V3 SPR

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Abstract

This Safety and Performance Requirements (SPR) document addresses the safety and performance requirements for the ADV-APV (Advanced Approach Procedures with Vertical Guidance) procedures in project 05.06.03. This version expands on the safety and performance work previously conducted within the scope of 05.06.03 with a focus on the details of safety and performance requirements for the initial approach segment.

The SPR also provides their allocation to Functional Blocks. They shall identify the requirements needed to fulfil each KPA and include, or reference, the sources justifying those requirements.

Performance requirements considered in this document shall apply to Services in the scope of the Operational Focus Area (02.01.01) addressed by the OSED.

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Executive summary

This is the 05.06.03 V3 SPR. It addresses ADV-APV (Advanced Approach Procedures with Vertical Guidance) safety and performance requirements for the Operational Concept elements that are specified in the 05.06.03 OSED [5].

The purpose of project 05.06.03 is to develop approach procedures with vertical guidance (APV). The basic “brick” is the APV-SBAS approach nowadays widely published (especially in the US but Europe increasing its publication). The ADV-APV concept includes in addition other navigation and approach operations and techniques that have recently been highlighted in the context of reduced environmental impact: CDO “Continuous Descent Operations” (or CDA), RF (Radius to fix) legs, and RNAV/RNP navigation.

The safety requirements section focusses on functionality and performance safety requirements identified through thorough analysis of the OFA SPR-level model of the ADV-APV concept. The performance related requirements detailed in the OSED 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 RNP APCH Navigation Specification detailed in AMC-20-27 and AMC-20-28 (LPV) are envisaged.

1 Introduction

1.1 Purpose of the document

This Safety and Performance Requirements (SPR) document provides the safety and performance requirements for Services related to the operational Processes defined V3 of the Advanced APV OSED [5]. The SPR also provides their allocation to Functional Blocks. They shall identify the requirements needed to fulfil each KPA and include, or reference, the sources justifying those requirements.

1.2 Scope

This document supports the operational services and concept elements identified in the Operational Service and Environment Definition (OSED) [5]. These services are expected to be operational (IOC) in the 2017-2020 timeframe.

This SPR relates to the operation concept for the OFA 02.01.01 for Advanced Approach Procedures with Vertical Guidance. This is developed in the OSED as initial and intermediate approach segments utilising A-RNP or RNP APCH with turns constructed with RF legs for lateral navigation in addition to continuous descent operations.

This version of the document is a final consolidated version. The concept which is assessed has been defined, developed, validated and approved.

