FINAL - SESAR Solution Guidance YY (LLR) - GEN

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Abstract

This deliverable aims at providing guidance about the SESAR Solution YY[1] (LLR) and its implementation; It records information to be added on top of what already exists. This information is about environment, operational scenarios, safety & performance requirements, regulation and any other information that will allow the community to understand the state of the art at the end of SESAR. In addition to the information coming from the project P04.10, this document considers the outcomes of relevant Demo projects. Based on results achieved in the frame of P04.10 validation activities, the achieved maturity level for the "*Low Level IFR Routes*" concept is V3 (in accordance to E-OCVM) and considered as a SESAR 1 Solution (#113: "*Optimised Low Level IFR routes for rotorcrafts*").

[1] The title of this document has initially been referred to "Solution YY" because the solution number hadn't been defined yet when the document was drafted. Taking into consideration latest SJU decisions, we can suppose that the correct reference will be **SESAR Solution #113:** "*Optimised Low Level IFR routes for rotorcrafts*"

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This deliverable consists of SJU foreground.

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Executive summary

RNP 1/0.3 Arrival Routes for Rotorcraft and for IFR, VFR and mixed VFR-IFR flights

Within the development of PinS approaches and SNI concept into VFR FATOs, the requirements for connecting low-level IFR routes based on navigation specification of RNP 1/0.3 to these new approaches needs to be developed and assessed. Those routes could provide a consistent path for navigation to and away the approach phase. Design requirements are already defined: RNP 1 in general and RNP 0.3 where necessary (constraining environment). For reference check PBN Manual (Doc 9613) 4th ed, Chapter 3 and Chapter 7. Those new low level routes are based on RNP 0.3 specification, that is for helicopters and low speed airplane only. According to PBN Manual, the RNP 0.3 Navigation specification has been defined primarily for helicopter applications (e.g low level routes). Dedicated rotorcraft routes not only will increase the Airspace capacity, but will improve safety, equity and accessibility in TMA. Furthermore the management of peculiar helicopter characteristics could be done with more efficiency and predictability than others. Routes are totally IFR compliant and guarantee high degree of safety and fly-ability in relation to altitudes (decrease the possibility to encounter icing condition), better separation among other rotorcraft or low speed aircrafts, and separation by design is assured in TMA. This features alleviate the ATCO workload.

Because of the low altitude, reversion to DME/DME navigation is likely not possible. Moreover, most rotorcraft and GA do not have DME/DME navigation capabilities. So, in case of GNSS loss, contingency procedures relying on ATC guidance needs to be used.

BACKGROUND

The continued growth of traffic and the need to provide greater flight efficiency makes it necessary to optimise available airspace. This is being achieved worldwide by enhanced Air Traffic Management and by exploiting technological advancements in the fields of Communication, Navigation and Surveillance. More specifically, the application of Area Navigation techniques, in all phase of flight, contributes directly to improved airspace optimisation.

In the near future, satellite-based instrumental flight procedures will radically change the way rotorcraft are operated, improving transportation inter-modality and efficiency. The peculiar rotorcraft capabilities of tight turns, steep climb and descent, combined to dedicated PBN-IFR procedures based on GNSS, will allow to avoid noise sensitive populated areas, interact with the conventional air traffic without interfering, and operate in optimal ways in obstacle-rich urban environments, increasing availability and safety even at night and in low visibility conditions.

The goal is a synchronised and predictable European ATM system, where partners and stakeholders are aware of the business and operational situations and collaborate to optimise the network.

The introduction of RNP will optimise route structures and automation. With the support of management tools, these will grant benefits in terms of safety, and flight efficiency improvements. Rotorcraft characteristic/needs and Airspace management needs can be matched using dedicated Low Level IFR routes PBN based [AOM-0810].

In this scenario has been envisaged the necessity to address and introduce new OI [AOM-0810] taking into consideration the existing rotorcraft needs in order to fulfil the SESAR gap into rotorcraft operations.

FINAL REMARK

In the future the incorporation of Enhanced low level IFR routes PBN based using satellite augmentation [AOM-0810] in medium/high dense airspace will consider the Increased TMA and ATM Performance through independent and dedicated IFR rotorcraft operations at low level.

That rotorcraft operational improvements, will facilitate the ability of the SESAR project to meet its stated aims, and in particular considering the PBN concept offers many advantages over the existing sensor-specific ATS IFR routes:

- Reduces the need for and reliance on sensor- specific, ground-based navigation aids (NDB, VOR, DME, GBAS) and reduces the cost of maintaining the ground-based navigation infrastructure;

- Allows more efficient use of airspace by increasing airspace capacity and improving operational efficiency, by reducing environmental impact and increasing aircraft fuel efficiency;
- Improves Airspace accessibility and flight safety;
- Avoids need for development of sensor-specific operations with each new evolution of navigation systems, which would be cost-prohibitive;
- Clarifies the way in which RNAV systems are used;
- Reduces pilot workload without safety issues by requiring precise on-board equipment;
- Reduces controllers workload for en-route phases based on PBN to reduce or even future replace radar vectoring.

Summarised by KPA and by SESAR pillars:

- Seamless transition from en-route to Terminal Routes
- To increase safety operational level
- To improve efficiency
- To reduce costs
- To increase Airspace capacity
- To reduce the environmental impact of noise and pollution (i.e: reduce fuel burn, reducing flight time, noise abatement segment/routes)

as consequence has been needed to investigate/asses the merging of tailored IFR rotorcraft routes RNP1/0.3 based, in the actual airspace architecture in P04.10 project/validation activities.

1 Introduction

1.1 Purpose of the document

This deliverable aims at providing guidance about the SESAR Solution YY (LLR – Low Level IFR Routes) routes for Rotorcraft and its implementation;

It records information to be added on top of what already exists. This information is about environment, operational scenarios, safety & performance requirements, regulation and any other information that will allow the community to understand the state of the art at the end of SESAR. In addition to the information coming from the project P04.10, this document considers the outcomes of relevant Demo projects

This concept is addressed in the context of Operational Package PAC02, SPC02.01, Operational Focus Area 02.01.01-Optimised 2D/3D Routes, specifically referring to the concept of Low Level IFR Routes (AOM-0810 Integration into the TMA route structure of optimised Low Level IFR route network for rotorcraft using RNP-1/RNP-0.3)

1.2 Intended readership

This document is intended for the following audience written for:

- P04.02: Consolidation of operational concept definition and validation (En-route)
- P05.02: Consolidation of Operational Concept Definition and Validation (TMA)
- OFA 02.01.01 Coordinator
- EHA: European Helicopter Association
- LSD.02.09 PROuD (PBN Rotorcraft Operations under Demonstration)

The main affected stakeholders are the Air Navigation Service Providers (ANSPs), aircraft manufacturers (Rotorcraft), airspace users and airports operators[2], as they are affected by the implementation of the operative strategically solutions concerning the enhancement of the en-route flight phases addressed.

1.3 Structure of the document

This document is comprised of six sections:

1. **Introduction:** Introduces the document
2. **Detailed Operating Method:** Description of the current operating methods related to Rotorcraft in SESAR environment. In the second part of the chapter is showed the new operating method introduced by P4.10 according to OFAs and related OI addressed
3. **Detailed Operational Environment:** Define the characteristics of the operational environment in which RC fly LLR, the roles and responsibility and the constraints.
4. **Use Cases:** Describe the P.4.10 use cases
5. **Requirements:** Describes the functional or operational requirements applicable
6. **E_OCVM Life cycle description & Validation activities results:** E_OCVM Life cycle description & Validation activities results;

[2] The Airport Operators are not officially part of the P04.10 (It means that they aren't included in the list of Project 04.10 Members). Nevertheless, they have been involved several times during designing of procedures and within the process of being drafted of the internal (ANPS) Risk Assessment Report to be submitted to the National Regulator (ENAC - Italian Civil Aviation Authority) before performing the flight operations (Live Trial VP-818).

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Term	Definition	Source
ADS-B Application	A means by which aircraft, can automatically transmit and/or receive data such as identification, position and additional data, as appropriate, in a broadcast mode via a data link.	ICAO
Airspace Management	Airspace Management is the process by which airspace options are selected and applied to meet the needs of the ATM community.	ICAO 9854
	Airspace Management is integrated with Demand and Capacity Balancing activities and aims to define, in an inclusive, synchronised and flexible way, an optimised airspace configuration that is relevant for local, sub-regional and regional level activity to meet users requirements in line with relevant performance metrics. Airspace Management primary objective is to optimise the use of available airspace, in response to the users demands, by dynamic time-sharing and, at times, by the segregation of airspace among various airspace users on the basis of short-term needs. It aims at defining and refining, in a synchronised and a flexible way, the most optimum airspace configuration at local, sub-regional and regional levels in a given airspace volume and within a particular timeframe, to meet users requirements while ensuring the most performance of the European Network and avoiding as much as possible any disruption. Airspace Management in conjunction with AFUA is an enabler to improve civil-military co-operation and to increase capacity for the benefit of all users.	P07.02 P04.02
Airspace Configuration:	Is a pre-defined and coordinated organisation of ATS routes of the ARN and /or terminal routes and their associated airspace structures, including airspace reservations/restrictions (ARES), if appropriate, and ATC sectorisation.	OSED 07.05.02 AFUA Step 1 V3 for V4
Airspace Restriction	A defined volume of airspace within which, variously, activities dangerous to the flight of aircraft may be conducted at specified times (a "danger area"); or such airspace situated above the land areas or territorial waters of a State, within which the flight of aircraft is restricted in accordance with certain specified conditions (a restricted area); or airspace situated above the land areas or territorial waters of a State, within which the flight of aircraft is prohibited (a prohibited area).	OSED 07.05.02 Step 1 V" for V4
Airspace Structure	A specific volume of airspace designed to ensure the safe and optimal operation of aircraft.	OSED 07.05.02 Step 1 AFUA V3 for V4
ANE-EXE	ANE is one of the TMA **sectorisation**, in which a dedicated Executive controller is assigned	
Area navigation (RNAV)	Method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.	ICAO Doc 9613 PBN Manual

Term	Definition	Source
	Note.— Area navigation includes performance-based navigation as well as other RNAV operations that do not meet the definition of performance-based navigation	
Approach procedure with vertical guidance (APV)	An instrument procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations. These procedures are enabled by GNSS and Baro VNAV or by SBAS. (PBN).	
APV Baro-VNAV	RNP APCH down to LNAV/VNAV minima.	
APV SBAS	RNP APCH down to LPV minima.	
Baro-VNAV	Barometric vertical navigation (Baro-VNAV) is a navigation system that presents to the pilot computed vertical guidance referenced to a specified vertical path angle (VPA), nominally 3°. The computer-resolved vertical guidance is based on barometric altitude and is specified as a VPA from reference datum height (RDH). (PANS OPS).	
CDFA – Continuous Descent Final Approach	Continuous Descent Final Approach is a technique for flying the final approach segment of an NPA as a continuous descent. The technique is consistent with stabilized approach procedures and has no level-off. A CDFA starts from an altitude/height at or above the FAF and proceeds to an altitude/height approximately 50 feet (15 meters) above the landing runway threshold or to a point where the flare manoeuvre should begin for the type of aircraft being flown. This definition is harmonized with the ICAO and the European Aviation Safety Agency (EASA).	
DCP	TMA Departure Manager	
Flight intent	The future aircraft trajectory expressed as a 4-D profile up to the destination (taking into account of aircraft performance, weather, terrain, and ATM service constraints). It is calculated and “owned” by the aircraft flight management system, and agreed by the Pilot.	ICAO Doc 9854
	In the SESAR Context, Flight Intent corresponds to the "agreed data of RB/MT” : the waypoints of the routes and associated altitude, possible time and/or speed constraints agreed between ATM actors.	WP B04.02 CONOPS Step 1
Final Approach Point/Fix (FAP/FAF)	In PANS-OPS ICAO Doc 8168 VOL I, FAF is described as the beginning of the final approach segment of an Non-Precision Approach, and FAP is described as the beginning of the final approach segment of a Precision Approach. Moreover, PANS-OPS ICAO Doc 8168 VOL II states that the APV segment of an APV SBAS procedure starts at the Final Approach Point. So, within this document, since only APV SBAS procedures are considered, the beginning of the final approach segment is called the FAP	PANS-OPS ICAO Doc 8168 VOL I
Final Approach Segment (FAS) Data Block	The APV database for SBAS includes a FAS Data Block. The FAS Data Block information is protected with high integrity using a cyclic redundancy check (CRC).	PANS OPS

Term	Definition	Source
GNSS – Global Navigation Satellite System	A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation.	ICAO Annex 10
Low Level IFR Routes	Low Level IFR Routes dedicated to Rotorcraft integration in dense / constrained airspace. Rotorcraft altitude (2000-4000 ft.) specific Low Level IFR routes are designed and optimised based on route network using RNP-1 / RNP-0.3. The integration in dense and constraint airspace TMA is due to rotorcraft peculiar flight characteristics and type of operation conducted, such as: • Helicopters not pressurised: the Maximum allowed altitude: FL100 (e.g 3000 m) • Most helicopters have no de-icing capability - Risk of encountering icing conditions increases with altitude. Typically standard IFR FL are often too high • Health of on-board patients during medical flights - Recommended altitude for patients in critical condition: not more than 3000 ft. AGL • Safety and environment • Visual flight at very low height (500 ft. or sometimes less) to stay below clouds in marginal weather conditions is frequent accident cause and impacts environment (e.g noise footprint)	ICAO Documentation
LNAV, LNAV/VNAV, LPV	Are different levels of approach service and are used to distinguish the various minima lines on the RNAV (GNSS) chart. The minima line to be used depends on the aircraft capability and approval.	
LNAV/VNAV	The minima line based on Baro-VNAV system performances that can be used by aircraft approved according to AMC 20-27 or equivalent. LNAV/VNAV minima can also be used by SBAS capable aircraft.	
LPV (Localiser Performance with Vertical Guidance)	The minima-line based on SBAS performances that can be used by aircraft approved according to AMC 20-28 or equivalent	
MAPt	Missed Approach Point	
Navigation specification	A navigation specification is a set of aircraft and aircrew requirements needed to support a navigation application within a defined airspace concept. The navigation specification: • defines the performance required by the navigation system, • prescribes the performance requirements in terms of accuracy, integrity, continuity and availability for proposed operations in a particular Airspace, • also describes how these performance requirements are to be achieved i.e. which navigation functionalities are required to achieve	ICAO Doc 9613 and WP B04.02 CONOPS Step 1

