacity KPA.

4.8 Resilience (% Loss of Airport & Airspace Capacity Avoided)

The PJ06-01 Solution does not impact the Resilience Focus Area.

4.9 Predictability (Flight Duration Variability, against RBT)

The PJ.06-01 Solution is potentially impacting the Predictability KPA in En-Route High and Very High Complexity operating environments.

However, the effect on in-flight variability in En-Route is dependent on the Free Routing Airspace design at local level and the overall impact on Predictability at ECAC level could not be assessed with enough level of confidence.

4.9.1 Performance Mechanism

Ability for Airspace Users to plan flight in FRA in optimised alignment with business needs is expected to improve in-flight variability, which is expected to be reduced thanks to less trajectory revisions (e.g. less tactical directs requested by pilots or given by ATCO to expedite the traffic).

However, the expected reduction of in-flight variability in En-Route is dependent on the Free Route Airspace design itself (and its level of optimisation regarding structural limitations) as well as, the overall impact of required tactical interventions on the flights trajectory at local level.

Some predictability benefits are nevertheless expected from the Solution PJ.06-01 with on average a better adherence to flight plan as filed in the execution phase.

The following figure presents the PJ06.01 Performance Mechanism with a focus on Predictability KPA.

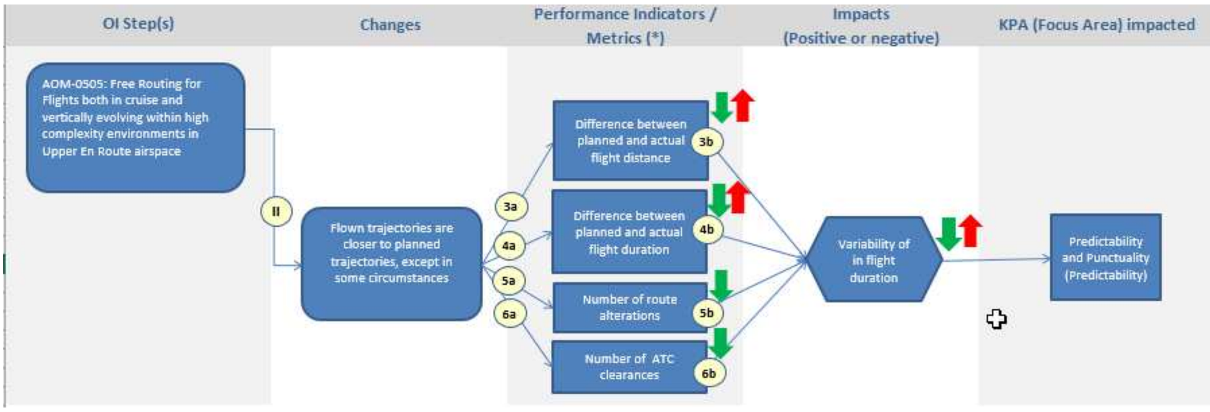


Figure 7: Benefit mechanisms – Stakeholder: ANSPs – Predictability KPA

A description of the **benefit and impact mechanisms describing how the Solution PJ.06-01 is expected to affect predictability performance** is provided in Appendix A of the PJ.06-01 SPR-INTEROP / OSED Part I document ([45]).

4.9.2 Assessment Data (Exercises and Expectations)

4.9.2.1 General

The contribution of PJ.06-01 to the Predictability KPA was assessed during the V3 validation exercises through a specific validation objective and related success criteria. The metrics planned to be used to assess these criteria included the following ones:

- Variance of difference between planned flight duration. and actual fight duration (local assessment - fixed route vs Free Route environment) (PRD1)
- Standard Deviation of the distribution of actual En-route duration vs. planned En-route duration (PRD6)
- Difference between Planned and actual Flight Distance (planned/planned (gate to gate) and Flown/Flown (Local assessment))
- Perceived predictability by ATCOs
- Number of route alterations
- Number of clearances (R/T and CPDLC)

More details about these validation objective/success criteria and metrics can be found in the PJ.06-01 VALP for V3 ([46]).

In addition of the quantitative metrics listed above (derived from the SESAR2020 Performance Framework), the predictability benefits were also estimated by calculating the variation in horizontal inefficiency (i.e. local % of wasted route compared to the great circle distance) between the planned and flown trajectories in all scenarios types using the difference [KEP-KEA].

The results of the V3 validation activities reported in the PJ.06-01 consolidated VALR ([49]) show that all these predictability-related success criteria are partially achieved.

OBJ-06.01-V3-VALP-011 Predictability **To assess the increase in predictability by implementing solution under validation in high / very high complexity environment.**				
Success Criterion ID	**Success Criterion**	**Success Criterion Status EXE-001**	**Success Criterion Status EXE-002**	**Validation Objective Status**
CRT-06.01-V3-VALP-011-001	Solution under validation ensures a 0,8 % reduction in variance of Block-to-Block flight time, in En Route very high complexity environment.	NOK (Variance of actual vs. planned flight time slightly increased)	N/A	POK
CRT-06.01-V3-VALP-011-002	Solution under validation ensures a 0,241% reduction in variance of Block-to-Block flight time, in En Route high complexity environment.	N/A	POK (OK, but variance values of low confidence)	
CRT-06.01-V3-VALP-011-003	The implementation of solution under validation in En Route high/very high complexity environment, reduces the variability of flights in execution (ATCOs or flight crew actions)	POK (Standard deviation of actual vs. planned flight durations slightly increased, but local % of wasted route reduced)	POK (Standard deviation of actual vs. planned flight durations reduced with low confidence, and local % of wasted route increased)	
CRT-06.01-V3-VALP-011-004	The implementation of solution under validation in En Route high/very high complexity environment, reduces difference between planned and flown trajectories.	OK	OK	

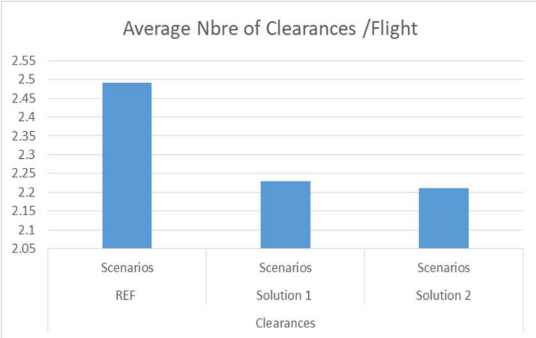
Table 18: PJ06-01 Validation Results Overview – Predictability KPA

4.9.2.2 EXE-06.01-V3-VALP-001 in En-Route – Very High Complexity sub OE

Below the Validation Results from EXE-06.01-V3-VALP-001 exercise related to Predictability benefits.