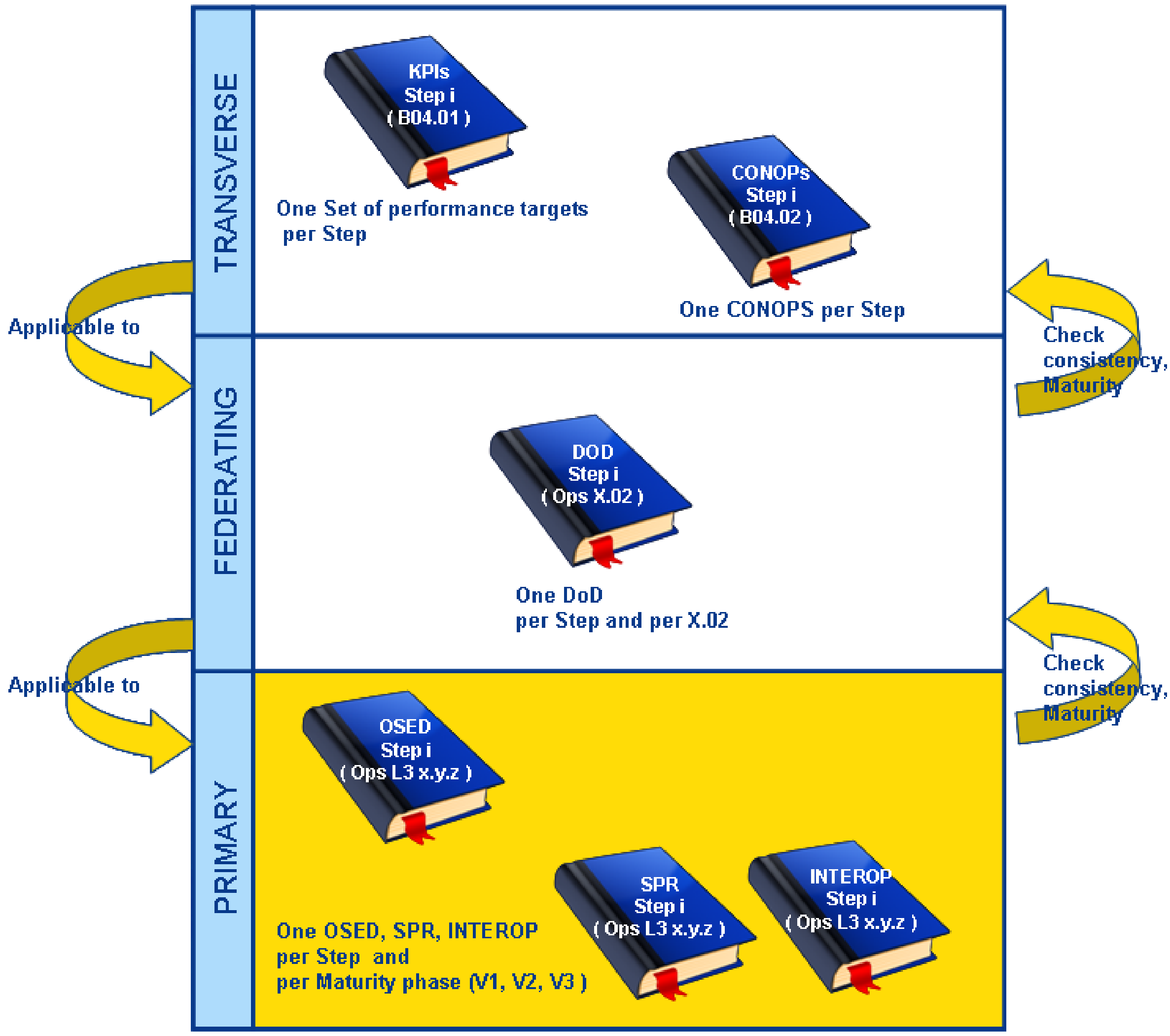


Figure 1: SPR document with regards to other SESAR deliverables

In Figure 1, the Steps are driven by the OI Steps addressed by the project in the Integrated Roadmap document [21].

1.3 Intended readership

The intended audience inside SESAR is: P9.9, P9.10, SWP5.2, SWP5.6, WP5, 16.06.01, 16.06.02 and the different partners of Project 05.06.03. Also Projects 06.08.05 and 06.08.08 because addressing also OIs AOM-0605.

It will be of interest for Air Navigation Service Providers who will in the future intend to implement in their operational environments the advanced procedure selected by 05.06.03. It will also be of interest to data base suppliers, aircraft operators, flight crew, air traffic controllers and aircraft manufacturers intending to work with such type of procedures.

This version is also specifically intended to be part of final V3 release of the project.

1.4 Structure of the document

The document is structured in accordance with the SESAR SPR template, and developed using the SESAR toolbox template [1].

The operational concept is summarized in chapter 2, based on the descriptions provided in the 05.06.03 OSED [5].

Safety and Performance Requirements are listed in chapter 3, per Operational Scenario as specified in the 05.06.03 OSED [5].

Appendix A.1.1 present the safety assessments performed and justifications derived for the safety requirements listed in chapter 3.

1.5 Background

The Operational Focus Area (OFA) 02.01.01 Optimised 2D/3D Routes consists of the following projects:

- 05.06.03: Approach Procedure with Vertical Guidance (APV)
- 09.09: RNP Transition to xLS (x=G, I or M)
- 09.10: Approach with Vertical Guidance APV

Project 05.06.03 is the operational project within the OFA, and is tasked to develop the OSED for the OFA and develop the safety assessment. The OSED has been developed to V3 maturity level and this edition of the SPR is also developed to V3 maturity.

This document is intended to be read in conjunction with the 05.06.03 SAR [6], which contains more detail as to the background information of this project, and specifically the safety assessment through which many of the requirements were derived. For the purposes of aiding the reader, some of the background information is replicated below.

1.5.1 The two phases of project 5.6.3

Project 5.6.3 is divided into two phases:

1. LPV
2. Advanced LPV (ADV-APV)

In the first phase a Safety Assessment was conducted for the standard LPV, and where the scope was defined as:

The scope in terms of flight phases is defined in the APV-SBAS Safety Assessment Report (SAR), to cover an APV procedure from the acquisition of the Final approach path, until DA/DH or in the case of a missed approach it include the initial/intermediate part of the missed approach, as illustrated in figure 1. This is consistent with PANS-OPS definition of APV that states: *"The APV segment includes the final approach, the initial and the intermediate phases of the missed approach Segment"* (PANS-OPS, Vol II, Part III, Section 3, Chapter 5.1.1)

The Local Safety Assessments have the same scope as the SAR.