Term	Definition	Source
	the prescribed performance and associated requirements related to pilot knowledge and training and operational approval. A Performance-Based Navigation Specification is either a RNAV specification or a RNP specification. RNAV specifies a required accuracy whilst RNP specifies, in addition to a required accuracy, an aircraft system alert in case of deviation, with the pilot responsible to remain the aircraft within the RNP accuracy; it allows reducing ATC buffer with the controller still responsible for the separation against traffic.	
Network Management	Network Management is an integrated activity with the aim of ensuring optimised Network Operations and ATM service provision meeting the Network performance targets., The Network Management Function is executed at all levels (Regional, Sub-regional and Local) throughout all planning and execution phases, involving, as appropriate, the adequate actors (NM, FM, LTM…)	P07.02 P04.02
Performance-Based Navigation (PBN)	Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace. *Note.— Performance requirements are expressed in navigation specifications in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept*	ICAO DOC 9613 PBN Manual
PinS	Point in Space is an approach procedure designed for helicopters only that includes both a visual and an instrument segment	ICAO PANS OPS 8168
RNAV specification	See Navigation specification	ICAO PBN Manual 9613
RNP specification	See Navigation specification	ICAO PBN Manual 9613
RNP operations	Aircraft operations using an RNP system for RNP navigation applications	ICAO Doc 9613 PBN Manual
RNP route	An ATS route established for the use of aircraft adhering to a prescribed RNP navigation specification	ICAO Doc 9613 PBN Manual
RF – Radius to Fix path terminator	– An ARINC 424 specification that defines a specific fixed-radius curved path in a terminal procedure. An RF leg is defined by the arc centre fix, the arc initial fix, the arc ending fix and the turn direction.	
RNAV Approach	This is a generic name for any kind of approach that is designed to be flown using the on-board area navigation system. It uses waypoints to describe the path to be flown instead of headings and radials to/from ground-based navigation aids. RNP APCH navigation specification is synonym of the RNAV approach.	
RNP APCH – RNP approach	The RNP navigation specification that applies to approach applications based on GNSS. As illustrated in figure 2 below, there are four types of RNP APCH that are flown to different minima lines published on the same	

Term	Definition	Source
	RNAV(GNSS) approach chart.	
SBAS – Satellite-Based Augmentation System	A wide coverage augmentation system in which the user receives augmentation information from a satellite-based transmitter. (ICAO Annex 10). The European SBAS is called EGNOS, the US version is called WAAS and there are also other SBASs in different regions of the World such as GAGAN in India and MSAS in Japan	

1.5 Acronyms and Terminology

Term	Definition
AC	Advisory Circular
ADEP	Aerodrome of Departure
ADES	Aerodrome of Destination
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
APCH	Approach
APV	Approach Procedure with Vertical guidance
ATC	Air Traffic Control
ATM	Air Traffic Management
CDA	Continuous Descent Approach
CDFA	Continuous Descent Final Approach
CDO	Continuous Descent Operation
CRC	Cyclic Redundancy Check
DA	Decision Altitude
DA/H	Decision Altitude/Height
E-ATMS	European Air Traffic Management System
EGNOS	European Geostationary Navigation Overlay Service
ETSO	European Technical Standard Order

Term	Definition
EU-OPS	This refers to European Union (EU) regulations specifying minimum safety and related procedures for commercial passenger and cargo fixed-wing aviation
FAF	Final Approach Fix
FAP	Final Approach Point
FAS	Final Approach Segment
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
INTEROP	Interoperability Requirements
LLR	Lçow Level IFR Routes
LNAV	Lateral Navigation
LPV	Localizer Performance with Vertical guidance
MEA	Minimum En-route Altitude
NOTAM	Notice To AirMen
OFA	Operational Focus Areas
OSED	Operational Service and Environment Definition
PANS-OPS	Procedures for Air Navigation Services – Aircraft Operations
PBN	Performance Based Navigation
RAIM	Receiver Autonomous Integrity Monitoring
RF	Radius to Fix
RNAV	Area Navigation
RNP	Required Navigation Performance
SBAS	Satellite-Based Augmentation System
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SJU	SESAR Joint Undertaking (Agency of the European Commission)

Term	Definition
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SNI	Simultaneous non Interfering
SPR	Safety and Performance Requirements
TSO	Technical Standard Order
VNAV	Vertical Navigation

2 Detailed Operating Method

2.1 Previous Operating Methods

Today, Rotorcraft reach their best operational performances, when flying unconstrained in VFR flight rules, an operating mode really dependent upon weather conditions and visibility. During winter months this way to operate can be adversely affected, by foggy cloudy weather and icing conditions which can prevent Rotorcraft to proceed VFR or make them subject to delays when operating to/from a controlled airspace (i.e: CTR) in a dense medium complexity ATM airspace

At present, there are many helicopters which are IFR certified and characterized by advanced avionic standards. When these rotorcraft are flying in IFR mode, due to the lack of rotorcraft specific routes, they are used to fly the same flight routes (airways) designed for aircraft.

These routes, being specifically designed for fixed-wing A/C, are constraining for rotorcraft implying important limitation on their operations as they have flight profiles which are not optimised for this category of operations. In particular rotorcraft categories have different needs and possibility in terms of descent rate and speed profile in order to optimise their performances.

Forcing them along the same routes (designed for fixed wing) can delay their operations to/from airports, and to/from ATM airspace with a negatively impact on the operations of either rotorcraft and either commercial fixed-wing A/C, increasing also Air Traffic Controller workload.

In current operations arriving and departing helicopters aiming to be insert in a management airspace structures within published routes and procedures rotorcraft specific are not totally compatible with their needs. Rather than proceeding directly to a final destination, rotorcraft are routed in such a matter that additional flight time is required, fuel management becomes a critical factor, passengers are impacted negatively and often experiencing delay. In order to avoid penalties to rotorcraft and commercial IFR aircraft, since no tailored routes are available taking into account the different performances achievable by helicopters with respect to aircraft, future harmonisation and developments will be needed..

Regarding the synchronisation of air and ground trajectories, rotorcraft flight plans may be modified during the flight for different reasons (weather change, local routings that are unknown to aircrew, change messages being delayed or not treated …), and these changes are not always known by all actors involved in the control of the flight.

Depending on the proximity of other traffic, these cases are currently caught by:

- Traffic Collision Avoidance Systems (TCAS)
- Short Term Conflict Alert (STCA)
- System conformance monitoring aids
- Controller monitoring.

Once the discrepancy has been raised, a lengthy controller pilot conversation ensues in order to re-synchronise the flight plans of the airborne and ground systems.

This uses up valuable frequency time and takes the controller away from their primary task of maintaining the separation of the other traffic.

Besides, this process is error prone: the clearance must be transmitted correctly, it must be heard and transcribed correctly, it must be read back correctly, it must be heard correctly, it must be checked against the initial clearance correctly and finally entered in to the FMS correctly. This must be done over R/T with its inherent “noise”, when the R/T is available (a scarce resource) and when the controller is not occupied with other tasks.

Speed control gives a certain predictability in the path the rotorcraft will fly, but is less accurate in achieving the required time over a waypoint. It does however have the advantage of being a positive control instruction that provides controllers with known parameters.

Time management requires the use of an airborne flight management system function known as the Required Time of Arrival (RTA). Only the most modern FMS have this function. When using time management the current position of the flight is known as is the end state (where it will be at a certain time) but the path in between these two points is variable as different FMS/airframe combinations manage the speed variation differently.

Because of the gap in the knowledge of how the aircraft will adjust its speed, controllers are reluctant to use time control. It is however sometimes used in very low traffic situations where the flight can be constantly monitored and there is no expected traffic that would be influenced by any change.

2.2 New SESAR Operating Methods

The rationale of the new operating Method is the coherent involvement in SESAR project of the need to properly consider all the possible air platform requirements in the development of the new ATM system allowing the correct integration of the rotorcraft element in the Single European Sky.
In the near future, satellite-based instrumental flight procedures will radically change the way Rotorcraft are operated, improving transportation inter-modality and both ATM and flight efficiency. The goal is a synchronised and predictable European ATM system, where partners and stakeholders are aware of the business and operational situations and collaborate to optimise the network. This first step initiates arrival time prioritisation together with wide use of data-link and the deployment of initial trajectory based operations, reflected in optimizing 2D/3D routes, moving then to i4D trajectory management.
The introduction of RNP will optimise route structures and automation. The Rotorcraft characteristic/needs and Airspace management needs can be matched by developing PBN based Low Level IFR routes in Medium dense / Medium complexity airspace (e.g. Milan TMA).
In this scenario the concept is addressing a new OI AOM-0810 taking into consideration the existing rotorcraft needs in order to fulfil the SESAR gap into rotorcraft operations.
The incorporation of rotorcraft optimised 2D/3D routes (i.e: low level IFR routes) operations in medium dense constraints Airspace with its selected OFA 02.01.01 (within P.4.10) 01 and the concept related to the OFA 01.03.01 reflected the necessity to insert a dedicated operational Improvement for dedicated rotorcraft Low Level IFR routes:

- Integration into the TMA route structure of optimised Low Level IFR route network for rotorcraft using RNP-1/RNP-0.3 [AOM-0810].

This rotorcraft operational improvement, associated with SNI operation concept at airports will facilitate the ability of the SESAR project to meet its stated aims like:

- To increase safety operational level
- To improve efficiency
- To reduce costs
- To increase Airspace capacity
- To improve access to busy and dense/complexity TMA architecture
- To reduce the environmental impact of noise and pollution (i.e: reduce fuel burn, reducing flight time)

2.3 Differences between new and previous Operating Methods

These operations with the relevant new OIs dedicated to rotorcraft will address the needs to investigate rotorcraft operations in en-route and in terminal airspace of airports as well as operations to and from heliports, located in congested or dense Airspace terminal area. The navigation specification of RNP1 and 0.3 accuracy may also be needed in en-route, in order to support operation at low level altitudes in mountainous remote areas and for airspace capacity reasons in medium density and complexity airspace. Rotorcraft with full IFR capabilities and low noise technologies will integrate smoothly into the air transport system [AOM-0810].

This will require the rotorcraft to feature specific navigation and approach capabilities to enable it to take off from aerodromes (i.e: helipad, heliport, small airports, and so on) enter the dedicated altitude IFR structure (Low Level IFR Routes), penetrate in IMC and finally land onto another helipad in most weather conditions. Such capabilities are nowadays made available by the rapid developing satellite-based technologies.

The success of this type of operations conducted by rotorcraft is to allow a fast point-to-point transport system (see the emerging concept of city smart mobility) based on ground infrastructures in the nearest vicinity or inside cities and densely populated areas; separated or either integrated from busy airports that are more and more often developed tens of miles away from the city centres.

To better understand which could be the main issues for rotorcraft insertion and management flying in the ATC environment, the current rotorcraft constraints are analysed. Rotorcraft can be operated for fast and direct transportation: they can be a direct link with virtually no delays. However, if the weather conditions do not allow VFR flight (VMC, Visual Meteorological Conditions), this trip takes on a significantly different structure when considering flight within the current IFR route structure.

Fast and direct transportation is necessary to maintain a positive profit margin. The increase in mission time is one of the main concerns. If a pilot or operator has a choice with regard to operating under VFR or IFR, many do not choose to fly IFR due to these additional time constraints. Furthermore, the current fixed-wing IFR environment does not offer the direct routing that rotorcraft operators need to actively participate in IFR operations.

Published routes are partially compatible with rotorcraft needs. Rather than proceeding directly to a final destination, rotorcraft are routed in such a matter that additional flight time is required, fuel management becomes a critical factor, and operations are impacted negatively.

Also other factors as which like operational altitude to fly were considered. There are different reasons that lead to select the correct altitudes considering: icing, noise abatement and efficiency issue.

- Icing is the greatest concern, indeed when flying under IFR, rotorcraft must fly at altitudes and along routes originally designated for fixed-wing aircraft. It is at these altitudes that icing is more likely to occur.
- At the same time, they must be aware of the noise impact of flying at lower altitudes that may be costly due to the potential of negative community reaction.
- The “efficiency” is a reason for selecting a lower altitude because it takes longer to reach and descend from higher altitudes and also requires more fuel. Another concern operating IFR is the lack of alternate airports or heliports along the designated IFR routes. Pilots are required to carry enough fuel to land at an alternate in case their original destination goes below minimums or is closed due to unforeseen circumstances such as heavy snow, severe icing, or ground incidents/accidents. This problem is exacerbated because there are not many IFR capable alternates available along the designated routes within range of their reserve fuel supply.

Rotorcraft transportation is primarily intended to be short distance, approximately 250-350 miles. Any additional routing other than direct point-to-point towards the primary advantages associated with rotorcraft operation. In fact, the overall rotorcraft advantage can be effectively eliminated. Development of specific IFR routes is considered as the key enabler for enhancing flight safety and service reliability of rotorcraft operations. Today, satellite navigation (GNSS) and the augmentation systems open the way to the development and the implementation of rotorcraft-specific low level IFR routes.

Specific SBAS-based procedures will provide accurate guidance for rotorcraft flying on specific IFR flight paths:

Rotorcraft applications (Corporate, Offshore Oil&Gas Support, Search & Rescue, Emergency Medical Services (HEMS)) require absolute flexibility supported by point-to-point IFR access to both congested airport and inaccessible locations. This imply for instance not only the development of a IFR procedures for rotorcraft that will not interfere with traffic requiring a runway for take-off and landing but also a net of dedicated routes which are helicopter tailored aimed to easily increased RC operation maintain high safety level in the Terminal Area.

For example in European countries, the IFR route network designed, is generally based on RNAV 5 routes at standard aircraft flight levels.

This standard IFR route network constraining rotorcraft to fly, in most cases, significantly higher than FL30, that are altitudes generally not used by rotorcraft due the high probability to encounter icing conditions.