<table>
<tr><th>Success Criterion ID</th><th>Success Criterion</th><th>Validation Results</th></tr>
<tr><td>CRT-06.01-V3-VALP-011-001</td><td>Solution under validation ensures a 0,8 % reduction in variance of Block-to-Block flight time, in En Route very high complexity environment.</td><td rowspan="2">
The KEP and KEA, as well as SESAR KPIs (PDR1, PRD6) have been used to measure the predictability results.
The results do not provide evidence that the local variance of flight time (in min2) or the variability (standard deviation in min) of actual vs. planned flight durations are improved in cross-border FRA compared to Fixed Route environment.
<table>
<tr><th></th><th>Solution 2 - XFRA 1 Cell</th><th>Solution 1 - XFRA 2 Cells</th><th>Reference</th><th>(Sol2-REF) / REF</th><th>(Sol1-REF) / REF</th></tr>
<tr><td>Mean difference (min)</td><td>0.409</td><td>0.408</td><td>0.456</td><td>-10.37%</td><td>-10.52%</td></tr>
<tr><td>Variance (min2)</td><td>0.935</td><td>0.912</td><td>0.907</td><td>3.14%</td><td>0.55%</td></tr>
<tr><td>Std deviation (min)</td><td>0.967</td><td>0.955</td><td>0.952</td><td>1.56%</td><td>0.28%</td></tr>
</table>
The local variances and standard deviations in the Solution scenarios are even slightly increased compared to Reference one.
(Note: The above results were obtained by removing 5% more extreme values of difference between planned and actual fight durations. Without excluding these outliers, the measured local variances are significantly increased in the FRA scenarios between 18% and 35% compared to the Reference scenario).
Although the in-flight variability is not improved, the results show that the variation in the local % of planned vs. flown wasted route (i.e. difference [KEP-KEA]) is reduced in cross-border FRA compared to Fixed Route environment, and this predictability benefit is further improved with the extension of cross border FRA operations.
<table>
<tr><th>VALIDATIONS</th><th>KEP (planned)</th><th>KEA (Flown)</th><th>[KEP-KEA]</th><th>[KEP-KEA] improvement REF > SOL</th></tr>
<tr><td>Reference - FRN</td><td>7.81%</td><td>5.55%</td><td>2.26%</td><td>N/A</td></tr>
<tr><td>Solution 1 - XFRA 2 cells</td><td>5.42%</td><td>4.49%</td><td>0.93%</td><td>1.33%</td></tr>
<tr><td>Solution 2 - XFRA 1 cell</td><td>5.26%</td><td>4.37%</td><td>0.89%</td><td>1.37%</td></tr>
</table>
A reduction of ~1.3 % of [KEP-KEA] is measured in the Solution scenarios, compared to Reference one. The variability of flights is therefore reduced in execution phase.
</td></tr>
<tr><td>CRT-06.01-V3-VALP-011-003</td><td>The implementation of solution under validation in En Route high/very high complexity environment, reduces the variability of flights in execution (ATCOs or flight crew actions)</td></tr>
<tr><td>CRT-06.01-V3-VALP-011-004</td><td>The implementation of solution under validation in En Route high/very high</td><td>The results show that the mean difference between planned and flown trajectories is reduced in cross-border FRA compared to Fixed Route environment.</td></tr>
</table>

<table>
<tr><td></td><td>complexity environment, reduces difference between planned and flown trajectories.</td><td>
<table>
<tr><th></th><th>Solution 2 - XFRA 1 Cell</th><th>Solution 1 - XFRA 2 Cells</th><th>Reference</th><th>(Sol2-REF) / REF</th><th>(Sol1-REF) / REF</th></tr>
<tr><td>Mean difference (min)</td><td>0.409</td><td>0.408</td><td>0.456</td><td>-10.37%</td><td>-10.52%</td></tr>
<tr><td>Variance (min2)</td><td>0.935</td><td>0.912</td><td>0.907</td><td>3.14%</td><td>0.55%</td></tr>
<tr><td>Std deviation (min)</td><td>0.967</td><td>0.955</td><td>0.952</td><td>1.56%</td><td>0.28%</td></tr>
</table>
An average reduction of ~10% in flight times is measured in the Solution scenarios, compared to the Reference one.</td></tr>
<tr><td>CRT-06.01-V3-VALP-031-003</td><td>In solution under validation in high/very high complexity environment the number of ATCOs tactical actions per flight is not increased (ATCOs initiatives or Flight crew requests)</td><td>The results show that the average number of ATCOs tactical action per flight is not increased (ATCOs initiatives or Flight crew requests) in cross-border FRA compared to Fixed Route environment. This average number is even slightly reduced.



Besides the number of flights not receiving any route modification clearance (Heading, direct or speed modification clearances) in the measured area is increased, logically leading to a reduced average number of route modification clearances per flight.

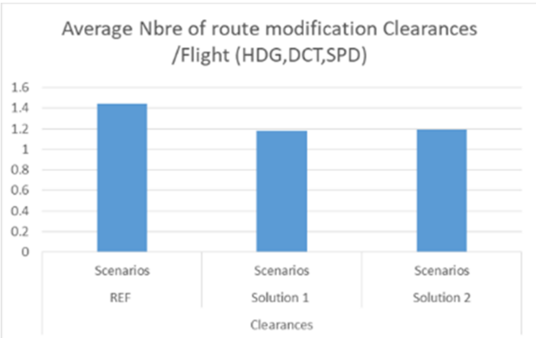

</td></tr>
</table>

Table 19: EXE-06.01-V3-VALP-001 Validation Results – Predictability KPA

4.9.2.3 EXE-06.01-V3-VALP-002 in En-Route – High Complexity sub OE

Below the Validation Results from EXE-06.01-V3-VALP-002 exercise related to Predictability benefits.