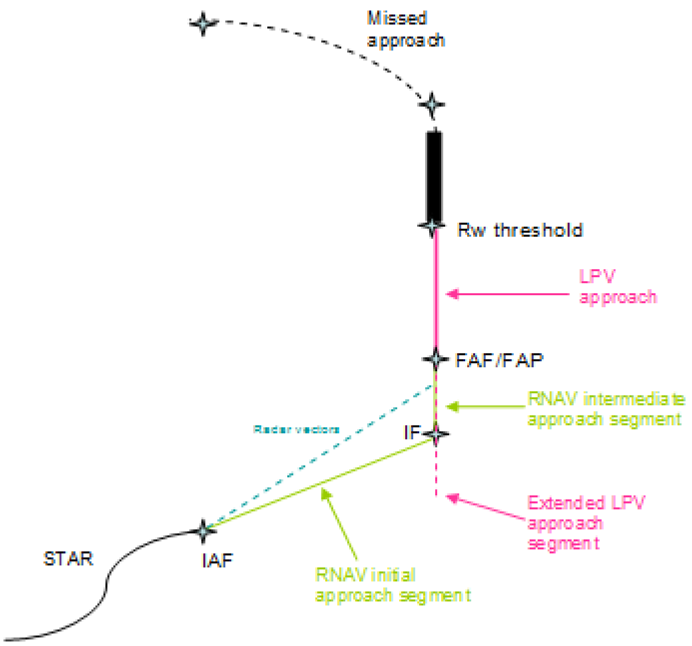
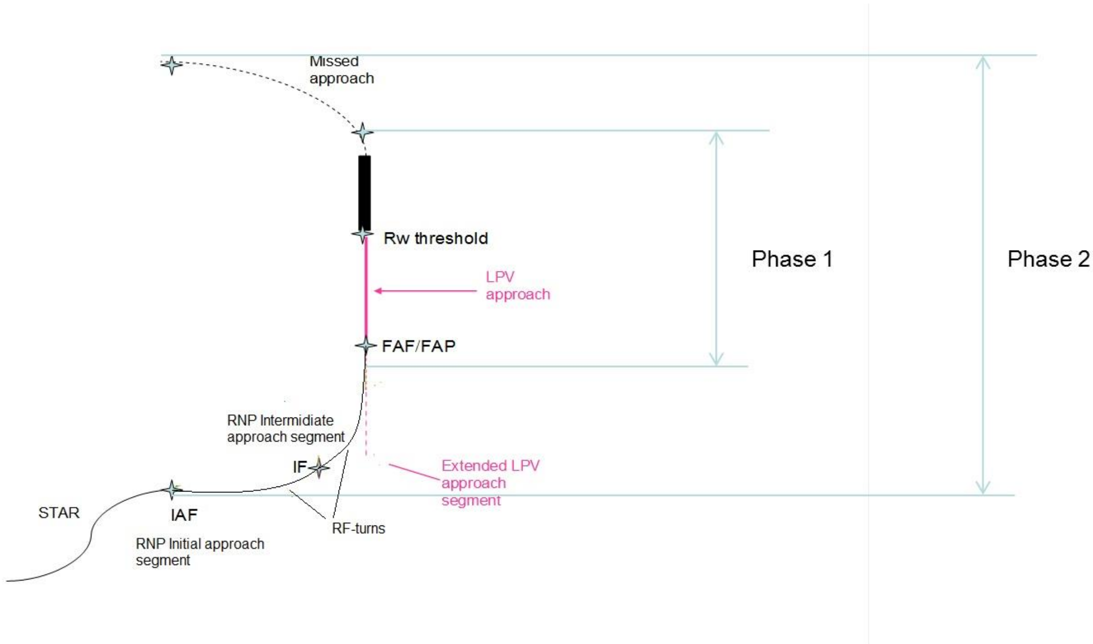


Figure 1: Interception of the LPV approach

This scope also corresponds with the scope of AMC 20-28 for APV-SBAS, stating (chapter 7): *"Functional criteria provided in this paragraph are those applicable to the LPV approach operation only. These criteria are therefore limited to the LPV*

Project Phase 1 scope as documented in the LPV Safety cases report

In the 2nd phase (ADV-APV) of the project, the scope has been extended to cover navigation and flight procedure from Initial Approach fix, and until the completion of the missed approach segment. The increase in the flight phase scope between Phase 1 and Phase 2 can be illustrated as follows:



The Phase 2 of the ADV-APV including RF-turn

1.5.2 The changes between Phase 1 and Phase 2 (LPV and ADV-APV)

The changes within the **previous** LPV scope are:

- LPV requires a straight intermediate segment to FAP, whereas ADV-APV will allow the use of a Radius to Fix (RF) turn to the FAP. (a change since SO#1 in LPV SAR may be affected)
- LPV procedure design require a level/flat portion of the intermediate segment to intercept the “glide path”, while ADV will be designed without a level part in the intermediate segment (either a straight segment or a RF turn) (a change since SO#3 in LPV SAR may be affected)