Moreover, e.g., the HEMS (Helicopter Emergency Medical Services) have a strong interest to go from one hospital to another one in IFR but high altitudes routes are not adapted for two main reasons:

- the distance between two hospitals is generally short and it would not be efficient to climb to fly at such IFR levels;
- with some pathologies, HEMS rotorcraft cannot climb too much without danger for the patients (the danger comes when flying above FL100 in an unpressurised rotorcraft or when climbing or descending too quickly, at say above 1000 ft/min).

Much Rotorcraft technology has been already developed but in some cases isn't properly considered or it is not yet approved for these kind of operations.

The aforementioned capabilities, coupled with the large variety of operational tasks carried out by the Rotorcraft, demand (require) a flexible and rapid response from an ATM system. However, the current ATM and airspace system has been developed essentially for the purposes of fixed-wing aircraft traffic without taking care of rotorcraft specific needs. This structuring is often reflected in the concept of operation of present and future ATM systems.

The Executive summary is the basis on which has been provided comments and suggestions taking into account Rotorcrafts needs to DOD's 4.02 and 5.02.

In the near future, GNSS and the PBN navigation specification within Low level IFR routes [AOM-0810], will allow to avoid noise sensitive populated areas, interact with the conventional air traffic without interfering, merging the actual ATM architecture with future development and operate in optimal ways in obstacle-rich urban environments, increasing availability and safety even at night and in low visibility conditions.

The introduction of RNP will optimise route structures and automation. With the support of management tools, these will grant benefits in terms of safety, and flight efficiency improvements. Rotorcraft characteristic/needs and Airspace management needs can be matched using dedicated Low level IFR route PBN based [AOM-0810].

The introduction of optimised Low Level IFR route in the new ATM architecture considering rotorcraft specific operational scenario will improve KPIs likes:

- Safety
- Capacity/traffic synchronisation
- Operational Efficiency

Helicopter are not pressurised, and maximum constraint allowed altitude is FL100 (10000ft/3000m). Most helicopters have no anti-ice capabilities on board, and the risk of encountering icing conditions increases with standard IFR altitude. For these reasons IFR flight levels are often too high. Considering rotorcraft specific operation mission (e.g: HEMS) flying higher imply health disease of on-board patients. For this specific aspect the recommended altitude for this kind of patient in critical condition is less than 3000 ft AGL. Nevertheless has to be considered the safety and environment aspect when visual flight are conducted at very low height (500 ft or sometime less) in order to stay below clouds in marginal weather conditions. This is a cause of frequent accident and impacts environment (noise footprint).

The use of route structures, including very Low Level IFR routes, will however be available for civil and military operation that require such support. When major hubs are close, the entire are below a certain level will be operated as an extended terminal area, with route structures eventually extending also into en-route airspace to manage the climbing and descending flows from and into the airports or other operating sites concerned.

3 Detailed Operational Environment

Project activities were aimed to provide evidences about the feasible implementation of an operational environment model in the ATM system. The model definition is built up on a busy TMA supplied with a set of airspace resources (e.g. very low altitude Routes, low level corridors, tailored Instrument Flight Procedures) and ad-hoc Operational Procedures (e.g. special VFR clearances) to support Rotorcraft operations, under IFR, filling at best their operational needs while minimizing penalizations for other Airspace Users. Furthermore, the concept was based on the implementation of a subset of technical enablers to improve the interoperability with other AUs/ATC (enhanced surveillance via ADS-B) and to increase the availability of information in the cockpit (e.g. weather information, NOTAMs).

Aim and need of the rotorcraft project were to investigate/asses the connection of RNP1/0.3 low level IFR route attested in a medium/high density and complexity ATM airspace with a possible low level IFR network.

The scope of the project was focused on:

- Development of dedicated connections between Low Level IFR routes (RNP 1 / 0.3) for a whole strategic net of Low Level IFR network.

The proposed project has had specifically addressed the acquisition of new knowledge on rotorcraft. It is expected that the project would lead to the achievement of a major milestone in the rotorcraft development process by demonstrating technological feasibility and by preparing the ground for further development on the way to a flying demonstrator.

The main project objectives have been:

- To validate the Rotorcraft operations concept;
- To investigate and evaluate the introduction of Rotorcraft operations in the European Air Traffic Management System;
- To assess the impact on SESAR operations in the current and future Rotorcraft system architectures;
- To solve Rotorcraft interoperability issue when Rotorcraft GNSS IFR tracks are published in an uncontrolled airspace (class G airspace)

3.1 Operational Characteristics

Low Level IFR Routes could be designed according different Navigation Specification. In P.04.10 has been considered RNP1 and RNP0.3 accordingly to specific airspace constraints, which imply a more tighter semi-width corridor.

According to ICAO data and foreseen included in the PBN manual, chapter 7 implementing RNP 0.3, a number of navigation systems using GNSS for positioning are capable of performing RNP 0.3 operations if suitably integrated into the flight display system. The RNP 0.3 specification takes advantage of known functionality and the on-board performance monitoring and alerting capability of many TSO-C145/C146 GPS systems which are installed in a wide range of IFR helicopters. ,

RNP 0.3 Navigation specification would identify a single accuracy requirement (lateral accuracy of ±0.3NM for at least 95% of the total flight time) as being applicable to all phases of flight from departure to the final approach fix: en-route operations, arrival and departure procedures and initial and intermediate approaches, by enabling to design narrow routes with reduced protection area width based on this accuracy requirement.

The RNP 0.3 operations require an on-board performance monitoring and alerting function based on 0.3NM for all phases of flight. The use of coupled AFCS (Automatic Flight Control System) for all RNP 0.3 operations is strongly recommended to comply with the required performance.

The development of RNP 0.3 routes based in this operational case on ABAS and SBAS equipment is then the solution identified by P.4.10 to meet helicopter operational needs.

Low-level routes are intended to be addressed through the RNP 0.3 navigation specification. The Advanced RNP navigation specification is foreseen to endorse RNP operations from the en-route to the approach phase of flight based on the scalable RNP concept. So, the implementation of RNP 0.3 routes will lead to reconsideration of the low-level airspace structure. Indeed to provide an adequate separation between IFR rotorcraft/ IFR aircraft on the one hand and IFR rotorcraft/VFR traffic on the other hand, it is necessary to choose the right airspace class for the new low level routes. The RNP 0.3 specification is based upon GNSS; its implementation with regards LLR is not dependent on the availability of SBAS.

The regulations may be categorized by operation, flight phase, area of operation and/or navigation specification. Most of the current PBN navigation applications are mainly aircraft dedicated applications, thus leading into some navigation specifications useless for helicopter operations.

REGULATIONS RELATED TO PBN (GNSS BASED) OPERATIONS FOR ROTORCRAFT						
Operation	**GNSS equipment**	**Operational Approval (training, equipment, approval...)**	**Procedure design and Charting**	**Flight Plan**	**ATC procedures (separation, phraseology, airspace class …)**	**Heliport/airport infrastructure (lightning…)**
En-route continental						
RNP 0.3	ETSO-C145a + ETSO-C115b Or ETSO-C146a	EASA AMC to be developed	ICAO Doc 8168 Vol. II to be amended ICAO Annex 4 to be amended	ICAO Doc 4444 to be amended	ICAO Doc 4444 to be amended	ICAO Annex 14
RNP 1	ETSO-C129a (class B or C) + ETSO-C115b Or ETSO-C145 + ETSO-C115b Or ETSO-C129a (class A1)	No EASA AMC developed	ICAO Doc 8168 Vol. II, Part III - Section 1 Chapter 2 and Chapter 5 - Section 3 Chapter 1 and Chapter 2 - Section 5 ICAO Annex 4 Chapter 9, Chapter 10	ICAO Doc 4444 Appendix 2	ICAO Doc 4444: - Chapter 5 - Chapter 12	ICAO Annex 14

Table 1: RNP 1.0/0.3 related regulations

A dedicated and tailored rotorcraft LLR, is comparable to a typical fixed wing IFR airway at low level, in terms of operative management and pilot point of view. From ANSP design point of view It interesting to note and to underline that the introduction of RNP 0.3 navigation specification applied to LLR based on PBN manual 4th edition and ICAO Doc. 8168 (PANS-OPS), § 2.2.3 identified a more tight route semi width than what applied to fixed wing.

Rotorcraft specific performances associated with advanced avionics and management systems granted the respectful of these design criteria and Performance required.

Those new low level IFR routes (LLR) are based on RNP 1 and 0.3 specifications, that is for helicopters and low speed airplane only, doesn't required at that stage new systems to be included in the EXE-VP-816/818. Therefore there are no validation systems under test requirements for those exercises outcomes. Nevertheless some future assumption could be done.

The following pictures provide an overview of the possible solution with regard RTA (Required Time of Arrival) updates concerning Low Level IFR Routes, rotorcraft tailored (for more details please refers to P04.10-D24 ed.00.00.08) and i4D assumption, for a better separation and respectful time constraint:

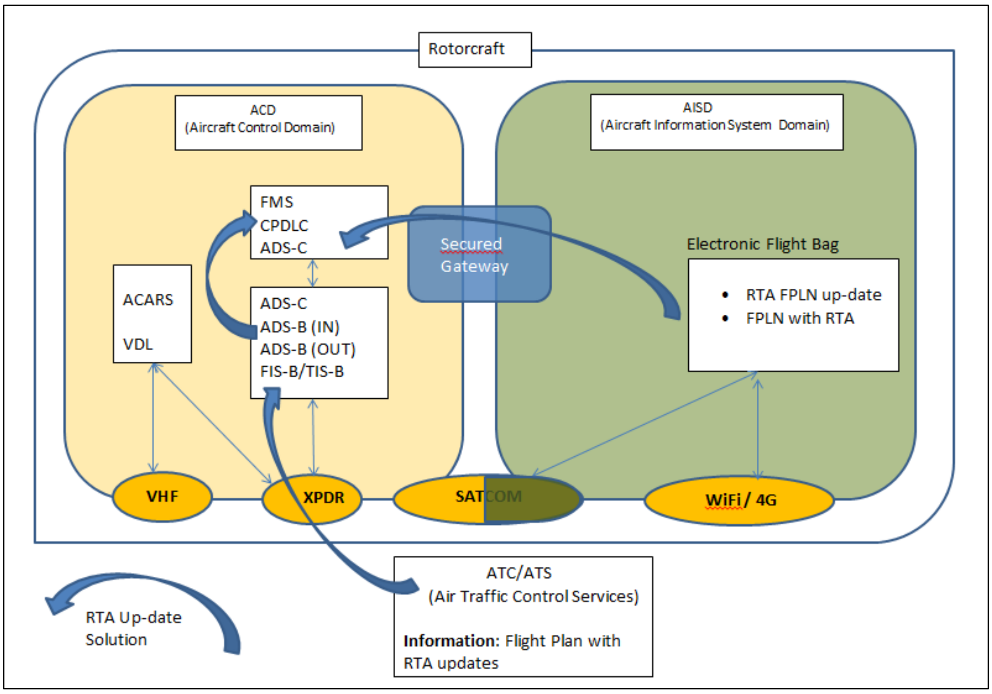


Figure 1: Rotorcraft possible internal functional architecture wrt ATC/ATS (LLR)

Considering LLR under CNS scheme, it should be identified:

Communication

- ADS-B out capability as future implementation in this specific Rotorcraft operations.

Navigation

- A dedicated NAV DB including all procedures (e.g. PinS departure and approaches on LIMC/LIML airports and LLR in Milan TMA) shall be storable and retrievable from helicopter Navigation system and not modifiable by pilot.
- Navigation functions and capabilities from the Navigation database shall be available to pilots in order to comply with possible ATCO route requirements.
- Automatic Flight Control System (AFCS):
- The AFCS is capable to follow the steering provided by the FMS in the horizontal and vertical/longitudinal (during approach phase only) planes through:
  a) IAS steering, during the approach, for deceleration at Initial and Final speeds (longitudinal guidance);
  b) Roll Steering (lateral guidance);
  c) Vertical Speed Steering, during the approach, to comply with FMS computed VPATH (vertical guidance).

Surveillance

- Radar coverage

Besides, FMS steering are within AFCS internal limitations in terms of deceleration rate, maximum bank angle and maximum vertical speed. All the RNAV approaches and LLR en-route procedure are loaded from NAV DB in both FMS system.

3.1.1 Airspace

It is expected that the operations are fully conducted within controlled airspace. The operations begin in en-route controlled airspace in the cruise phase of flight and continue into terminal airspace until approach to the airport FATOs.

Performance Based Navigation (PBN) procedures will be used to systemise/optimise route structures and procedures, primarily for SIDs and STARs in TMA.

It is assumed that the lateral spacing between parallel STAR segments being flown by RNP1 (or RNP0.3 where operationally suitable) flights in the TMA while RNP-based arrival and departure routes are made available to the Airborne Navigation Systems to plan the descent and climb accordingly to the final insertion waypoint to/from LLR..

For the TMA operations, the establishment of a LLR requires the introduction of rotorcraft specific corridors, according to routes design requirements based on ICAO DOC. 9613 with regards specific RNP 0.3 navigation specification.

Considering rotorcraft specific and tailored LLR, create the need for a specification that has a single accuracy of 0.3 NM for all phases of flight, recognizing that such a specification would enable a significant part of the IFR helicopter fleet to obtain benefits from PBN. Specifically, the operations they had in view included:

1. Reduced protected areas, potentially enabling separation from fixed wing traffic to allow simultaneous non-interfering operations in dense terminal airspace;
2. Low-level routes in obstacle-rich environments reducing exposure to icing environments;
3. Seamless transition from en route to terminal route;
4. More efficient terminal routing in an obstacle-rich or noise-sensitive terminal environment, specifically in consideration of helicopter emergency service IFR operations between hospitals;
5. Transitions to helicopter point-in-space approaches and for helicopter departures (already developed in a dedicated deliverable: Solution Guidance xx PinS-GEN)

3.1.2 Separation standards

The separation minima are the current standards used in the airspace considered.

The controller maintains the responsibility for separation. There is no difference in the controller activity otherwise to consider the rotorcraft specific performances and flight altitude.