Success Criterion ID	Success Criterion	Validation Results

<table>
<tr>
<td>CRT-06.01-V3-VALP-011-002</td>
<td>Solution under validation ensures a 0,241% reduction in variance of Block-to-Block flight time, in En Route high complexity environment.</td>
<td>The KEP and KEA, as well as SESAR KPIs (PDR1, PRD6) have been used to measure the predictability results.

The results show that the use of Free Route either with advanced and basic tools, reduces the local variance (in min2) of flight time and the variability (standard deviation in min) of the flown vs. planned trajectories. The measurement covers only the simulated sectors of Madrid.</td>
</tr>
<tr>
<td>CRT-06.01-V3-VALP-011-003</td>
<td>The implementation of solution under validation in En Route high/very high complexity environment, reduces the variability of flights in execution (ATCOs or flight crew actions)</td>
<td>
<table>
<tr><td></td><td colspan="8">Advanced tools</td><td colspan="3">Basic tools</td><td colspan="5">Reference</td></tr>
<tr><td>Run</td><td>1.1</td><td>1.2</td><td>3.2</td><td>5.2</td><td>6.2</td><td>7.1</td><td>9.1</td><td>ALL</td><td>2.1</td><td>6.1</td><td>ALL</td><td>3.1</td><td>4.1</td><td>5.1</td><td>8.1</td><td>ALL</td></tr>
<tr><td>Variance</td><td>5,7</td><td>8,5</td><td>7,6</td><td>N/A</td><td>4,7</td><td>3,4</td><td>9,9</td><td>6,6</td><td>1,4</td><td>1,0</td><td>1,2</td><td>2,0</td><td>14,0</td><td>34,0</td><td>28,6</td><td>19,7</td></tr>
<tr><td>Variability</td><td>2,4</td><td>2,9</td><td>2,8</td><td>N/A</td><td>2,2</td><td>1,8</td><td>3,1</td><td>2,6</td><td>1,2</td><td>1,0</td><td>1,1</td><td>1,4</td><td>3,7</td><td>5,8</td><td>5,3</td><td>4,4</td></tr>
</table>
Table 21: variance

The value difference between runs of similar scenarios is high, thus the level of confidence in the result is low.

Although the local variance and variability (standard deviation) are reduced, the variation in the local % of planned vs. flown wasted route (i.e. difference [KEP-KEA]) is not reduced in Free Route neither with advanced nor basic tools, compared to the Reference scenario.

<table>
<tr><td></td><td>KEP</td><td>KEA</td><td>[KEP-KEA]
(in %)</td><td>[KEP-KEA] Improvement (%)</td><td>% [KEP-KEA] reduction</td></tr>
<tr><td>REF</td><td>4,4</td><td>3,78</td><td>0,62</td><td>N/A</td><td>N/A</td></tr>
<tr><td>Basic ATC tools</td><td>1,5</td><td>2,78</td><td>-1,28</td><td>1,9</td><td>306,45%</td></tr>
<tr><td>Advanced ATC tools</td><td>1,8</td><td>2,75</td><td>-0,95</td><td>1,57</td><td>253,23%</td></tr>
</table>
Table 22: [KEP-KEA]

The difference [KEP-KEA] is not positive in the FRA scenarios and the predictability is degraded. This outcome is related to minimum structural limits defined during the FRA airspace design. The KEP values in the designed FRA are very low and any deviation from the planned trajectory increases the flight length, thus the KEA is higher that the KEP. This behaviour is the opposite in the reference scenario where the KEP is higher than the KEA.
</td>
</tr>
<tr>
<td>CRT-06.01-V3-VALP-011-004</td>
<td>The implementation of solution under validation in En Route high/very high complexity environment, reduces difference between planned and flown trajectories.</td>
<td>The results show the use of Free route either with advanced and basic tools, reduces the mean difference between planned and flown trajectories. The measurement covers only the simulated sectors in Madrid ACC.

<table>
<tr><td></td><td colspan="8">Advanced tools</td><td colspan="3">Basic tools</td><td colspan="5">Reference</td></tr>
<tr><td>Run</td><td>1.1</td><td>1.2</td><td>3.2</td><td>5.2</td><td>6.2</td><td>7.1</td><td>9.1</td><td>ALL</td><td>2.1</td><td>6.1</td><td>ALL</td><td>3.1</td><td>4.1</td><td>5.1</td><td>8.1</td><td>ALL</td></tr>
<tr><td></td><td>2.0</td><td>2.2</td><td>2.1</td><td>3.4</td><td>1.6</td><td>1.6</td><td>2.6</td><td>2.2</td><td>1.2</td><td>1.2</td><td>1.2</td><td>1.3</td><td>3.6</td><td>5.7</td><td>4.5</td><td>3.8</td></tr>
</table>
Table 20: trajectories differences

The variability between runs was assessed by the standard deviation of the measurements, which are 0.62 in FRA with</td>
</tr>
</table>

		advanced tools, 0.04 with basic MTCD, and 1.87 in the reference scenarios. The variability is lower in Free Route than in Reference scenarios.
CRT-06.01-V3-VALP-031-003	In solution under validation in high/very high complexity environment the number of ATCOs tactical actions per flight is not increased (ATCOs initiatives or Flight crew requests)	The actions per ATCO were not recorded by the platform and have not been analysed.

Table 20: EXE-06.01-V3-VALP-002 Validation Results – Predictability KPA

4.9.2.4 Historical data

Several FRA projects already implemented in Europe monitored predictability benefits in terms the impact they had on KEP-KEA difference. In particular it was observed that national FRA at ACC level project typically mainly introduce an improvement in horizontal flight efficiency (i.e. decrease of KEA), while the national FRA initiatives and including cross-border activities typically lead to a more significant reduction of the difference [KEP-KEA].