The change within the **new** added ADV-APV scope is:

- The introduction of Radius to Fix (RF) turns in segments from IAF to FAP, and in the final missed approach segment. The following figure from the ADV-APV OSED illustrate the concept with the following figure:

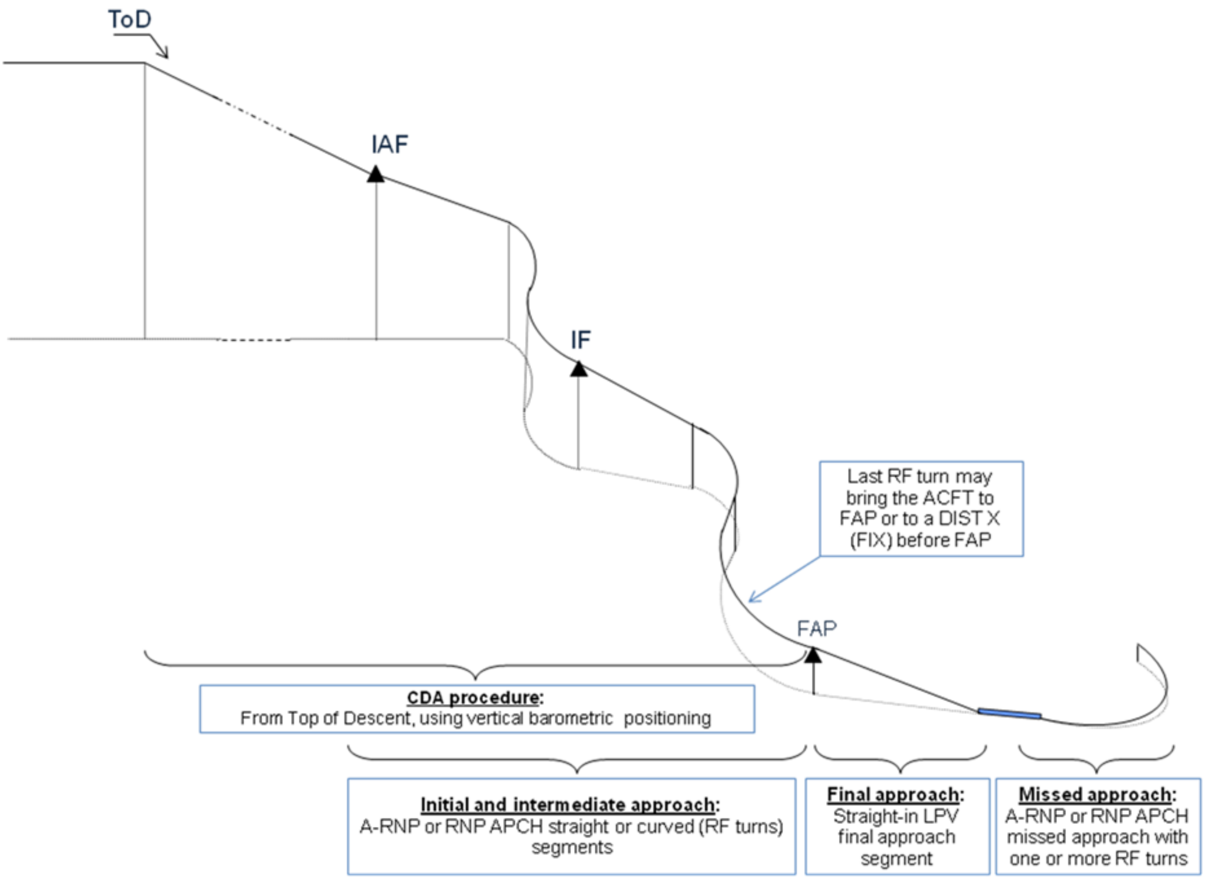


Figure 2: Illustration of the Advanced APV concept

1.6 Glossary of terms

Most of the definitions of the following terms are included in the ICAO PBN Manual **Error! Reference source not found.** or PANS OPS [23] or ICAO Annex 10 [25], but they are included here to help the reader:

ABAS - Aircraft-based augmentation system. An augmentation system that augments and/or integrates the information obtained from the other GNSS elements with information available on board the aircraft. (ICAO Annex 10). RAIM is a form of ABAS.

Advanced RNP (**A-RNP**) – A navigation specification not associated with a specific type of application; instead it provides for a single assessment of aircraft eligibility that will apply to more than one navigation accuracy requirement and multiple applications across all phases of flight. The A-RNP addresses in particular the RNP APCH specifications, requires the RF functionality and is intended to be applicable for other navigation accuracy requirements of less than 1 NM in terminal airspace applications. (PBN).

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.