It interesting to note and to underline that the introduction of RNP 0.3 navigation specification applied to LLR based on PBN manual 4^{th} edition and ICAO Doc. 8168 (PANS-OPS), § 2.2.3 identified:

Route area semi-width: ½ A/W = 1.5 XTT + BV

- XTT: Cross Track Tolerance error (3σ)
- BV: Buffer Value depending on A/C type and flight phase

Phase of flight	*BV for CAT A–E*	*BV for CAT H*
En-route, SIDs and STARs (greater than or equal to 56 km (30 NM) from departure or destination ARP)	3 704 m (2.0 NM)	1 852 m (1.0 NM)
Terminal (STARs, initial and intermediate approaches less than 56 km (30 NM) of the ARP; and SIDs and missed approaches less than 56 km (30 NM) of the ARP but more than 28 km (15 NM) from the ARP)	1 852 m (1.0 NM)	1 296 m (0.7 NM)
Final approach	926 m (0.5 NM)	648 m (0.35 NM)
Missed approaches and SIDs up to 28 km (15 NM) from the ARP	926 m (0.5 NM)	648 m (0.35 NM)

Table 2: Route semi-width

Thanks to reduced Buffer Values, helicopter (CAT H) routes are narrower than for fixed-wing aircraft (CAT A/E), this lead to a:

- Further width reduction thanks to RNP 0.3

As indicated and summarised in the table below:

		CAT A/E RNAV 1	CAT H RNAV 1	CAT A/E RNP 1	CAT H RNP 1	CAT H RNP 0.3
En Route ; SID & STAR ≥ 30 NM	XTT Values	2 NM	2 NM	1 NM	1 NM	0.3 NM
	½ A/W	5 NM	4 NM	3.5 NM	2.5 NM	1.45 NM
Terminal ; STAR < 30 NM 15 NM < SID < 30 NM	XTT Values	1 NM	1 NM	1 NM	1 NM	0.3 NM
	½ A/W	2.5 NM	2.2 NM (not published yet)	2.5 NM	2.2 NM	1.15 NM
SID ≤ 15 NM	XTT Values	1 NM	1 NM	1 NM	1 NM	0.3 NM
	½ A/W	2 NM	1.85 NM (not published yet)	2.0 NM	1.85 NM	0.80 NM

Table 3: Route semi-width comparison

3.1.3 Traffic characteristics

For Step 1 the traffic complexity and density can be described as medium to high.

There will be no any significant changes to the composition of the traffic, in terms of aircraft types, from today's global fleet, however it is important that the concept addresses rotorcraft as well as mix of traffic types (e.g. wake category / speed profile / manoeuvrability), leading to sequencing and/or metering issues.

3.1.4 CNS Requirements

This table would be a general overview on the already existing equipment and futures ones that are part of the CNS requirements taking into account the LLR:

Communication means	Direct Controller-Pilot Communication via voice (R/T) and/or datalink (CDPLC) and ADS-C capability
Surveillance means	Radar / ADS-B surveillance
Navigation means	To support A-RNP route and procedures structure, GNSS Augmentation Systems (e.g. GBAS, SBAS)

Table 4: Ground equipment

3.1.4.1 Ground

The controller is provided with the traffic surveillance data.
Furthermore, the controller may be provided with additional tools to be supported in the Conflict Detection in order to manage the Separation of the traffic.
This set of tools will assist the controller in managing the potentially large number of interacting routes. The following aspects of today's operations are assumed:

- Radar separation Minima (usually 5-3 NM in Terminal Airspace) and
- Minima imposed by Wake Turbulence on the final approach segment.
- It will still be possible to use conventional separation modes although there will be less tactical intervention.

3.1.4.2 Airborne

Communication means	- Digital Radio Navigation System - A data link connection capability, which supports information exchanges on CPDLC and ADS-C capability. - AGDL (Airport Ground Data Link) solutions for RC - Transmission of Graphical weather information
Surveillance means	- ADS-B out equipage - Cockpit Weather display - CDTI - Cockpit Display of Traffic Information - Emergency Avionics systems (CVR/FDR, ELT) - Health & Usage Monitoring System (HUMS)
Navigation means	- RNP capability - Dual Flight Management System (FMS) with GPS - 4-axis digital AFCS (Automatic Flight Control System) - GNSS/SBAS receiver linked to a FMS supporting all required PBN elements (including RFs) is necessary - MFD - Multi-Function Display - Digital Map - Traffic and terrain avoidance systems (TCAS II, HTAWS, SVS, EVS)

Table 5: Airborne CNS evaluation

3.2 Roles and Responsibilities

3.2.1 ATCO

The ATCO are still responsible for preventing collisions and expediting and maintaining the orderly flow of traffic. To prevent collisions, ATC units issue the clearances and traffic information depending on the service provided which is function of the type of flight (i.e. IFR or VFR) and the class of airspace.

Taking into consideration LLR, the integration of this kind of specific tailored rotorcraft routes do NOT introduce change of responsibilities or change of practices in the Air traffic controllers duties.

3.2.2 Flight Crew

There is no change to the responsibilities of the Flight Crew regarding the safe conduct of the flight during LLR. Flight crews are still responsible for the safe and efficient control and navigation of their individual rotorcraft in all airspace. However, procedures will now include flight crews' use of the advanced on board avionics technologies, improving the decision-making process for the safe and efficient management of the flight.

3.2.3 Exchanges between Air Traffic Controller and Flight Crew

The on board avionics system, for example in the near future will download the rotorcraft track/profile to the ATC unit via the ADS-C EPP.

With that technology there will be a completed integrated management through data link network and upgrade in real time of the RTA (required time of arrival) overhead determinate waypoints, characterizing the LLR design.

The ATCO will crosscheck the rotorcraft and ground flight plans, and the adherence to the published LLR respecting the required RNP specification.

In case of discrepancy on the trajectory, a corrective action shall take place between the ATCO and the flight crew, through the CPDL-C data link. If the flight crew rejects the ground proposal, then a voice communication is set to identify the solution.

The rotorcraft is always under radar control coverage or monitored from the ground via data-link down-links ADS-B (IN/OUT).

Information exchanged via Ground-Air-Ground communications are essential and based on the standard IFR phraseology in use to date and worldwide recognised throughout ICAO regulations.

3.3 Constraints

Main constraints that might impact the Low Level IFR Routes are:

- Some LLR could be designed with some demanding navigation specification, so the RC performance will be affected by FMS and autopilot installed on board;
- The rotorcraft navigation system, shall have capability and meet defined requirements for accuracy and availability to operate in managed airspace, granting such kind of RNP (PBN) required;
- The rotorcraft communications system, which shall include the data link systems that provide the link into the ATM environment and provide the means for importing information about the weather situation.

Operative issue considering LLR routes with different Navigation Specification:

- LLR are designed according to strategically separate them to other dedicate operating areas, airways, routes, taking into consideration airspace constraints.
- LLR are designed at lowest possible TMA altitude respecting constraints and some ATCO issue could raise during day by day separation management, especially near airports. This could be easily tactically overcome by ATCO. In some operative areas there should be the necessity to let the rotorcraft to respect some climb or descent vertical gradient in a confined space.

4 Use Cases

4.1 Use Case

This use cases below describe particular occurrence, in a busy medium complexity and medium density TMA, where a dedicated rotorcraft LLIR KY159 and KY179 has been developed. The unique R/C capabilities in low speed flight or high cruise speed, thigh bank angles, allow routes to be designed that are minimising noise nuisance , miles flown, optimised altitudes and also, where possible, that can be flown independently from fixed wing, operationally separated and with low impact in airspace management ATCO workload.

The main goal of validation activities (performed by P04.10) has been to verify the efficiency of these concepts on the current working methods. By separating the two traffic flows "Commercial aviation" from " low-performance/low-speed" traffic (e.g. rotorcraft which can be considered as helicopters, tiltrotor, etc.) through the designing of dedicated network routes (PBN based) gives an opportunity for this airspace users to use an high-density airspace without interfering with high-performance/high-speed commercial users (commercial jets), while assuring the same or increased safety level thanks also to the adoption of Low level IFR routes RNP 1 and 0.3 based relying to the GNSS technologies.

An optimized network of Low Level (IFR) RNP routes in the ENR/TMA (controlled airspace), potentially combining VFR and IFR movements on the same routing, have the potential to increase both airspace and aerodrome capacity, reducing the rotorcraft holding time for TMA entry, and increase safety of the (combined) operations, but there is a definite need to address specific issues that could be derivable only through Research and Development activities.

The introduction of the RNP 1 and 0.3 navigation specification, will enable the design and development of dedicated routes which may include closely spaced parallel routes, Fixed Radius Transition (FRT) and Tactical Parallel Offset (TPO) functionality in En Route and arrival procedures which include Radius to Fix (RF) in a complex airspace like the Terminal Manoeuvring Area.

This will allow the design of specific and dedicated routes (En-Route/TMA) for rotorcraft, separated from the routes conceived for the conventional traffic (commercial aviation).

An optimized network routes PBN based (enabled by affordable equipment) provide an inherent basis for separation where presently radar monitoring would mean too much workload for the controller, and are therefore normally banned today (try to fly into one of the busier TMA's in Europe with a small aircraft).

Surely, adding these dedicated routes constitutes a very large benefit for Rotorcraft operations that have been identified as field of exploration.

4.1.1 Precondition

The crew of the helicopter is responsible for the following:

- Adherence to the route cleared for the rotorcraft by ATCO.
- Adherence to the minimum altitudes and heights allowed by the law that the helicopter is allowed to fly. This includes:
    a. Terminal Area Altitude (TAA) (Minimum Sector Altitude (MSA)),
    b. Designed or ATCO separation management altitudes and clearance
- Operating the rotorcraft and its (sub)systems (autopilot, FMS, fuel, landing gear, radios, etc.). This includes selecting the proper routes and verifying the correct one has been selected by comparing against an approach chart and PFD display pages,
- Performing a proper crew briefing, (only obligatory if the crew consists of more than one member) including checking NOTAMs (e.g. about SBAS/GBAS system status), weather, etc., so that all crew members involved are informed and prepared for the en-routes phases.

The responsibility of ATC comprises the following:

- to ensure the necessary separation between the relevant traffic in the airspace of the controller’s responsibility,
- To provide the proper clearance for the route to be flown,
- Provide information to the crew about the guidance system (e.g. SBAS, GBAS) status.

4.1.2 Post Condition

The crew of the helicopter is responsible for the following:

- Perform the RNP based routes as retrieved from Navigation database
- Perform a contingency procedure in case for example of GNSS loss signal, or degraded performances on requested routes (Evaluated during P.4.10 validation activities in a separated simulation sessions)

The pilot’s use of the navigational equipment when executing Low level Ifr Routes relying on GNSS.

The responsibility of ATC comprises the following:

- to ensure the necessary separation between the relevant traffic in the airspace of the controller’s responsibility,
- to provide the proper clearance for the route to be flown

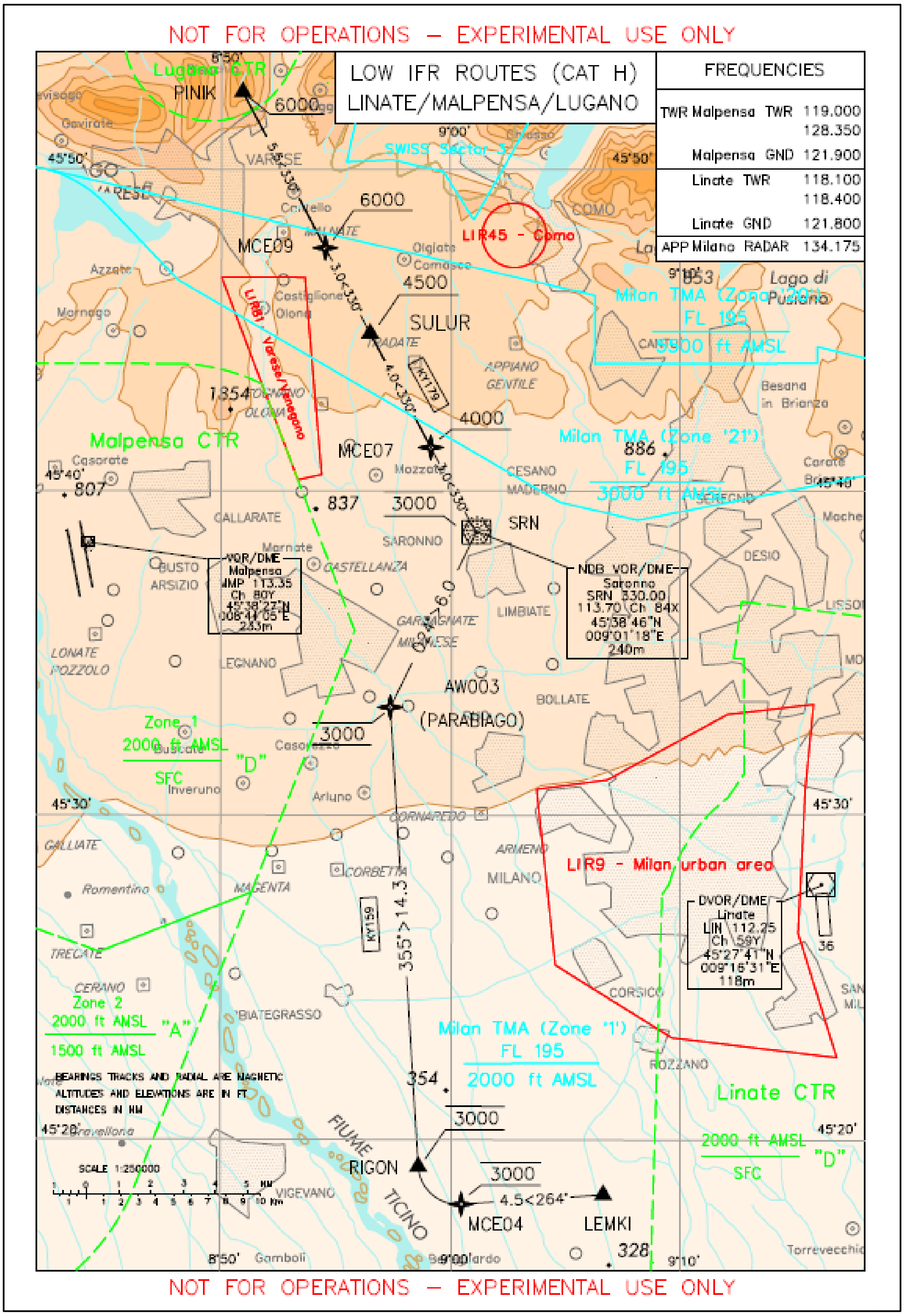


Figure 2: Low Level IFR Routes (KY159, KY179)