In the figure below extracted from the EUROCONTROL annual performance report 2016 ([42]), "*it can also be seen that the gap between the flight plan efficiency and the efficiency in the actual flown trajectory (the vertical distance between a point and the diagonal) is narrower than for the other States (1.0 percent point smaller gap). Actual operations closer to plan improves the level of predictability for all players involved.*"

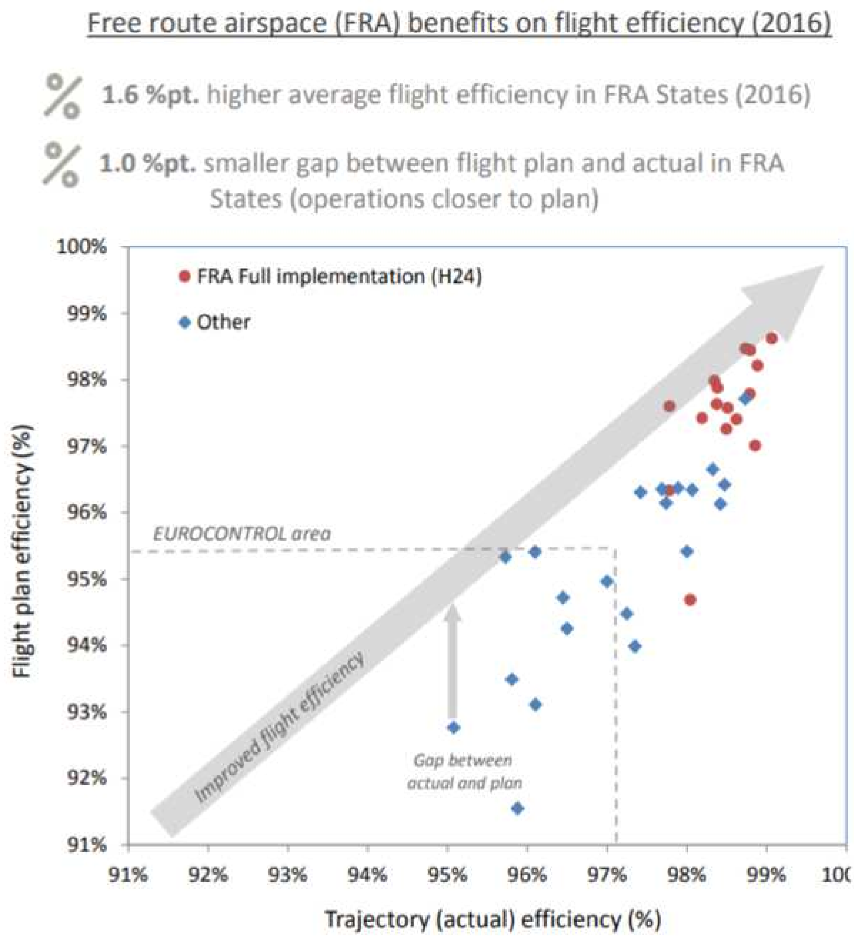


Figure 8: General trends in FRA improvements in terms of KEP (plan) and KEA (actual) – Source PRR 2016

Note: The figure shows the level of flight efficiency in in actual trajectories (X-Axis) and filed flight plans (Y-Axis) by State in 2016. States in which FRA is available 24 hours are shown in red.

4.9.3 Extrapolation to ECAC wide

Initial estimation of PRED benefits (expert-based judgement before V3 validation exercises)

In absence of V3 validation results during the PAGAR 2018 campaign, expert based judgment was used to get a very rough estimation of the solution benefits and experts estimated that **the variability variances are expected to improve by 1 min^2**.

This expert-based variability variance reduction into Predictability (PRD1) benefits ECAC wide using SESAR2020 Common and other assumptions as detailed below.

- Solution applies to High and Very High Complexity En-Route Airspace, which represents (SESAR2020 Common Assumption ENR-VH + ENR-H) 57.61% of the traffic (see below excerpt from the SESAR2020 Common Assumption)

- Expert assumption for Year 2035 is that 80% to 100% of the High and very high complexity airspace will be concerned with FRA and within this airspace not all the flight will fly Free Route, 90% will but some (10%) might still fly in conventional way.

Average per ECAC flights: 1 min^2 * 57.61% *(80%*90% to 100%*90%) = 0.415 min^2 to 0.518 min^2 improvement in flight variance

% improvement in flight variance: 0.415 min^2 to 0.518 min^2/49 min^2 = 0.85% to 1.06%

This initial expert-based estimation was revisited after the V3 validation activities.

Final assessment of PRED benefits (based on V3 validation results)

The V3 validation results for both En-Route High and Very High Complexity environments did not confirm the variability variance benefits initially estimated by expert-based judgement.

From the V3 validation results, it seems that the predictability benefits are very influenced by the airspace design of the structurally limited cross-border FRA. Mean difference between flown and planned flight durations is improved in both validation exercises but:

- In EXE-06.01-V3-VALP-001, the airspace structure of the very high complexity FRA leaves an improvement of the difference [KEP-KEA], but a slight degradation of the Variance KPI.

- In EXE-06.01-V3-VALP-002, the airspace structure of the high complexity FRA leaves an improvement in the Variance KPI, but a degradation of the difference [KEP-KEA]. Besides, the level of confidence in the results is low considering the high difference in the values observed between runs of similar scenarios and the minimum structural limits of the designed FRA.

Based on these V3 validation results**, it is therefore not possible to extrapolate ECAC wide any variability variance benefits from the implementation of FRA across ACCs/FIRs**.

Based on historical data and annual reports issued by EUROCONTROL such as the PRR 2016, there are evidences that national FRA initiatives and including cross-border activities typically lead to a significant reduction of the difference [KEP-KEA].

Building on the V3 validation results, this general trend is expected to be supported by the implementation of the Solution PJ.06-01 in En-Route high and very high complexity environments. It is however not possible to extrapolate to which extent.

In summary

Below the absolute expected performance of the Solution PJ.06-01 (and its contribution to the SESAR2020 VT starting point).