Area navigation – A method of navigation which permits aircraft operation on any desired flight path within the coverage of ground or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these. (PBN).

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).

Basic GNSS – Refers to core constellation augmented by ABAS. The term “Basic GNSS receiver” designates the GNSS avionics that at least meet the requirements for a GPS receiver as outlined in Annex 10, Volume I, and the specifications of RTCA/DO-208 or EUROCAE ED-72A, as amended by United States Federal Aviation Administration FAA TSO-C129A or European Aviation Safety Agency ETSO-C129A (or equivalent). (PANS OPS).

CDA/CDO - Continuous Descent Approach (CDA), or Continuous Descent Operation (CDO), is an aircraft operating technique in which during the descent, an aircraft reduces engine thrust and avoids level flight to the extent permitted, thereby reducing fuel burn and emissions.

CDFA – 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).

CRC – Cyclic Redundancy Check

DA/H – Decision Altitude/Height – Used in Precision and APV Approaches.

EGNOS – The European Geostationary Navigation Overlay Service. This is the European Satellite Based Augmentation System (SBAS).

EGNOS SoL – The EGNOS Safety of Life Service is the Service offered to aviation users as described in the EGNOS Sol Service Definition Document issued by the European Commission.

ESSP – European Satellite Services Provider is the EGNOS operator and Navigation Service Provider certified according to the SES regulation as an ANSP.

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.

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)

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).

GPS NPA – An RNP APCH flown to LNAV minima. The term is also used in the ICAO classification of approaches.

LNAV, LNAV/VNAV, LPV and LP – 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 – **Lateral Navigation** – The minima line on the chart for RNP Approaches without vertical guidance.

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.

LP Approach Procedures – At some airports, it may not be possible to meet the requirements to publish an approach procedure with LPV vertical guidance. This may be due to: obstacles and terrain along the desired final approach path, airport infrastructure deficiencies, or the inability of SBAS to provide the desired availability of vertical guidance (i.e., an airport located on the fringe of the SBAS service area). When this occurs, a State may provide an LP approach procedure based on the lateral performance of SBAS. The LP approach procedure is a non-precision approach procedure with angular lateral guidance equivalent to a localizer approach. As a non-precision approach, an LP approach procedure provides lateral navigation guidance to a minimum descent altitude (MDA); however, the SBAS integration provides no vertical guidance. (Definition from ICAO PBN Manual)

MDA/H – Minimum Descent Altitude/Height, used in a Non-precision Approach when not flown using the CDFA technique.

Navigation specification – A set of aircraft and aircrew requirements needed to support Performance-based Navigation operations within a defined airspace. There are two kinds of navigation specification:

- RNAV specification. A navigation specification based on area navigation that does not include the requirement for on-board performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

- RNP specification. A navigation specification based on area navigation that includes the requirement for on-board performance monitoring and alerting, designated by the prefix RNP, e.g. RNP 4, RNP APCH.

For both RNP and RNAV designations, the expression “X” (where stated, e.g. RNP 1) refers to the lateral navigation accuracy (total system error) in nautical miles, which is expected to be achieved in at least 95 per cent of the flight time by the population of aircraft operating within the airspace, route or procedure.

NPA – **Non-Precision Approach**

PBN – **Performance-Based Navigation** – Area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace. (PBN).The PBN concept specifies Navigation Specifications in terms of navigation system performance accuracy, integrity and continuity along with the functionality required on-board an aircraft for the proposed operations.

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 $RNAV_{(GNSS)}$ approach chart.

RNP AR APCH – An approach which always requires a specific operational approval (SPA). Such procedures are useful in particular environments rich in obstacles and dense terminal areas.

RNAV – Area Navigation. A PBN navigation specification based on area navigation that does not include the requirement for on-board performance monitoring and alerting.

RNP – Required Navigation Performance. A PBN navigation specification based on area navigation that includes the requirement for on-board performance monitoring and alerting.

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.

SPA – Specific operational approval required by EU-OPS, EASA-OPS or State rules on air operations for certain types of instrument navigation operations.

Stabilised approach – minimum operational criteria's' such as aircraft configuration, aircraft speed, lateral and vertical positioning etc., for the flight crews to continue the approach.

VNAV – Vertical Navigation.