LOW IFR ROUTE LIML (Milano Linate) – LIMC (Milano Malpensa) – LSZA (Lugano)

KY159

Path Terminator	Waypoint Name	Fly Over	Track °Mag	Turn Direction	Altitude Constraint	Speed Limit	Recommended Navaid	Bearing/ Range to Navaid	Navigation Performance
IF	LEMKI	-	-	-	-	-	-	-	RNP 0.3
TF	MCE04	-	264° (266.3°)	-	@ 3000	-	-	-	RNP 0.3
RF	RIGON Centre: MCE03 r=1.25NM	-	-	R	@ 3000	120	-	-	RNP 0.3
TF	AW003 (PARABIAGO)	-	355° (356.5°)	-	@ 3000	-	-	-	RNP 0.3

KY179

Path Terminator	Waypoint Name	Fly Over	Track °Mag	Turn Direction	Altitude Constraint	Speed Limit	Recommended Navaid	Bearing/ Range to Navaid	Navigation Performance
IF	AW003 (PARABIAGO)	-	-	-	-	-	-	-	RNP 1
TF	SRN	-	024° (026.1°)	-	@ 3000	-	-	-	RNP 1
TF	MCE07	-	330° (332.1°)	-	+ 4000	-	-	-	RNP 1
TF	SULUR	-	330° (332.1°)	-	+ 4500	-	-	-	RNP 1
TF	MCE09	-	330° (332.1°)	-	+ 6000	-	-	-	RNP 1
TF	PINIK	-	330° (332.1°)	-	+ 6000	-	-	-	RNP 1

ENAV – Rome

Figure 3: Low Level IFR Routes (KY159, KY179) details

5 Requirements

5.1 Interoperability Requirements

5.1.1 Requirements for ATC CNS/ATM Applications

No new IER (Information Exchange Requirements) is identified in the OSED so there are no interface interoperability requirements for the LLIR in a medium density , medium complexity TMA.

The current exchanges linked with PinS and LLIR are :

- Procedures

New Low Level IFR Routes rotorcraft specific, are designed for busy and congested medium density medium complexity TMA, giving an example of effectiveness and feasible operative model easily applicable in ECAC countries. In the same way these new LLIR are designed as connection with specific approach and departure procedures (PinS) to/from FATOs. The way these routes are managed from the (ANSP) procedure designers to the aircraft navigation database is the same process as for current RNP routes.

If this process is changed for a complete design data chain, there is no identified incompatibility with the aforementioned procedures. LLIR procedures will be managed as standard IFR routes with the Criteria of a Reduced Area Semi-widths.

The compatibility between standard IFR routes (airways) and dedicated rotorcraft Low level IFR routes in TMA is the rationale of the reported requirements:

[REQ]

Identifier	REQ-04.10-GEN3-LLIR.0010
Requirement	The construction of the Low Level IFR routes shall respect the guidance given by PANS OPS 8168 volume II.
Title	Routes concept procedure design criteria
Status	<Validated>
Rationale	To cope with current procedure design and ease the widespread use of the concept, and to prevent loss of separation with obstacles, terrain or other flying rotorcrafts.
Category	<Design>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

Note 1: issues have been raised by EXE-04.10-VP-818/816 concerning the coding of the procedures within FMS NavDB :

- Coding process based on ARINC424 and ARINC 19 of RF leg inside an airways such as LLR would require evolution of the ICAO PANS-OPS and ARINC 424/19 standards. The coding standards and navigation information stored into navigation database and managed by FMS doesn't recognize the possibility to fly a RF inside an airways. Such procedure/segments/routes wishing to apply RF would have to use the RNP AR specification.

- The possibility to fly and storage the LLIR with RF (MCE04/RIGON) into the Navigation database, it has been possible, due to the coded KY159 as a STAR from LIML to LIMC.

➢ Flight plans

The way to inform the ATM/ATS of its IFR flight plan by an airspace user planning to use a LLIR is the same as for standard IFR routes or airways.

➢ Voice (ATC – rotorcraft)

The Ground-Air-Ground exchange communication between the ATS/ATCO and the rotorcraft when performing a LLIR are the same as for standard routes.

Air traffic Controller and in general ATC services (ATS) in areas where RNP is implemented should have covered a complete set of information required among ATS services itself and between pilots such as:

- Functional capabilities in area navigation systems work, including limitation of this RNP1 and 0.3 specification
- Upgrade of any degradation regarding: Accuracy, integrity availability and continuity information provided by on-board navigation system
- ATC contingency procedures
- Separation minima
- Standard Phraseology
- Radar vectoring techniques
- Altitudes constraints
- Impact of the requesting change routes during procedures, for ATC reasons.

The rotorcraft CNS functionalities required to support the LLIR are refined into some INTEROP requirements. There is no new information exchanged between ground and Rotorcraft systems therefore there are no interoperability requirement on the Rotorcraft System on how to manage any possible new information.

Listed below the main enablers related to rotorcraft specific aspects:

Enabler code	Enabler title
A/C-04b	Flight management and guidance for RNP 0.3 [Category H (rotorcraft)] in all phases of flight, except final approach and initial missed approach
A/C-07	Flight management and guidance for RNP transition to ILS/GLS/LPV

An important note is that the Interoperability requirements were not originally placed in the OSED, and in addition at that time, no SPR and INTEROP document was available. This Document want to be a merge of information and documents, suggested by SJU as final deliverable. Thus, the requirements on expected benefits are consolidated here with a specific INTEROP identifier. For that reason considering also SPR REQ TRACEs, there will be not evidences/connection to relationship and identifier to OSED.

Related Interoperability requirements:

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0010
Requirement	The Avionics shall be able to elaborate an absolute aircraft position based also on SBAS system
Title	Rotorcraft GNSS Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED TO>	<Functional block>	Position Determination	N/A
<ALLOCATED_TO>	<Functional block>	Lateral Positioning	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0020
Requirement	A continuous navigation data display shall be used as primary flight indicator in order to provide indication to pilots with possible failure, actual status, integrity, lateral deviation (cross track deviation), helicopter position relative to the desired path
Title	Rotorcraft Display Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Displays & Controls	N/A
<ALLOCATED_TO>	<Functional block>	Flight path management gate-to-gate	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0030
Requirement	To perform an LLR RNP 1/0.3, the avionic systems shall assess if the proper EPU (Estimated Position Uncertain), computation capability performance is available
Title	Rotorcraft Navigation Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED TO>	<Functional block>	Flight Path Management Gate to Gate	N/A
<ALLOCATED TO>	<Functional block>	Navigation Position Determination	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0040
Requirement	Any means of navigation display shall be installed in order to display to the

	pilots, the actual navigation sources used, the active waypoint, velocity, time, distance and bearing to the active waypoint
Title	Rotorcraft Display Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Displays & Controls	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0050
Requirement	The functions and capabilities to execute RNP 0.3 considering terminal procedure shall be implemented in the navigation database stored on the helicopter navigation systems
Title	Rotorcraft Navigation Data Bese Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Database	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0060
Requirement	The functions and capabilities to execute path terminators transition (excluded what ARINC 424 don't consider in LLR such as RF) shall be implemented in the helicopter navigation systems
Title	Rotorcraft FMS Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Flight Path Management Gate to Gate	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0070
Requirement	The FMS shall provide RNAV/RNP capability with RF legs only for the Terminal procedure (SID and STAR). (see req above)
Title	Rotorcraft FMS Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).

Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Flight Path Management Gate to Gate	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0080
Requirement	The functions and capabilities to select from the Navigation database shall be available to pilots in order to comply with possible ATCO route requirements
Title	Rotorcraft FMS Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Navigation Database	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0090
Requirement	To perform an RNAV-GNSS route within RNP 1 or 0.3, the avionic systems shall compute, linear deviation, indicated as XYK
Title	Rotorcraft FMS Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Flight Path Management Gate to Gate	N/A
<ALLOCATED_TO>	<Functional block>	Navigation Position Determination	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0100
Requirement	The capabilities to display the XTK deviation, on desired track and selected RNP shall be available on rotorcraft navigation system
Title	Rotorcraft FMS Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance

<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Flight Path Management Gate to Gate	N/A
<ALLOCATED_TO>	<Functional block>	Navigation Position Determination	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0110
Requirement	The capabilities to display navigations systems accuracy, integrity, availability and continuity including helicopter performance monitoring shall be available to pilots during navigation phase
Title	Rotorcraft FMS accuracy, integrity, availability and continuity including helicopter performance monitoring, Display Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Display & Controls	N/A
<ALLOCATED_TO>	<Functional block>	Flight path management gate-to-gate	N/A

[REQ]

Identifier	REQ-04.10-INTEROP-LLIR.0120
Requirement	The navigation database shall be protected against pilots data stored modification. There will be the means to display : • The navigation data validity period • The possibility to verify and check retrieving the data stored, relating to single waypoints • The capacity to select from data stored the relevant segment of SID STAR and LLIR to be flown accordingly to the selected RNP
Title	Rotorcraft Navigation Database Capability
Status	<Validated>
Rationale	This is an rotorcraft required functionality to support LLIR operations (departure and approach).
Category	<Operational>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A
<ALLOCATED_TO>	<Functional block>	Navigation Database	N/A

5.1.2 Dynamic functions/Operations

There are no “dynamic functions / operations” to be considered as interoperability requirements for the low Level IFR Routes (LLIR).

5.2 Safety Requirements

5.2.1 Requirements for Safety

The safety requirements and assumptions developed in this paragraph and evaluated during the project 04.10 timeframe are directly compatible with those in the previous phase and are therefore achievable for the same reasons (stated below). In particular it is noted that the level of performance strictly connected with safety is stated in line with existing standards.

- It is under light that safety requirements have been determined/derived and evaluated only for elements under the managerial control of airborne side (Flight crew, Pilots and flying platform) and from ANSP regarding Airspace Design, in conjunctions with LLIR.
- No additional safety requirements are needed to be identified for the ANSP due to the fact that the existing either the standard ones (e.g. ICAO references) either similar ones have already been implemented in several States. Assumptions are easily implemented because they are relying mainly on ICAO Doc. 9613 - PBN Manual and ICAO Doc. 8168 (PANS-OPS).

Some safety requirements should be easily satisfied because they are not different from those applicable to the “solution scenario” existing standards which are well known by the aeronautical community (e.g. GNSS/SBAS,RNP1 and 0.3 navigation specification ..etc).

The assurance of validation and verification of the safety assessment requirements is an on-going activity. A qualitative safety assessment has been performed from airborne side on the basis of the Use Cases, Solution Scenarios VS Reference Scenario and Operating Method described in the OSED and validated through the exercises described in the VALP and recorded in the synthesis of validation results VALR for IT1 and IT2. An on-going activity (questionnaires, pilot and flight crew feedback, post analysis and de-briefing activities) is being performed to map the safety objectives and requirements generated here to the validation objectives and results, to ensure that all requirements have been assessed. For that reasons some safety requirements are evaluated together and the outcomes has been complementary. Some requirements are the same identified with regards PinS APV operation. This is due to the continuity of safety during rotorcraft “life cycle” flight operation.

[REQ]

Identifier	REQ-04.10-SPR-LLIR.0010
Requirement	The capabilities to display the followed RNP shall be available to pilots in order to verify and control any possible RNP system failure
Title	LLIR Display the capable RNP
Status	<Validated>
Rationale	This requirement is derived for continuity of safety from the SPR level model used with the APV operations. This is judged as validated as it requires the concept to conform to applicable standards
Category	<Functional>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-LLIR.0020
Requirement	The function shall inform the crew in case of GNSS signal integrity loss through PFD.
Title	Display capable in case of GNSS failures
Status	<Validated>
Rationale	This requirement is derived for continuity of safety from the SPR level model used with the APV operations.
Category	<Functional>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

807
808 [REQ]

Identifier	REQ-04.10-SPR-LLIR.0030
Requirement	The avionic systems shall provide indication of loss of navigation capability to the pilot in less than 0.6 seconds in case of SBAS level of service unavailability
Title	LLIR FMS capability in case of GNSS/SBAS failures
Status	<Validated>
Rationale	This requirement is derived for continuity of safety from the SPR level model used with the APV operations.
Category	<Safety>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Review of Design>

809
810 [REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

811
812 [REQ]

Identifier	REQ-04.10-SPR-LLIR.0040
Requirement	The Guidance function shall use its sensors to provide the guidance functionality with accuracy, integrity, continuity and availability compliant with RNP1 and RNP 0.3 requirements.
Title	FMS management capability
Status	<Validated>
Rationale	This requirement is derived for continuity of safety from the SPR level model used with the APV operations...
Category	<Functional>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Review of Design>

813
814 [REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

815
816 [REQ]

Identifier	REQ-04.10-SPR-LLIR.0050
Requirement	SBAS Service Provider shall inform the NAV Service Provider on a foreseen degradation of the SBAS system performance by providing a NOTAM in accordance with ICAO Annex 15., in order to preventable inform Flight crew on board or before the flight initiation.
Title	NOTAM for Degradation of SBAS System from AIS Service Provider
Status	<Validated>
Rationale	This requirement is derived for continuity of safety from the SPR level model used with the APV operations.
Category	<Functional>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Test>

817
818 [REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

819
820 [REQ]

Identifier	REQ-04.10-SPR-LLIR.0060
Requirement	The airspace concept shall be designed with respect to the guidance given by PANS OPS 8168 volume II and ICAO Doc 9613 (PBN Manual).
Title	Design of the airspace concept