KPIs / PIs	Unit	Calculation	Mandatory	Benefit in SESAR1 (if applicable)	Absolute expected performance benefit in SESAR2020	% expected performance benefit in SESAR2020
PRD1 Variance[19] of Difference in actual & Flight Plan or RBT durations	Minutes²	Variance of Difference in actual & Flight Plan or RBT durations	YES	*-3.64 % SESAR1 from D72 1.78Min^2*	*Unknown*	*Unknown*
PRD6 En-Route variability	Minutes	Standard Deviation of the distribution of actual En-route durations vs. planned En-route durations	NO	*Not estimated*	*Unknown*	*Unknown*

Table 21 is showing the impact on flight phases (provided when it is possible).

	Taxi out	TMA departure	En-route	TMA arrival	Taxi in
PRD1 Variance[20] of Difference in actual & Flight Plan or RBT durations	N/A	N/A	Positive or negative impact (depending on the airspace design of cross-border FRA at local level)	N/A	N/A
PRD6 En-Route variability	N/A	N/A		N/A	N/A

Table 21: Predictability benefit per flight phase, standard deviation improvement.

4.9.4 Discussion of Assessment Result

The SESAR2020 Validation Targets [43] allocated to the Solution is a reduction of variability variances between actual and flight plan durations by 0.930% (0.97% contribution to SESAR2020 VT starting point) decomposed into 0.595% (64%) in En-Route Very high complexity sub-OE and 0.335% (66%) in En-Route high complexity sub-OE.

The PJ.06-01 performance assessment conducted at V3 level did not provide evidence that these Validation Targets are achievable. Besides, **the impact of the Solution PJ.06-01 on the variability**

[19] Standard Deviation is also accepted.

[20] Standard Deviation is also accepted.

variances at ECAC level is not estimated, as it could vary depending on the implementation of FRA across ACC/FIR boundaries.

Some predictability benefits are nevertheless expected from the Solution PJ.06-01 in terms of local % of actual vs. planned wasted routes (i.e. difference [KEP-KEA]), which benefits will also depend the airspace design of cross-border FRA at local level.

4.9.5 Additional Comments and Notes

N/A

4.10 Punctuality (% Departures < +/- 3 mins vs. schedule due to ATM causes)

The PJ06-01 Solution does not impact the Punctuality KPA.

4.11 Civil-Military Cooperation and Coordination (Distance and Fuel)

The PJ06-01 Solution does not impact the Civil-Military Cooperation and Coordination KPA.

4.12 Flexibility

Flexibility means the ability to react to late flight plan changes and requests. The main PI / metric, FLX1, is "Average delay for scheduled civil/military flights with change request and non-scheduled / late flight plan request."

The PJ06-01 Solution does not impact the Flexibility KPA.

4.13 Cost Efficiency

According to the applicable version of EATMA, no specific Cost Efficiency performance targets is allocated to Solution PJ.06-01:

- Cost Efficiency - ATCO Productivity (CEF2): 0% increase in Flights per ATCO-Hour on duty (0% contribution to the SESAR2020 Validation Target starting point);

Considering the potential negative impact of Free Routing operations on Human Performance of ATCOs (and therefore on ATCO productivity and Airspace Capacity) if not supported with adequate

ATM capabilities, it was nevertheless necessary to assess the effect of the Solution PJ.06-01 on Airspace Capacity KPA in En-route airspace of high and very high complexity.

The outcomes of the V3 validation activities give confidence that the PJ.06-01 Solution contributes to:

- not adversely affect the En-Route Capacity Focus Area with the implementation of structurally cross-border FRA in En-Route High and Very High Complexity operating environments – Refer to section 4.6 for further details.

- not adversely affect the ATCOs Performance in cross-border FRA in En-Route High and Very High Complexity environments – Refer to section 4.16 for further details.

Taking these results into consideration, and even though no specific assessment on ANS Cost Efficiency was performed in the context of the V3 validation activities, **it is considered that the Solution PJ.06-01 will have a neutral effect on ANS Cost Efficiency at network (ECAC wide) level with the implementation of structurally limited cross-border FRA in En-Route High and Very High Complexity operating environments**.

4.14 Airspace User Cost Efficiency

The Solution PJ.06-01 is contributing to improve Airspace Users Cost Efficiency through the improvement of Flight Efficiency (in terms of fuel burn and flight duration) in En-Route High and Very High Complexity operating environments.

Initial expectation was that Predictability / In-flight variability benefits brought by the Solution could translate into strategic delay savings (i.e. schedule buffer reduction deriving in strategic delays savings in terms of min/flight). However considering on the insignificant value and low confidence in the Predictability (PRED1, PRED6) benefits measured during the V3 validation activities, as well as the granularity of schedule buffers (around several minutes) compared to the average flight time reduction with the Solution (of less than 1 min), such strategic delay savings are unlikely thanks to the Solution PJ.06-01 only.

It is therefore considered **that the Solution PJ.06-01 does not impact the Airspace User Cost Efficiency KPA beyond the benefits already counted as part of fuel savings (FEFF1) and flight times reduction (FEFF3) in En-route** – Refer to section 4.4 for further details.

4.15 Security

With respect to Free routing operations and in term of cyber security, no difference can be made between these operations and operations supported by the ARN. Moreover the PJ.06-01 Solution does not specifically impact the Security KPA as no technical system and data exchanges specific for Free Routing are required.

In particular, the Solution does not introduce any new communication and data exchange systems between air traffic control centres and aircraft like for instance new CPDLC system or between ground centres (ANSPs, NMOC, airline operation centres). All data exchange between previously mentioned entities is based on the same, currently used systems (e.g. using OLDI protocol for ATC-ATC flight data exchanges).

Therefore the hypothese is that replacing the air route network with free route airspace and deploying the solution does not create any new cyber security threats which potentially could compromise the safety of flight operations.

4.16 Human Performance

Considering the potential negative impact of Free Routing operations on Air Traffic Controllers' situational awareness and workload, if not supported with adequate ATM capabilities, it was necessary to demonstrate that the Solution PJ.06-01 contributes to not adversely affect the Human Performance KPA in En-route airspace of high and very high complexity.