1.7 Acronyms and Terminology

Term	Definition
AC	Advisory Circular
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
APCH	Approach
APV	Approach Procedure with Vertical guidance
A-RNP	Advanced RNP
ATC	Air Traffic Control
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
CDA	Continuous Descent Approach
CDFA	Continuous Descent Final Approach
CDO	Continuous Descent Operation

Term	Definition
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
EU-OPS	This refers to European Union (EU) regulations specifying minimum safety and related procedures for commercial passenger and cargo fixed-wing aviation
EUROCAE	European Organization for Civil Aviation Equipment (a non-profit making organization for resolving technical problems with electronic equipment for air transport).
FAF	Final Approach Fix
FAP	Final Approach Point
FAS	Final Approach Segment
GAGAN	GPS Aided Geo Augmented Navigation
GLS	GNSS Landing System
GPS	Global Positioning System
GNSS	Global Navigation Satellite System
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
INTEROP	Interoperability Requirements
LNAV	Lateral Navigation
LP	Localizer Performance
LPV	Localizer Performance with Vertical guidance
MSAS	Multi-functional Satellite Augmentation System
NOTAM	Notice To AirMen
NPA	Non Precision Approach
OFA	Operational Focus Areas

Term	Definition
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
RNP AR	Required Navigation Performance Authorization Required
RTCA	RTCA - Radio Technical Commission for Aeronautics (a US volunteer organization that develops technical guidance for use by government regulatory authorities and by industry).
RVR	Runway Visual Range
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)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SPR	Safety and Performance Requirements
TSO	Technical Standard Order
VNAV	Vertical Navigation
WAAS	Wide Area Augmentation System
xLS	ILS, MLS, GLS

2 Summary of Operational Concept (from OSED)

2.1 Description of the Concept Element

The purpose of project 05.06.03 is to develop approach procedures with vertical guidance (APV). The basic “brick” is the APV-SBAS approach nowadays widely published (especially in the US but Europe increasing their publication). Moreover, other navigation and approach operations and techniques have recently been highlighted in the context of reduced environmental impact: CDO “Continuous Descent Operations” (or CDA), RF (Radius to fix) legs, and RNAV/RNP navigation. The advanced operational concept developed presented in the OSED aims to combine these operations and techniques.

This SPR focusses on the requirements for the Initial and Intermediate approach segments of the Advanced APV concept described below. For details of ADV-APV Final Approach and Missed Approach segments, please refer to the OSED [5] for a description.

- **Initial and Intermediate approach segments:**
  - A-RNP or RNP APCH (RNP values from 1 down to 0.3) with turns constructed with RF legs for lateral navigation in preference to fly-by or fly-over waypoints, and, when suitable, with an RF leg joined directly with the start of the final approach segment.
  - CDA for the vertical profile with barometric vertical reference.

2.2 Description of Operational Services

The following Operational Processes are applicable to this project. This includes:

- Monitoring Traffic (ADV-APV approaches and those using different procedures, de-conflict with arrivals)
- Separate Traffic (approach)
- Merge Traffic (approach)

Please refer to the OSED [5] for a detailed description.

2.3 Description of Operational Environment

In the context of ADV-APV the operational environment is complex and considers the following items:

- Airspace Structure and Boundaries (Approach procedure should allow for CDA)
- Traffic Levels and Complexity (High traffic levels and types of aircraft)
- Environmental Conditions (Weather, terrain features and obstacles)

For further details of the operational environment and its key properties please refer to the OSED [5] for a detailed description.

3 Requirements

3.1 Operational Service SVC-05.06.03-OSED-Execute Trajectory

3.1.1 Safety Requirements

3.1.1.1 Functionality and Performance Safety Requirements

Identifier	REQ-05.06.03-SPR-ALPV.0010
Requirement	The NAV Service provider shall provide to AIS Provider a list of aerodromes capable for ADV-APV approach operations, based upon information provided by the SBAS service provider as to which aerodromes will be supported by the required SBAS performance.

Identifier	REQ-05.06.03-SPR-ALPV.0020
Requirement	Terrain, obstacle and survey aerodrome data used in the design of the flight procedure for the required accuracy and integrity of ADV-APV operations shall be provided by the Aerodrome to the AIS Provider in compliance with the data quality requirements of ICAO Annex 14, ICAO Annex 15 and ICAO Doc 9906 and EU Reg 73/2010.

Identifier	REQ-05.06.03-SPR-ALPV.0030
Requirement	Survey terrain, aerodrome, obstacle and profile data used in the design of the flight procedure for the required accuracy and integrity of ADV-APV operations shall be provided by the Mapping Authority to the AIS Provider in compliance with the aeronautical data/information quality requirements of EU Reg 73/2010 and ICAO Doc 9906.

Identifier	REQ-05.06.03-SPR-ALPV.0040
Requirement	Runway, terrain and obstacle data for the location where ADV-APV operations will be operated shall be provided by the AIS Provider to procedure designer in compliance with the aeronautical data/information quality requirements of EU Reg 73/2010, ICAO Annex 15 and ICAO Doc 9906.

Identifier	REQ-05.06.03-SPR-ALPV.0050
Requirement	The ADV-APV approach procedure and chart design and definition of the FAS data block shall be provided by the procedure designer to the AIS provider in compliance with the data quality requirements of ICAO Doc 8168 volume II, ICAO Doc 9613 (PBN Manual), APV-SBAS criteria and ICAO Doc 9906.