Status	<Validated>
Rationale	This requirement is derived for continuity of safety from the SPR level model used with the APV operations.
Category	<Functional>
Validation Method	<Dress Rehearsal><Flight Trial><Fast Time Simulation><Live Trial>
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0010
Requirement	The Low Level IFR route (KY179) shall be flyable from ADEP to ADES (and vice versa) but not contemporarily flyable in opposite direction.
Title	Route flyability
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	<Expert Group (Judgement Analysis)>
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0020
Requirement	The Low Level IFR route (KY159) shall be flyable from ADEP to ADES (and vice versa) but not contemporarily flyable in opposite direction.
Title	Route flyability
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0030
Requirement	In case of operational conditions different from ones taken as reference, rotorcraft operations shall be suspended giving priority to normal operations. Rotorcraft operations shall be resumed when operational conditions abovementioned are restored.
Title	Operational conditions to perform rotorcraft operations
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0040
Requirement	Interactions between live trial rotorcraft procedures and other IFR procedures shall be available to Air traffic controllers.
Title	Interactions between live trial procedures and other IFR procedures
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0050
Requirement	Temporary orders of service during activity shall be available for all Units affected by rotorcraft operations.
Title	Orders of service to inform ATCO
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0060
Requirement	Orders of service shall specify that rotorcraft operations are performed in VMC conditions.
Title	VMC conditions
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0070
Requirement	An AIM shall be put in place in order to inform Airspace users of rotorcraft activities.
Title	Information to users
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian

	Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0080
Requirement	At least three hours before the beginning of operations, a planning of activities shall be provided to Air traffic controllers
Title	Planning of activities
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0090
Requirement	ATS units (Lugano TWR) shall be informed in advance about the flight activity on the used route (KY 179)
Title	Information to ATS units
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0100
Requirement	The best time slot available to perform the Flight Trial shall be identified taking into account the needs of airport ATS Units
Title	Time slot for performing Flight Trial
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0110

Requirement	In order to avoid runway closure or military zones activation causing runway change, a coordination between the ATS units (Civil and Military) shall be performed
Title	Coordination between Civil and Military ATS units
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-ATCO.0120
Requirement	COPs between the TWR\CTRs and ACC\ATS units shall be provided for the transfer of responsibility of rotorcraft during procedure execution (approaching\departing)
Title	Identification of COP
Status	<Validated>
Rationale	This requirement is derived from Safety Assessment performed by Italian Air Navigation provider and approved by Regulator.
Category	<Safety>
Validation Method	Expert Group (Judgement Analysis)
Verification Method	<Review of Design><Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES_TO>	<Operational Focus Area>	OFA02.01.01	N/A

This additional information hereafter reported does not consider deviation with respect what planned in P04.10 VALP IT2 regarding VP-818 (Flight Trials) and any not-nominal event haven't been considered during flying sorties due to several safety constraints.

This is why, not-nominal events such as Contingency Events applied to PBN failures like:

1. On board loss of GNSS integrity
2. Loss of GNSS signal

The evaluation has to be considered as propaedeutic and integrant to the VP-818 outcomes reported in the P04.10-D09-IT2_VALR, giving an added value to the project, thanks to a specific simulation aspect.

With the scope to realize the simulation environment reflected by Solution scenario, one of the main objectives was to evaluate Pilot/Crew feedback on specific "cases study" concerning some contingency events which have not been assessed during flight trials due to safety reasons.

The Contingency procedure evaluated in this additional simulation session " Dress Rehearsal VP-818", considering the LLIR RNP 1 and 0.3 (KY159 and KY179), demonstrate that in case of:

1. On board loss of GNSS integrity or
2. Loss of GNSS signal

no additional effort or decrease in pilot human performances has been highlighted or evaluated from pilot point of view. ATCO actions and management, reverse to pilot vectoring clearances.

Pilot perceived level of safety and associated situational awareness is granted by the Avionics monitoring and alerting, displayed on PFD and MFD during failures. Once the pilot has identified the impossibility to maintain the required RNP, he communicates to ATCO the failures using the standard phraseology:

<<*…Unable to maintain RNP due to…*>>

with no additional workload or unexpected crew coordination on board.

After this stage, the Pilot once identified also the "failures typology", makes all needed actions to secure that the flight will be conducted with the needed level of safety, ensuring an efficiency way without any impacts on the flight operations and in a fully agreement with the ATCO guidance's and vectoring instructions.

The evaluation has identified a very slightly increasing of mental demand effort due to more coordination/communication issue required with ATCO.

This evaluation concerned to LLIR during remoted contingency procedures may occur, are to be intended as qualitative. Even if qualitative the positive outcomes make evidence and confirm such of the INTEROP requirements analysed in previously chapters: 5.1.1 Requirements for ATC CNS/ATM Applications. No specific SPR requirements has been evaluated or identified due to the fact that this contingency procedures can be traced as already codified standards put in place in day by day operation.

5.3 Performance Requirements

The Performance requirements listed in this paragraph are based on existing Navigation Specification(s) which are required to deliver the stated operational requirement. No additional Quality of Service requirements, beyond those reflected within the guidance on procedure validation provided by ICAO are foreseen.

For the design side, it is considered that the applicable safety and performance requirements documentation are:

- ICAO DOC 9906
- The Quality assurance manual for flight procedure design:
  a) VOL I Flight procedure design and quality assurance System
  b) VOL II Flight validation of Instrument Flight Procedures
- Guidance of the flight inspection provided in ICAO DOC 8071
- PBN Manual 4th edition regarding RNP 0.3- Chapter 7

For the airborne side, it is considered that the applicable safety and performance documentation requirements regarding RNP 0.3 are:

- TSO-C145a and TSO-C115B regarding navigation system (FMS)
- TSO-C146a regarding avionic equipment for IFR flight
- TSO-C193, specific to RNP 0.3 certified rotorcraft capability.
- TCA-DO208 Appendix E for on-board monitoring and alerting

The (initially planned) final project deliverables (OSED/SPR/INTEROP…) have been replaced by the SESAR Solution Guidance (e.g. this document). So, the requirements that should have been included into the standard SESAR documentation (e.g. SPR) are now consolidated here with a dedicated SPR identifier.

[REQ]

Identifier	REQ-04.10-SPR-LLIR.0070
Requirement	The LLIR shall allow a reduction in the overall track miles, resulting in less flight time, less fuel consumption and consequently less pollution emission respect standard routes/airways at higher altitudes.

Title	Benefit: Optimised and reduced track miles VS a standard routes
Status	<Validated>
Rationale	It has been available thanks to the flexibility and trajectories optimisation with RNP 1 and 0.3; thanks to a shorter and tighter corridors/routes. This composition can allow the construction of shorter trajectories, (e.g. when noise sensitive areas and rich terrain obstacles areas are to be considered). This favours rotorcraft optimised shorter paths in congested TMA..
Category	<Performance>
Validation Method	<Live Trial>
Verification Method	<Test>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-LLIR.0080
Requirement	The implementation of LLIR shall improve the rotorcraft Airspace accessibility.
Title	Benefit: improved airspace accessibility
Status	<Validated>
Rationale	Thanks to a procedure with optimised segments with different RNP values in TMA environment may allow to: - Reduced Pilot Workload - Reduced track mileage - Reduced fuel consumption - Increase safety operational level - Improve efficiency - Increase Airspace capacity - Improve access to busy and dense/complexity TMA architecture
Category	<Performance>
Validation Method	<Live Trial>
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

[REQ]

Identifier	REQ-04.10-SPR-LLIR.0090
Requirement	The airborne FMS shall have the capability to automatically execute path terminators.
Title	Benefit: improved airspace accessibility
Status	<Validated>
Rationale	Thanks to path terminators with optimised segments with different RNP values in TMA environment may allow to: - Reduced Pilot Workload - Reduced track mileage - Reduced fuel consumption - Increase safety operational level - Improve efficiency - Increase Airspace capacity - Improve access to busy and dense/complexity TMA architecture
Category	<Performance>
Validation Method	<Live Trial>
Verification Method	<Review of Design>

[REQ Trace]

Relationship	Linked Element Type	Identifier	Compliance
<APPLIES TO>	<Operational Focus Area>	OFA02.01.01	N/A

As stated in previously chapter coding process based on ARINC424 and ARINC 19 of RF leg inside an airways such as LLIR would require evolution of the ICAO PANS-OPS and ARINC 424/19 standards. The coding standards and navigation information stored into navigation databased and managed by FMS doesn't recognize the possibility to fly a RF inside an en-route segment. As stated in PBN manual the capability to automatically execute leg transition and maintain tracks consistent with the following ARINC 424 path terminators or equivalent are only for:

- Initial Fix (IF)
- Course to Fix (CF)
- Course to Altitude (CA)
- Direct to Fix (DF)
- Track to Fix (TF)

In order to consider RF legs transition inside en-route phases it would require an evolution of the ICAO PANS-OPS and ARINC 424/19 standards.

5.4 Information Exchange Requirements

No new IER (Information Exchange Requirements) are identified in the OSED so there are no interface interoperability requirements for the Low Level IFR routes. Standard information and phraseology exchanged among Crew on board and ATCO, are based on the same standards used to date in typical IFR flight (ICAO DOC 4444 [21]).

6 E_OCVM Life cycle description & Validation activities results

6.1 V2 Validation Exercise Results

The results have been derived from qualitative data obtained through questionnaires and platform data recordings respectively, with opportune information integration with comments provided by all the actors involved (operative experts and exercise experts) through debriefing session.

This kind of analysis has allowed to verify consistency and confidence of data collected and has provided a good quality of exercise results, which gives a solid base for the second iteration validation activities (Live Trials).

Results of the EXE04.10-816 exercise in V2 maturity level, concern the Low Level IFR routes flyability and operational acceptability from on-board point of view, considering "pilot in the loop" concept are here summarised. The main findings within this validation exercise are as follows:

- the Pilot workload remained unaltered during the simulation runs and his performances haven't been impacted, remaining always at highest level. It's evaluated also an additional time availability to other cockpit duties (based on: the pilot and *over the shoulder* observers' feedbacks have confirmed that during the operations they have had enough time to dedicate to possible additional tasks).
- The lateral and vertical transition is correctly performed, with satisfying situation awareness.
- NASA TLX and questionaries' post analysis regarding LLIR have shown a decreased pilot work load respect "standard IFR planning".
- Environmental post analysis evaluation has demonstrated in Solution Scenario a marked decrease in Fuel consumption, flight time and distance flown respect Reference Scenario
- From pilot prospective no rules or change of practices has been envisage or noted performing LLR RNP1/0.3. Low level IFR routes flown at the coded altitude (design constrains) did not involve any changes or deficit in Pilot human performance. The RF legs are correctly flown for the continuity of LLIR coded as STAR.
- Operations are easy, efficient, reliable and proposed procedures does not have an impact on the existing working methods. Then, Pilots were always in control of any situation with no decrease in their perceived situational awareness.

EXE-04.10-VP-815 allowed assessing the impact of Simultaneous-Non-Interfering operations (PinS procedures to/from FATO) and the impact of Low Level IFR routes (RNP-1/RNP-0.3) operational concepts in the TMA multiples Airports environment.

Quantitative data collection methods allowed gathering different results sufficient to validate proposed objectives and related success criteria.

All the investigated aspects of the implementation of the new operational concepts have been reached.

According to the results provided by the Fast-Time Simulation activity and looking to the execution of the scenarios, the main benefits reachable through the implementation of operational concepts like the Simultaneous-Non-Interfering PinS procedures and the Low Level IFR Routes for helicopters (RNP-1/RNP-0.3) are:

- The ATCO Workload is not negatively affected by with the new operational concepts, as no changes on the calculate WL are calculated comparing the Reference and the Solution Scenario;
- Moving rotorcraft operations to FATO with dedicated procedures can generate an increase in the number of movements for the runways (Fixed Wing). When a rotorcraft is in the Arr/Dep sequence its performances (Speed, slow manoeuvring) negatively affects the sequence

management; it's possible to consider that one rotorcraft operation corresponds to about 5 aircraft operations. So referring to the Figure 25 it's possible to quantify this benefit.

- The Fuel Burnt, CO2 Emissions and Distance Flown concerning rotorcraft operations were reduced comparing the two scenarios
- The Fuel Burnt and CO2 emissions concerning the aircraft operations (fixed-wing) were reduced comparing the two scenarios

Recommendations for procedure improvement and Needs for Standardisation:

- the exercise did not show any need to update existing airborne regulation or standardisation documents.

Needs to update the system documents (functional requirements, architecture document):

- the avionics platform enabled to perform the PinS procedure and Low Level IFR route. No specific change in the functional requirements or in the architecture has been identified.

This following section contains recommendations for next phases. Within the VP-815 simulation session the following recommendations could be suggested:

- In order to realize the same analysis done for LIMC Airport, it's recommended to implement a Pins Approach Procedure (VFR) also for LIML Airport. A solution could be to use the same path expected for the departure of rotorcraft, in the opposite way for arrival. In this manner, no interference with fixed wing aircraft would occur.
- Regarding the LLR to LSZA, It's recommended to consider a MEA/L (Minimum En route Altitude/Level) above 5000ft from MCE01, in order to avoid the interference from the fixed wings departure to 35R.
- In order to have a full validation of the concept, it would be recommended to plan additional validation sessions in different operational contexts, to further scope the concept.
- Further validations could address the management of rotorcraft operation on the movement area to assess the benefits on the ground movements (taxiway segment, parking position dedicated, etc.) when moving rotorcraft to FATO.

6.2 V3 Validation Exercise Results

Flight Trials have allowed to positively assess validation objectives and related success criteria defined. The identified Validation Objective has been successfully met. Qualitative and quantitative data have allowed to assess very important results.

Significance of the results refers to statistical and operational significance. Statistical significance is based on the number of independent variables of the Validation Exercise and the number of exercise runs carried out.

Operational significance concerns operational realism of the Validation Exercise which depends on a number of factors which are very much dependent on the chosen environment. Being a live trial, conducted in real environment with live traffic the exercise was characterized by a very high operational significance.

Moreover the exercise schedule was designed in order to repeat runs the adequate number of time to have reliable results. Finally statistical significance is not applicable.

1. <u>Expected benefits</u>

In the frame of the production of initial project documents such as DOD and OSED, the following potential benefits had been identified by the members of the P04.10 project team and the operational airspace user expert group supporting them.