4.16.1HP arguments, activities and metrics

The Human Performance (HP) assessment for the Solution PJ06.01 was conducted according to the four steps of the SESAR2020 Human Performance assessment process, namely: Step 1 – Understand the concept: Baseline, Solution and Assumptions, Step 2 – Understand the Human Performance Implications, Step 3 – Improve and Validate the concept and Step4 – Collate findings & conclude on transition to next V-phase.

The HP assessment was conducted on the basis of the two main validation exercises (real time simulations) performed at V3 maturity level:

- Thread 1 – Skyguide (EXE-06.01-V3-VALP-001): Very high complexity environment
- Thread 2 – ENAIRE (EXE-06.01-V3-VALP-002): High complexity environment

The results of the HP assessment are reported in Part IV of the Solution PJ.06-01 SPR-INTEROP/OSED for V3. The complete list of identified benefits and issues and related objectives and success criteria as well as the derived Human Performance activities per partner are described in a separate HP Log.

Below is the list of HP arguments and HP performance indicators that have been addressed at the level of the solution, including the list of measurements taken during the validation activities and coverage status depending on whether the mitigations were found and validated up to date.

PIs	Activities & Metrics	Second level indicators	Covered
HP1 Consistency of human role with respect to human capabilities and limitations	Observations Questionnaire Debriefings	**HP1.1** Clarity and completeness of role and responsibilities of human actors	Closed
		HP1.2 Adequacy of operating methods (procedures) in supporting human performance	Closed

PIs	Activities & Metrics	Second level indicators	Covered
		HP1.3 Capability of human actors to achieve their tasks in a timely manner, with limited error rate and acceptable workload level	Closed
HP2 Suitability of technical system in supporting the tasks of human actors	Questionnaire Debriefings	**HP2.1** Adequacy of allocation of tasks between the human and the machine (i.e. level of automation).	N/A
		HP2.2 Adequacy of technical systems in supporting Human Performance with respect to timeliness of system responses and accuracy of information provided	N/A
		HP2.3 Adequacy of the human machine interface in supporting the human in carrying out their tasks.	Closed
HP3 Adequacy of team structure and team communication in supporting the human actors	Questionnaire Debriefings	**HP3.1** Adequacy of team composition in terms of identified roles	N/A
		HP3.2 Adequacy of task allocation among human actors	N/A
		HP3.3 Adequacy of team communication with regard to information type, technical enablers and impact on situation awareness/workload	Closed
HP4 Feasibility with regard to HP-related transition factors		**HP4.1** User acceptability of the proposed solution	N/A
		HP4.2 Feasibility in relation to changes in competence requirements	N/A
		HP4.3 Feasibility in relation to changes in staffing levels, shift organization and workforce relocation.	N/A
		HP4.4 Feasibility in relation to changes in recruitment and selection requirements	N/A
		HP4.5 Feasibility in terms of changes in training needs with regard to its contents, duration and modality.	N/A

The Human Performance related outcome of the real time simulations was overall positive.

The validation exercises show that the implementation of structurally limited cross-border FRA concept in high and very high complexity environment has no negative impact on ATCO's performance when assisted by appropriate ATC support tools adapted to free routing environment. Human performances are maintained thanks to the Solution PJ.06-01, but ATCOs are more dependent on the advanced ATC support tools and to the quality of the FRA structure put in place to maintain an acceptable complexity level.

- The **roles and responsibilities** were considered complete and unambiguous. However, some uncertainties between sectors regarding the responsibilities of solving traffic conflicts close to the boundaries were reported in both exercises.
  To address this issue, specific HP recommendations were defined at V3 SPR level.

- Structurally limited cross-border FRA implementation in high and very high complexity environment does not significantly modify ATCOS working principles and **operating methods** have not been altered with the use of the adapted ATC support tools. The need for clear definition of handover procedures during transitions between sectors was highlighted.
  To reinforce this need, a specific HP requirement was defined at V3 SPR level.

- The **usability and effectiveness of the CWP HMIs** tested in both exercises was deemed as sufficiently adequate by ATCOs even if there is there is room for improvement. The information provided was also deemed as satisfactory to perform ATCOs tasks.

- ATCOs **situational awareness and cognitive workload** were considered adequate to perform their work both in high and in very high complexity environments. The adequacy was considered closely related to the usability of the advanced supporting tools in FRA environment.

- The ATCOs **internal team communication** and **communication management with adjacent sectors** were considered unambiguous and efficient in both high and in very high complexity environment.

More details can be found in can be found in the PJ.06-01 Human Performance Assessment Report included in the PJ.06-01 SPR-INTEROP / OSED Part IV document ([54]).

The outcomes of the V3 validation activities give confidence that the PJ.06-01 Solution contributes to not adversely affect the Human Performance KPA, with the implementation of structurally cross-border FRA, in En-Route High and Very High Complexity operating environments.

4.16.2Extrapolation to ECAC wide

N/A

4.16.3Open HP issues/ recommendations and requirements

All HP issues have been closed following the PJ.06-01 validation exercises. Below is an indication of the number of issues addressed, as well as the number of HP recommendations and requirements defined for the Solution. For the detailed description, please refer to the HP Plan/ HP Log and the HP Assessment Report ([54]).

PIs	Number of open issues/ benefits	Nr. of recommendations	Number of requirements
HP1 Consistency of human role with respect to human capabilities and limitations	0 / 0	5	8
HP2 Suitability of technical system in supporting the tasks of human actors	0 / 0	7	1
HP3 Adequacy of team structure and team communication in supporting the human actors	0 / 0	4	1
HP4 Feasibility with regard to HP-related transition factors	0 / 0	0	0

4.16.4Concept interaction

The Solution PJ.06-01 might interact with many other SESAR2020 Solutions as Free Routing environment will be the default environment in En-Route after PCP implementation. The other SESAR Solutions potentially interacting with Solution PJ.06-01 are enumerated in section 3.2.

More validation activities would be required to conclude on the level of interaction, and potential Human Performance issues, between these other SESAR Solutions and Solution PJ.06-01.

4.16.5 Most important HP issues

Below the most important issues that might have a major impact on the performance of the Solution. For more details, please refer to the HP Plan/ HP Log and the HP Assessment Report ([54]).