Identifier	REQ-05.06.03-SPR-ALPV.0060
Requirement	The ADV-APV procedure shall be published in the Aeronautical Information Publication (AIP) and distributed between the AIS Provider and Air Operator/NAV Database supplier (integrator and packer)/ATS and between Air Operator and Aircraft/Flight Crew in compliance with the aeronautical data quality requirements of ICAO Annex 15, EU Reg 73/2010, and ED-76.

Identifier	REQ-05.06.03-SPR-ALPV.0070
Requirement	The Final Approach Segment Data Block description (including the CRC) shall be provided by the procedure designer for procedure validation in

	compliance with the aeronautical data quality requirements of ICAO Annex 10, ICAO Doc 8168 volume II, ICAO Doc 9613 (PBN Manual) and EU Reg 73/2010.

Identifier	REQ-05.06.03-SPR-ALPV.0080
Requirement	The NAV Database supplier (integrator and packer) shall provide the navigation data (including the FAS Data Block and necessary waypoints) supporting the ADV-APV procedure in a correct format for the loading on the airborne system via the Air Operator in conformance as a minimum with the requirements of EASA AMC 20-27, AIR-OPS and EASA LOA type 1 and 2.

Identifier	REQ-05.06.03-SPR-ALPV.0090
Requirement	The NAV Database supplier (integrator and packer) shall adapt the validated ADV-APV procedure from the AIP into approach charts and maps to the needs and procedures of the flight crew, including combined RNP 0.3/1NM segments, RF legs to FAP, CDA, missed approach with RF legs and distribute to the Air Operator via EASA LOA.

Identifier	REQ-05.06.03-SPR-ALPV.0100
Requirement	The Air Operator shall provide the ADV-APV procedure approach charts and maps to the flight crew, including clear RNP 0.3/1NM segments, RF legs to FAP, CDA, missed approach with RF legs, in compliance with EU-OPS and ICAO Annex 6.

Identifier	REQ-05.06.03-SPR-ALPV.0110
Requirement	In accordance with ICAO Annex 11 and PANS-ATM, to perform tactical vectoring for approach interception as necessary, the ATC shall have the capability to monitor the aircraft trajectory, i.e. that the aircraft complies with the published procedure.

Identifier	REQ-05.06.03-SPR-ALPV.0120
Requirement	The NAV data of the ADV-APV path to be flown (including any lat/vert deviations from the published path and status of LPV approach capability) shall be derived from the NAV database system and transmitted to the aircraft's Display and Auto flight system based on compliance and certification with EASA AMC 20-27.

Identifier	REQ-05.06.03-SPR-ALPV.0130
Requirement	Flight crew shall select the ADV-APV arrival/approach procedure to be flown, corresponding to the selected runway end, from the aircraft's Flight Management System (the procedure being extracted from the NAV database system), including transition from RNP (with or without VNAV) to LPV guidance mode, based on compliance and certification with EASA AMC 20-27 and 20-28.

Identifier	REQ-05.06.03-SPR-ALPV.0140
Requirement	The ADV-APV operations data from the NAV database system shall be displayed to the flight crew, including degraded modes, in accordance with the published procedure (they are RNAV flight path and associated data – e.g. constraints…-, timely display, combined RNP 0.3/1NM segments, RF legs to FAP, change from the RNP segment to the LPV segment, missed approach and LPV approach data –e.g. ident, channel…) based on compliance and certification with EASA AMC 20-27 and AMC 20-28.

Identifier	REQ-05.06.03-SPR-ALPV.0150
Requirement	The flight crew shall be able to select the AFS mode, i.e. either the Autopilot and/or the Flight Director based on compliance with EASA AMC 20-27 and

	AMC 20-28, including automatic transition from RNP (with or without VNAV) to LPV guidance mode.

Identifier	REQ-05.06.03-SPR-ALPV.0160
Requirement	In compliance with EASA AMC 20-27, it shall be possible for the aircraft to continue providing navigation (including speed, altitude, heading, vertical speed) through conventional navigation systems in the event of loss of GNSS.

Identifier	REQ-05.06.03-SPR-ALPV.0170
Requirement	ATS (APP controller for controlled aerodrome or ACC controller for uncontrolled aerodrome) shall provide the Flight Crew with the ATC Descent and Approach clearance before or at the Initial Approach fix in accordance with ICAO Annex 11 and PANS-ATM.

Identifier	REQ-05.06.03-SPR-ALPV.0180
Requirement	Flight crew shall receive QNH/Altimeter setting from the ATIS or ATC for the ADV-APV approach in accordance with ICAO Annex 11 and PANS-ATM and acknowledge to ATS when transitioning below transition altitude.