➢ Scalable RNP / Combined use of RNP1 and 0.3:

- **Less fuel consumption and less pollution emission is a result of reduced track miles flown**:

It has been available thanks to the flexibility and optimisation of trajectories legs with RNP 1 and 0.3; thanks to a shorter an rotorcraft specific paths/segments/routes. This can allow the construction of shorter trajectories, (e.g. when noise sensitive areas and rich terrain obstacles areas are to be avoided). In general this favours rotorcraft optimised shorter paths.

- **Increased precision on horizontal and vertical paths**

  Thanks to the implementation of RNP values from 1 down to 0.3:

  - **Increases ground track predictability and situational awareness in TMA airspace**

    Better situation awareness either for Air Traffic Controllers either pilots;

  - **Better noise distribution to specific non-sensitive areas**. At medium density medium complexity TMA this could lead to a fully tailored rotorcraft routes, with specific aspects in optimised routing (reduction of: time/distance/fuel burnt/pollution);

  - **Increases Airspace accessibility**, LLIR with PBN legs (RNP 1/0.3) can make design routes possible to construct shorter and more efficient paths taking into consideration either the surrounding terrain either the airspace constraints.

- **Expected decrease in Flight Crew and ATCO workload** compared to previously operations, in TMA. the tailored and optimised rotorcraft LLIR may decrease ATC operational workload within a mixed equipage environment involving rotorcraft and aircraft. For such environments, the state of the art on board avionics equipment is required to successfully implement such procedures in dense and complex terminal airspace.

Those expected benefits has been based on the R&D needs hereafter summarised:

With regard the Low Level IFR routes concept [for Rotorcraft using RNP1/ RNP0.3 (in all flight phases)]) there is a need to validate and assess some issue such as:

- the introduction of Low Level IFR route network for rotorcraft using RNP-1 / RNP-0.3 is needed for a pan-European concept and SESAR is the right framework to define such a concept.
- the investigation about the merging of RNP1/RNP0.3 low level IFR routes will provide a consistent path for navigation to and away (connection to) the approach phase
- the concept of RNP1 and RNP0.3 where necessary (constraining environment) are already defined but the RNP0.3 concept is conceived only for the rotorcraft operations and it has never been validated
- the validation activities could provide also further assessment related to the safety issues linked to the use of the safety nets to support the Low Level VFR routes
- by the introducing of metering points with time constraints (CTO/CTA) inside of Low Level airspace the validation activities could open the possibility of the investigation about a sort of low-level Free Route Airspace in conjunction with i4D concept of operation.
- there is a need to assess a contingency procedure in case of GNSS loss, because at low level altitude the rotorcraft are not be able to perform the reversion to DME/DME navigation specifications.

Outcomes of exercises EXE-04.10-VP-818/816, have confirmed these benefits (qualitative and some quantitative) and provided results on other areas.

Outcomes of exercises EXE-04.10-VP-815, have confirmed these benefits (quantitative) and provided results on other areas.

2. Confirmed expected benefits

➢ From Ground segment the EXE-04.10-VP-818 outcomes are recaps in the following table as per overall results obtained per each Human Performance investigated area for each executed trials related to ground assessment:

Activity	Rotorcraft operations	Workload	Situational awareness	Teamwork	Acceptability	
					Overall acceptability	Impact on operations
Trial#1	Flight 1: LIMC - LIMC Flight 2: LIMC - PINIK (LSZA) Flight 3: PINIK (LSZA) - LIMC	✓	✓	✓	✓	✓
Trial#2	Flight 1: LIML - PINIK (LSZA) Flight 2: PINIK (LSZA) - LIML	✓ by exception of DCP	✓ by exception of ANE EXE	✓	✓ by exception of DCP	✓ by exception of DCP and ANE EXE
Trial#3	Flight 1: LIML - LIMC Flight 2: LIMC - PINIK (LSZA) Flight 3: PINIK (LSZA) - LIMC	✓	✓	✓ by exception of DCP	✓	✓
Trial#4	Flight 1: LIML - PINIK (LSZA) Flight 2: PINIK (LSZA) - LIMC	✓	✓	✓	✓	✓

Table 6: Ground results, please refers to D09–IT2 document, for major details

Notwithstanding that several recommendations have been provide by controllers in order to completely assure acceptability and feasibility of Low Level IFR Routes, PinS approach/departure to/from the VFR FATOs.

All involved controllers really appreciated :

- Low level IFR route connecting LIML and LIMC airport (KY159).
- IFR Traffic interaction in TMA take place at low altitudes, and didn't penalize the management of the largely sequence of trajectories released from those, usually used for the traffic vectoring from and to the Lombard airports;
- In case of damage to the GNSS system the "unusual situation" can be treated in analogy to what is today for the failures of the radio-navigation apparatuses (including the phraseology ground side), once declared the helicopter's ability to navigate using conventional navigation means (navaids and / or Flight Management system) or the need for assistance from the ATS surveillance system;
- In the case of low IFR traffic in TMA and in case of on-board failure (total or partial) would be preferable respect conventional means of navigation the vectoring ATCO clearances allowing a greater " ATCO situational awarness"

- In case of loss of precision RNP (on board failure-apparatus) is necessary to identify and standardize the information on significant deviations(lateral deviation respect desired track);
- Considering SRN-PINIK (KY179) leg, the fixed wing Malpensa departures can be better managed, keeping up (just max A6000 / FL90) the rotorcraft traffic on KY179, rather than using crossing procedure on the SID; the inbound sequence is not procedurally affected since even, an inbound of SRN to FL100 is on a proper descent profile just to LIMC and the same for LIML
- LLR KY159 flown between A3000 / A5000 northbound is easily manageable by ATCO with a procedural crossing on the SIDs from LIMC (no other measures as RSYD, RNB, HR, seem necessary even if available or used); Probably It should find a new point on the SID from LIMC to SRN, laterally separated from KY159 (south of SRN), slightly altering the take-off rate required;
- Performance expressed during the flight test (AW001) during the simulated approach to LIMC (ILS R35R) both in terms of GS (of the order of 130 kts until 1nm from Touch Down), because of vertical speed and descent rates and tack , did not appear particularly impacting on the normal dynamics used by ATCO in organizing a sequence to a "busy" airport, even in congested traffic conditions where appears not particularly heavy.
- Nowadays, since most fixed wing aircraft have similar performances, the air traffic control system is managed with the main goal to accommodate the most demanding aircraft among the types in use. Therefore, the priority to be assigned to a specific airspace users depends on the ATC procedures, airspace, available volumes, altitude, separations to be ensured, procedure layouts, runways alignment distances etc.

  So, the impact of new operational procedures on the air traffic controllers side, can strongly depend on the individual airport environment, specific procedures applied and on the amount of VTOL traffic, even if today's controllers are :

  - quite familiar with the performances and characteristics of helicopters;
  - not at all familiar with the performances and characteristics of tilt rotor aircraft;
  - not familiar with steep/segmented/curved/slow approaches and departures specific controller training will be required.

  Vice versa from the Pilot perspective, today the segregation of helicopters into “G” airspace or into controlled airspace but with low altitude traffic, has strongly reduced the capacity to face with complex environment both in terms of attention and reaction to controllers (and other pilots) information/clearances than in the ability to adapt their performances according to the requests of a busy scenario; [remark: a dedicated pilot rating (endorsement?) to work within complex environment should be recommended]
- On international / intercontinental airports with traffic "heavy" and pilots used to deal with other aircraft from homogeneous characteristics, with almost standard operating practices, it would be important to avoid creating "unusual" situations such as, designing procedures PINs that have trajectories not immediately interpretable by the commercial aviation pilots; specifically, for example, pseudo orthogonal trajectories (at least until MAP) compared to those of instrument approach or that have a potential impact angle “visually” unsafe; these angles may be a source of possible operational stress even for ATCOs with monitoring responsibilities compared to the totality of the movements in the CTR (IFR and / or VFR).

➢ From airborne side results of the VP-818 flight trials exercise concern the Low Level IFR routes flyability and operational acceptability, considering “pilot in the loop” concept are here summarised.

The main findings within this validation exercise are as follows:

- Pilot performances during the LLIR remained always at highest level. it’s evaluated also an additional time availability to other cockpit duties (based on: pilot and crew feedbacks assuring enough room for additional task.
- The lateral and vertical transition is correctly performed, with satisfying situation awareness.

- NASA TLX and questionaries' post analysis regarding LLR have shown and confirms a decreased pilot work load respect "standard IFR planning" already evaluated in EXE816.
- The RF leg is correctly flown for the continuity of LLR and related PinS approaches, considering KY159 as a STAR between LIMC and LIML.
- From pilot prospective no rules or change of practices has been envisage or noted performing LLR RNP1/0.3. Low level IFR routes flown at the coded altitude (design constrains) did not involve any changes or deficit in Pilot human performance
- Operations are easy, efficient, reliable and proposed procedures does not have an impact on the existing working methods. Then, Pilots were always in control of any situation with no decrease in their perceived situational awareness.
- The Contingency procedure evaluated in the additional simulation session Dress Rehearsal VP-818, considering the LLR RNP 1 and 0.3, demonstrate that: in case of Loss of signal integrity or GNSS failure, no additional effort or decrease in pilot human performances has been highlighted or evaluated from pilot point of view. ATCO actions and management, reverse to pilot vectoring clearances.
- In addition to the planned activities, during flight trials pilot /crew and post analysis data observed and shown the helicopter capability to maintain RNP 0.3 all Phase of Flight. Pins Dept from LIMC, KY159 and PinS Apch to LILK – LNAV/LPV (including missed approach) have been flown maintaining RNP 0.3. During Flight Trials, air traffic services units, coordinated by ENAV, have traced the Rotorcrafts seamlessly verifying both radar coverage along the IFR routes at low altitudes (KY159 and KY179), and verifying the high precision navigation performances and safety guaranteed by AW139 and AW1839.

- Needs for Standardisation:
  - The exercise did not show any need to update existing airborne regulation or standardisation documents.
  - The avionics suite bay, installed on flying platform enabled to perform the Low Level IFR route. No specific change in the functional requirements or in the architecture has been identified.
  - Referring to ADS-B technology evaluation, future investigation and R&T activities shall be performed in SESAR2020 programme.

- Application of RNP-0.3 is beneficial for improving further (compared to RNP-1) IFR rotorcraft integration both in Terminal Airspace (TMA) and En-Route:
  - In dense Terminal Airspace, RNP-0.3 eases the design of strategically separated Low Level IFR routes connected to rotorcraft Point-in-Space approaches / departures at Airports (SNI operations) and other dedicated operating sites (city heliports, hospital helipads)
  - En-Route, both in controlled and uncontrolled airspace, RNP-0.3 eases the integration of Low Level IFR routes in constraining areas (mountainous terrain or/and environment sensitive areas, it's also relevant for Terminal Airspace)

Based on results achieved in the frame of P04.10 First and Second Iterations validation activities, the achieved maturity level for the **AOM-0810** (at the end of the Project), is V3 (in accordance to E-OCVM). It has to be noted that P04.10 results will be part of Release 5 (R5 bacth-2) and considered as a SESAR 1 Solution (#113: "*Optimised Low Level IFR routes for rotorcrafts*").

The status of SESAR 1 Solution will allow the community to deploy LLR in Europe as any other SESAR Solutions. Accordingly, this means the R&D activities are achieved and then, no work can be claimed in SESAR 2020.

The following table presents the storyboard of the Maturity Level for the Operational Improvement concerned (AOM-0810).

Operational Improvement	Initial Maturity Level	Simulation Technics	Achieved IT1 MAT LEV	Achieved IT2 MAT LEV	Maturity Level at the end of P04.10	Confirmed potential benefits identified	Notes
AOM-0810 Integration into the TMA route structure of optimised Low Level IFR route network for rotorcraft using RNP-1/RNP-0.3	V1	FTS	V2	-	V3	V2\V3: - Reduced\unaltered workload for ATCO ; - Reduced Pilot Workload - Reduced track mileage - Reduced fuel consumption - Better transition to PinS rotorcraft approaches\ departures to/from heliports (FATOs) and from en-route to terminal route (and viceversa) - More direct routing in dense terminal airspace - Airspace de-confliction of low altitude airways (more slots available on SIDs and STARS)	**All P 4.10 validation activities covered the whole concept. (V3 maturity level)** A major benefits of the implementation of Low Level Routes based on RNP 1, RNP 0.3 criteria is the ability to support reduced en-route obstacle clearance area semi-widths for rotorcraft operations. The benefits come with operations that are classified as RNP1 or RNP 0.3 operations for the en-route phase of flight.
		RTS	V2	V3[3]			
		LT	V2	V3			

Table 7: AOM-0810 (LLR) maturity level P04.10 storyboard

Some specific Human performance outcomes can be summarised as follow:

As reported above, notwithstanding Low Level IFR Routes are considered globally feasible and acceptable by controllers, they provided the following recommendations to completely solve issues encountered during the execution of the trials:

- KY179 fly-ability should be further investigated and regulated. Furthermore when in operation the route should be assigned and then cleared just after tactical evaluation from the controller.
- The introduction of holding procedures on SRN and PINIK could be a good option to solve interferences between rotorcraft flying KY179 and other traffic.
- KY 159-179 flyable simultaneously in both directions.

Some specific Safety outcomes can be summarised as follow:

According to feedbacks provided by ATCOs involved in the Flight trials some recommendations are provided:

- Evaluate the interactions between Milano Malpensa departure procedures and Malpensa PinS approach/Route KY 179 in order to reduce the number of coordination needed between ATS units involved;
- Evaluate a possible update of current phraseology

[3] An additional activity has been conducted in background within P04.10 second iteration validation activities (during the execution of VP-818). This activity (precisely a **RTS** - Real Time Simulation) has been performed linking, via remote locations, two IBPs provided respectively by ENAV (Ground ATCOs IBP) and Leonardo Helicopters (Rotorcraft Cockpit Simulator) in order to assess peculiar contingency events that might occur flying using GNSS technology but that couldn't be addressed in the real ATM environment due to poss ble decrease of the safety level.