PIs	Most important issue of the solution	Most important issues due to solution interdependencies
HP1 Consistency of human role with respect to human capabilities and limitations	ISS-PJ06-01-001 Description of Roles and associated responsibilities may not cover all affected human actors	N/A
	ISS-PJ06-01-002 Updated/New description of roles & responsibilities may not cover all tasks to be performed by the human actors	N/A
	ISS-PJ06-01-003 Roles and responsibilities could not be clear and consistent. In particular: For ATCO: The task sharing between ATCO team members of adjacent sectors could not be obvious, especially about the decision making of the conflict resolution (Who is in charge to execute the resolution?)	N/A
	ISS-PJ06-01-004 Evaluate the adequacy of the operating methods.	N/A

PIs	Most important issue of the solution	Most important issues due to solution interdependencies
	ISS-PJ06-01-005 Evaluate feasibility of duty tasks in a timely manner. Potential additional workload may have a negative impact on this aspect	N/A
	ISS-PJ06-01-006 Controllers' workload may be negatively impacted by high-complexity/high density free route operations	N/A
	ISS-PJ06-01-007 The new operating methods in FRA could be more complex compare to the ones in ATS route network	N/A
	ISS-PJ06-01-008 How high-complexity/high density free route operations impact on controllers' situational awareness (Potential reduction of ATCO's Situational Awareness)	N/A
HP2 Suitability of technical system in supporting the tasks of human actors	ISS-PJ06-01-009 Provided HMI information could not be fit for purpose and thus not supporting controllers in achieving their duty tasks	N/A
	ISS-PJ06-01-010 Evaluate Usability of the proposed user interface (input devices, visual displays/output devices, alarms& alerts) for the new/updated items introduced due to free routing operations (if any)	N/A
	ISS-PJ06-01-011 Evaluate that individual situational awareness is not negatively affected by user interface design of the new/updated items introduced due to free routing operations (if any)	N/A
HP3 Adequacy of team structure and team communication in supporting the human actors	ISS-PJ06-01-012 Evaluate if the need of specific information (requirements) to achieve new/updated tasks, by single team members, is satisfied through intra-team and inter-team communications	N/A
	ISS-PJ06-01-013 Evaluate if phraseology supports intra-team and inter-team communication and there is no lack of its support to perform additional/modified duty tasks	N/A
	ISS-PJ06-01-014 The communications load may increase due to additional/modified tasks (e.g. ground-ground)	N/A
	ISS-PJ06-01-015 Controllers situational awareness may be negatively impacted by high-complexity/high density free route operations	N/A
HP4 Feasibility with regard to HP-related transition factors	N/A	N/A

All these HP issues are covered by the HP recommendations and requirements defined for the Solution PJ.06-01 at the end of V3.

4.16.6 Additional Comments and Notes

N/A

4.17 Other PIs

No further PIs from the SESAR2020 Performance Framework update has been assessed for the PJ.06-01 Solution.

4.18 Gap Analysis

The table below summarises the gap analysis of the PJ.06-01 performance assessment results with performance targets from PJ19 done in sections REF _Ref17812136 \r \h 4.3.4, 4.4.4, 4.6.4 and 4.9.4.

KPI	Validation Targets – Network Level (ECAC Wide)	Performance Benefits Expectations at Network Level (ECAC Wide or Local depending on the KPI)[21]	Rationale[22]
FEFF1: Fuel Efficiency – Fuel burn per flight	-27.686 Kg	-15.76 kg	Positive effect on Fuel Efficiency, but less than expected as benefit estimates limited to above FL305 in HC & VHC ACCs based on very conservative forecast of ACC complexity scores)
CAP2: En-Route Airspace Capacity – En-route throughput, in challenging airspace, per unit time	N/A	0% (local)	Neutral effect on Airspace capacity (at local level)

[21] Negative impacts are indicated in red.

[22] Discuss the outcome if, and only if, the gap indicates a different understanding of the contribution of the Solution (for example, the Solution is enabling other Solutions and therefore is not contributing a direct benefit).

KPI	Validation Targets – Network Level (ECAC Wide)	Performance Benefits Expectations at Network Level (ECAC Wide or Local depending on the KPI)[21]	Rationale[22]
PRD1: Predictability – Variance of Difference in actual & Flight Plan or RBT durations	-0.930% [23]	Unknown	Positive / negative effect on Predictability (depending on airspace design of cross-border FRA at local level)
SAF1: Safety - Total number of fatal accidents and incidents with ATM Contribution per year	N/A[24]	0 % reduction in the total number of fatal accidents per year	Neutral effect on Safety / Mid-Air Collision En-Route

Table 22: Gap analysis Summary

[23] In Validation Targets [18] the unit for PRD1 is % Reduction in variance of block-to-block flight time.

[24] In Validation Targets [18] the unit for SAF1 is % reduction in the total number of fatal accidents per year.

5 References

This PAR complies with the requirements set out in the following documents:

[1] 08.01.03 D47: AIRM v4.1.0

[2] B05 Performance Assessment Methodology for Step 1

[3] PJ19.04 D4.4 Performance Framework (2018), Edition 01.00.00, August 2018

[4] B.05 Guidance for Performance Assessment Cycle 2013

[5] B.05 D72, Updated Performance Assessment in 2016

https://stellar.sesarju.eu/servlet/dl/ShowDocumentContent?doc_id=1669873.13&att=attachment&statEvent=Download

[6] B05 Data Collection and Repository Cycle 2015

[7] Methodology for the Performance Planning and Master Plan Maintenance (edition 0.13)

https://stellar.sesarju.eu/servlet/dl/ShowDocumentContent?doc_id=4731333.13&att=attachment&statEvent=Download

Content Integration

[8] B.04.01 D138 EATMA Guidance Material

[9] EATMA Community pages

[10] SESAR ATM Lexicon

Content Development

[11] PJ19.02.02 D2.1 SESAR 2020 Concept of Operations Edition 2017, Edition 01.00.00, November 2017