3. Future expected implementation benefits

The Outcomes of exercises EXE-04.10-VP-818 and 816, have confirmed the benefits (qualitative and some quantitative) and provided some foreseen assumption for future implementation and research technology activities to be conducted in SESAR2020 such as:

- Integration and validation of RNP 0.3 all phase of flight (as already verified and monitored during Flight Trials EXE-818) and assumption to down lower the RNP. This will increase airspace and airport capacity in some specific environmental operational scenario (i.e: mountainous areas, congested and rich obstacles environment, urban areas..etc), in which more tighter corridors and precise paths are required and applicable.
- Integration of ADS-B IN capabilities in addition to integrated on board data link technologies.
- Integration of future rotorcraft i4D concept with regards RTA (Required Time of Arrival).
- Evaluation of additional contingency procedures may occur in case of GNSS signal loss. Integration/analysis and applicability of AHRS during on board system failure (i.e: activities related to SESAR2020-PJ.13-02-03).

4. P04.10-EXE-VP 818 and 815 - Low Level IFR routes Key elements

The integration of Rotorcraft operations in dense / constrained airspace such as Milan TMA has been evaluated troughs the solution scenario:

Designing and testing specific ATS routes defined as “Low Level IFR Routes RNP1/RNP0.3”, (below standard flight level structure, e.g. 3000 ft) allowing an optimized use of the airspace (more slots available on SIDs and STARs) within Medium dense/complex Terminal Area (Milan TMA).

A Major benefit of RNP1\RNP 0.3 rotorcraft operations is the ability to support reduced en-route obstacle clearance area semi-widths. Additional benefits includes: Airspace de-confliction of low altitude airways, more efficient terminal routing in an obstacle rich or noise sensitive (Milan Area) terminal environment and SNI operations in dense terminal airspace

- Class “A” Low Level IFR Route (KY159) RNP 0.3 (3000 ft for the entire route) between Linate and Malpensa airports
- This kind of route has been designed with RNP 0.3 requirement due to the proximity the procedure itself to the Restricted Area overhead Milano urban centre (R9).
- RF (Radius to Fix) segment to reduce tactical intervention from the controller.
- Class “A” Low Level IFR Route (KY179) RNP 1.0 (between 3000ft and 6000 ft) between Milan Area and Lugano CTR
- This route (which links Malpensa and Lugano airports) together with the KY159 (which links Linate and Malpensa airports) represent the first European example of Low Level IFR routes network specific for rotorcraft airspace users;
- This low level IFR routes network made up KY159 (RNP0.3) and KY179 (RNP1), and specified for rotorcraft, allow to connect in IFR mode several airports located within Milan Area Control Centre with SWISS airspace, specifically with Lugano airport.

Hereafter are graphically presented the solution scenario flown and under controlled ATCO activities with regards EXE-04.10-VP-818 (Live Trial), which gives an idea of operations conducted during the validation activity.

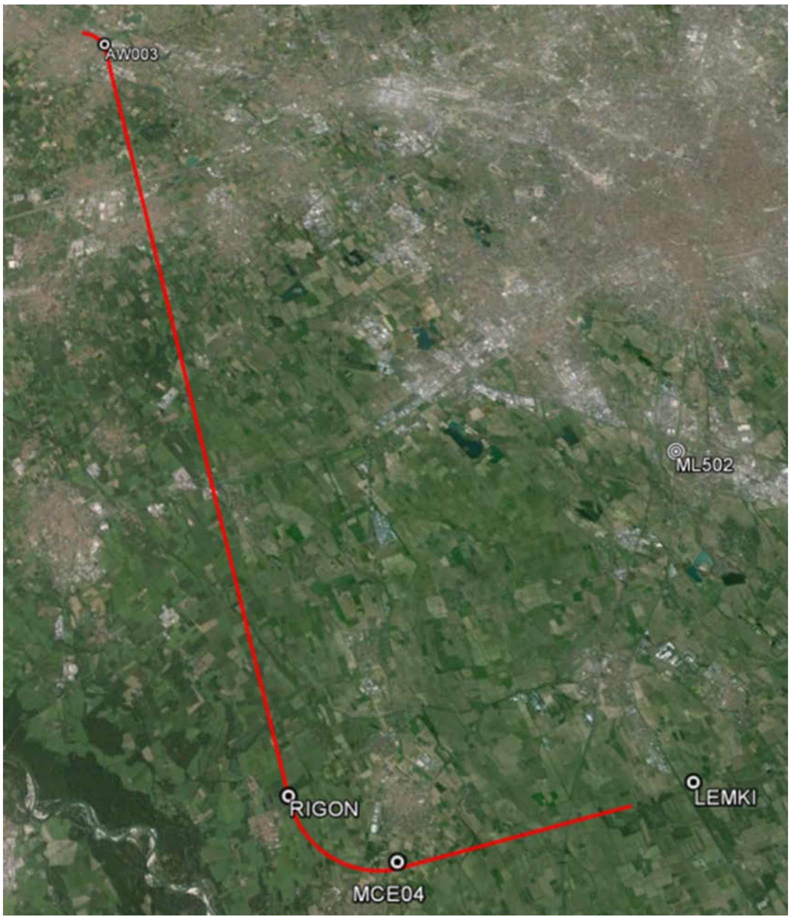
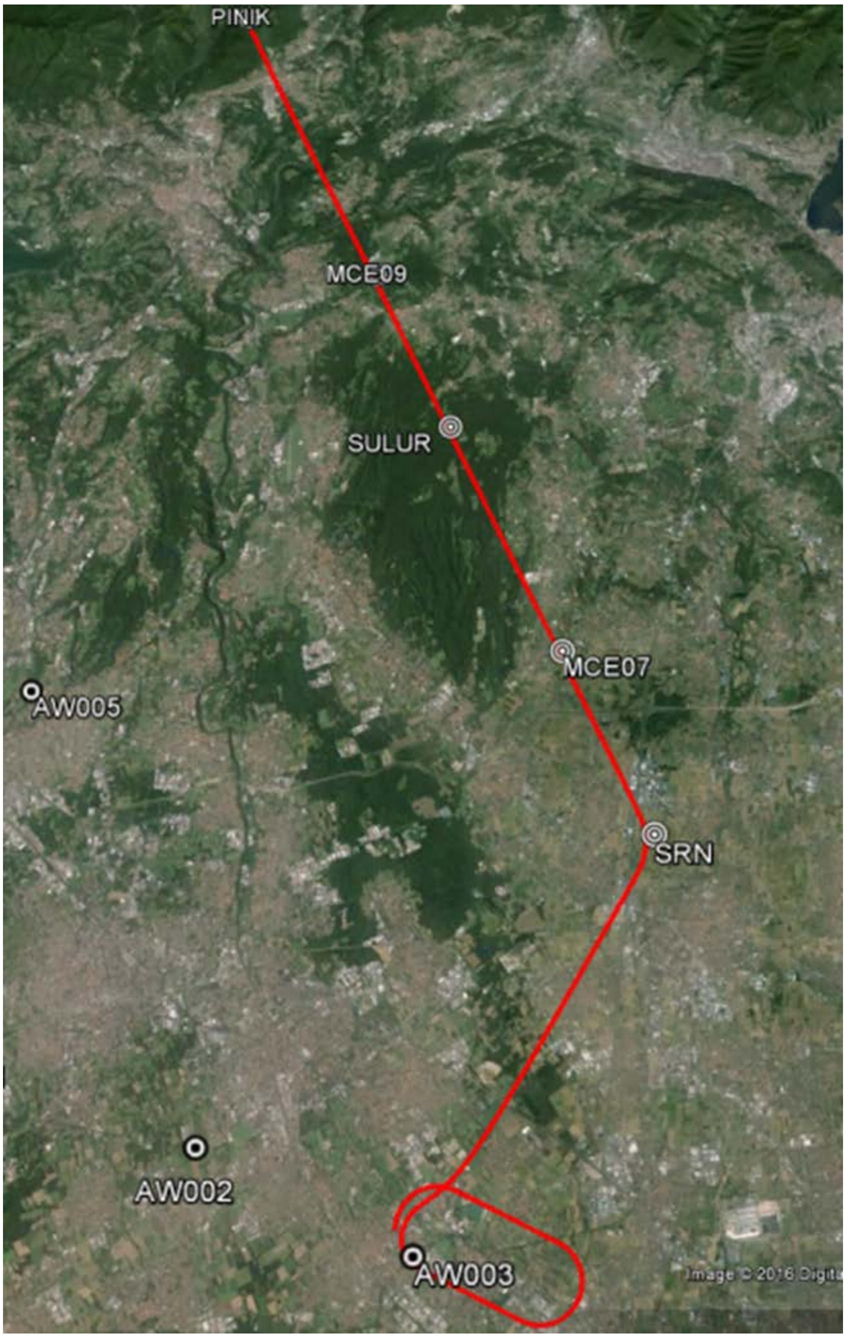


Figure 4: LLR KY159 (LEMKI to AW003), codified as STAR

All the KY 159 route during flight validation activities was flown at 120 Kts 3000 feet: All the legs were flown with a cross track error (XTE) not appreciable on the display because <0.01Nm.

1297 

1298 Figure 5: LLR KY179 (AW003 to PINIK),

1299 KY179 was executed in ALT_IAS_NAV mode (ALTA mode during climb) at 140 Kts using the MCP
1300 power setting. During climb the ROC was automatically set at 1000 fpm.
1301 The XTE also during this phase was not appreciable on the display because near to 0.00 Nm.

KY179 has been flown in opposite direction, back from PINIK, and was verified the seamless transition to the approach phases:

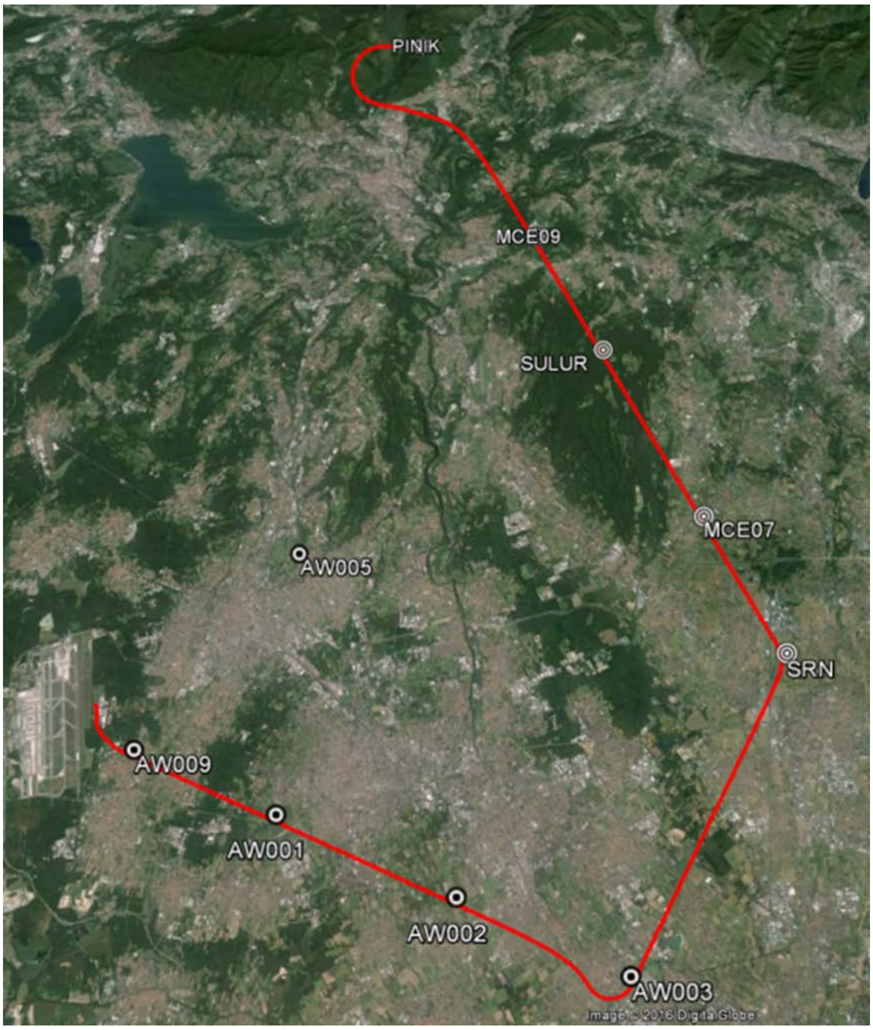


Figure 6: LLR KY179 (PINIK to Helipad),

During this phase the AFCS system was engaged in ALT-IAS-NAV mode.
The descend was executed at step using ALTA mode. The descend was delayed respect to the TOD point calculate by FMS due to ATC clearance, and when cleared the IVSI was increase and hold to maximum for ALTA mode (-1500 fpm) in order to reach SRN waypoint at 3000 feet. The approach to LIMC(H) was executed as for the previous test, and helicopter land on AW helipad.

7 References

7.1 Applicable Documents

[1] Template Toolbox 03.00.00 https://extranet.sesarju.eu/Programme%20Library/SESAR%20Template%20Toolbox.dot

[2] Requirements and V&V Guidelines 03.00.00 https://extranet.sesarju.eu/Programme%20Library/Requirements%20and%20VV%20Guidelines.doc

[3] Templates and Toolbox User Manual 03.00.00 https://extranet.sesarju.eu/Programme%20Library/Templates%20and%20Toolbox%20User%20Manual.doc

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

[5] EUROCONTROL ATM Lexicon https://extranet.eurocontrol.int/http://atmlexicon.eurocontrol.int/en/index.php/SESAR

7.2 Reference Documents

The following documents provide input/guidance/further information/other:

[6] WP C.03, C.03-D03-Regulatory Roadmap Development and Maintenance Process https://extranet.sesarju.eu/Programme%20Library/Forms/General.aspx

[7] WP C.03, C.03-D02-Standardisation Roadmap Development and Maintenance Process https://extranet.sesarju.eu/Programme%20Library/Forms/General.aspx

[8] SESAR Business Case Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[9] SESAR Safety Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[10] SESAR Security Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[11] SESAR Environment Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

[12] SESAR Human Performance Reference Material https://extranet.sesarju.eu/Programme%20Library/Forms/Procedures%20and%20Guidelines.aspx

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