System and Service Development

[12] 08.01.01 D52: SWIM Foundation v2

[13] 08.01.01 D49: SWIM Compliance Criteria

[14] 08.03.10 D45: ISRM Foundation v00.08.00

[15] B.04.03 D102 SESAR Working Method on Services

[16] B.04.03 D128 ADD SESAR1

[17] B.04.05 Common Service Foundation Method

Performance Management

[18]PJ19.04.01 D4.5 Validation Targets (2018), Edition 01.00.00, April 2018

https://stellar.sesarju.eu/servlet/dl/ShowDocumentContent?doc_id=6784461.13&att=attachment&statEvent=Download

[19]16.06.06-D68 Part 1 –SESAR Cost Benefit Analysis – Integrated Model

[20]16.06.06-D51-SESAR_1 Business Case Consolidated_Deliverable-00.01.00 and CBA

[21]Method to assess cost of European ATM improvements and technologies, EUROCONTROL (2014)

[22]ATM Cost Breakdown Structure_ed02_2014

[23]Standard Inputs for EUROCONTROL Cost Benefit Analyses

[24]16.06.06_D26-08 ATM CBA Quality Checklist

[25]16.06.06_D26_04_Guidelines_for_Producing_Benefit_and_Impact_Mechanisms

Validation

[26]03.00 D16 WP3 Engineering methodology

[27]Transition VALS SESAR 2020 - Consolidated deliverable with contribution from Operational Federating Projects

[28]European Operational Concept Validation Methodology (E-OCVM) - 3.0 [February 2010]

System Engineering

[29]SESAR Requirements and V&V guidelines

Safety

[30]SESAR, Safety Reference Material, Edition 4.0, April 2016

https://stellar.sesarju.eu/jsp/project/qproject.jsp?objId=1795089.13&resetHistory=true&statInfo=Ogp&domainName=saas

[31]SESAR, Guidance to Apply the Safety Reference Material, Edition 3.0, April 2016

https://stellar.sesarju.eu/jsp/project/qproject.jsp?objId=1795102.13&resetHistory=true&statInfo=Ogp&domainName=saas

[32]SESAR, Final Guidance Material to Execute Proof of Concept, Ed00.04.00, August 2015

[33]Accident Incident Models – AIM, release 2017

https://stellar.sesarju.eu/servlet/dl/ShowDocumentContent?doc_id=3658775.13&att=attachment&statEvent=Download

Human Performance

[34]16.06.05 D 27 HP Reference Material D27

[35]16.04.02 D04 e-HP Repository - Release note

Environment Assessment

[36]SESAR, Environment Reference Material, alias, “Environmental impact assessment as part of the global SESAR validation”, Project 16.06.03, Deliverable D26, 2014.

[37]ICAO CAEP – “Guidance on Environmental Assessment of Proposed Air Traffic Management Operational Changes” document, Doc 10031.

Security

[38]16.06.02 D103 SESAR Security Ref Material Level

[39]16.06.02 D137 Minimum Set of Security Controls (MSSCs).

[40]16.06.02 D131 Security Database Application (CTRL_S)

5.1 Reference Documents

The following documents were used to provide input / guidance / further information / other:

[41]ED-78A GUIDELINES FOR APPROVAL OF THE PROVISION AND USE OF AIR TRAFFIC SERVICES SUPPORTED BY DATA COMMUNICATIONS.[25]

[42]EUROCONTROL PRR 2016 - Performance Review Report, An Assessment of Air traffic Management in Europe during the Calendar Year 2016, June 2017

[43]SESAR PJ19: Validation Targets (2019)

[44]SESAR 2020 common assumptions (2019) Ed. 00.00.02, 22 July 2019

[45]SESAR Solution PJ.06-01: SPR-INTEROP/OSED for V3 - Part I, PJ06-D2.1.030, Edition 00.03.01

[46]SESAR Solution PJ06-01 Validation Plan (VALP) for V3, PJ06-D2.1.430 Part I, Edition 00.01.01

[47]SESAR Solution PJ06-01 VALR (V3) Thread #1, PJ06-D2.1.530 Appendix A, Edition 00.01.01

[48]SESAR Solution PJ06-01 VALR (V3) Thread #2, PJ06-D2.1.530 Appendix B, Edition 00.01.01

[49]SESAR Solution PJ06-01 Consolidated VALR (V3), PJ06-D2.1.530, Edition 00.01.01

[25] *The EUROCAE ED-78A has been used as an initial guidance material. ED-78A is useful, but is not an applicable document, because it mostly addresses the V4-V5 phases, whilst the SESAR R&D programme is focussed on development (V1-V2-V3, and because of its partial compliance with safety regulatory requirements).*

[50]SESAR 04.03-M602 Validation Report of EXE-04.03-VP-797, Edition 00.01.00, September 2016

[51]SESAR 11.01.05-D23 Contribution to EXE-04.03-VP-797- Free Route Step 1 V2 Validation Report, Edition 00.01.00, August 2016

[52]SESAR Solution PJ.06-01 Safety Plan, PJ06-D2.1.430 Part II, Edition 00.00.01

[53]SESAR Solution PJ.06-01 Safety Assessment Report, PJ06-D2.1.030 Part II Edition 00.02.01

[54]SESAR Solution PJ.06-01 Human Performance Assessment Report, PJ06-D2.1.030 Part IV Edition 00.02.00

Appendix A Detailed Description and Issues of the OI Steps

The SESAR Solution PJ06-01 contributes the OI Step AOM-0505 as described in Dataset 19.

OI Step ID	Title	Consistency with latest Dataset
AOM-0505	Free Routing for Flights both in cruise and vertically evolving within high and very high complexity environments in Upper En Route airspace	Data Set 19

Table 23: OI Steps allocated to the Solution

In the current EATMA modelling the Solution PJ06-01 only inherits from the "Required" Enablers of the OI Step, whereas the Solution also covers some "Optional" Enablers as further described in section 3.1.

Besides one "Required" Enablers of the OI Step, i.e. Enabler NIMS-37: "Basic complexity assessment tools", is out of scope of the Solution.

More details about the OI Step coverage by the Solution can be found in the PJ.06-01 SPR-INTEROP / OSED Part I document ([45]).