Identifier	REQ-05.06.03-SPR-ALPV.0190
Requirement	Flight crew shall receive aerodrome visibility and temperature information from the ATIS or ATC for the ADV-APV approach in accordance with ICAO Annex 11 and PANS-ATM.

Identifier	REQ-05.06.03-SPR-ALPV.0200
Requirement	In accordance with ICAO Annex 11 and PANS-ATM, information, tactical clearance and instructions (vectoring/heading, altitude, speed constraints) shall be provided by ATS and monitored for compliance as necessary.

Identifier	REQ-05.06.03-SPR-ALPV.0210
Requirement	On receipt from ATIS or ATC, Flight Crew shall input QNH/Altimeter setting into the aircraft's ALT system, in compliance with EU OPS and EASA AMC 20-27.

Identifier	REQ-05.06.03-SPR-ALPV.0220
Requirement	The ALT system shall indicate to the Flight Crew (to assist DA/H action) the barometric altitude during the ADV LPV approach based on compliance with EASA AMC 20-28.

Identifier	REQ-05.06.03-SPR-ALPV.0230
Requirement	The Flight Plan content, including ADV-APV details of the accepted flight plan, shall be provided to ATS by Flight Data Processing in compliance with ICAO Annex 11, ICAO PANS-ATM and ICAO Doc 7030 EUR.

Identifier	REQ-05.06.03-SPR-ALPV.0240
Requirement	Flight crew shall read back all ATC clearances and instructions (heading and/or speed), QNH/altimeter settings, in compliance with ICAO Annex 11 and PANS-ATM.

Identifier	REQ-05.06.03-SPR-ALPV.0250
Requirement	Aircraft's NAV system shall receive aircraft positioning GPS signals in space from the GPS Service Provider in compliance with ICAO Annex 10 vol I chapter 3.7.3.1.

Identifier	REQ-05.06.03-SPR-ALPV.0260
Requirement	Aircraft's NAV system shall receive aircraft positioning SBAS signals in space from the SBAS Service Provider in compliance with ICAO Annex 10

	vol I chapter 3.7.3.1.

Identifier	REQ-05.06.03-SPR-ALPV.0270
Requirement	ADV-APV approach validation report shall demonstrate that the designed procedure (including missed approach) is fly-able, ensuring stabilised approach and captured glideslope from a continuous descent approach (including avoidance of unexpected early capture of the LPV Final Approach Segment) for the aircraft classes that will utilise the procedure for a range of temperatures in compliance with ICAO PANS-OPS Doc 8168 volume II APV-SBAS criteria, ICAO Doc 9906, ICAO Doc 9613 (PBN Manual) and ICAO Doc 8071 Vol II.

Identifier	REQ-05.06.03-SPR-ALPV.0280
Requirement	Air Operator shall provide necessary flight information to ATS flight data processing, confirming ADV-APV ability (equipment and training) and appropriate segment capture through compliance with EASA AMC 20-27, ICAO PANS ATM and ICAO Doc 7030 EUR.

Identifier	REQ-05.06.03-SPR-ALPV.0290
Requirement	Flight data processing shall indicate to the Air Operator if the flight plan is approved or rejected in compliance with ICAO PANS-ATM and ICAO Doc 7030 EUR.

Identifier	REQ-05.06.03-SPR-ALPV.0300
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.

Identifier	REQ-05.06.03-SPR-ALPV.0310
Requirement	AIS Service Provider shall inform the Air Operator and ATS on a foreseen degradation of the SBAS system performance impacting ADV-APV approach by providing a NOTAM in accordance with ICAO Annex 15.

Identifier	REQ-05.06.03-SPR-ALPV.0320
Requirement	Air Operator shall inform Flight Crew on a foreseen degradation of the SBAS system performance impacting ADV-APV approach by forwarding NOTAM in accordance with ICAO Annex 15.

Identifier	REQ-05.06.03-SPR-ALPV.0330
Requirement	Flight crew shall indicate to ATS the preferred approach procedure when this is different to the default procedure at the aerodrome, in compliance with ICAO Annex 11 and PANS-ATM.

Identifier	REQ-05.06.03-SPR-ALPV.0340
Requirement	The Final Approach Segment Data Block description (including the CRC) shall be provided by the AIS Provider for navigation database coding in compliance with the aeronautical data quality requirements of ICAO Annex 10, ICAO Doc 9613 (PBN Manual) and ICAO Doc 8168 volume II

Identifier	REQ-05.06.03-SPR-ALPV.0350
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).

3.1.1.2 Additional Safety Requirements – Abnormal Operational Conditions

Identifier	REQ-05.06.03-SPR-ALPV.1360
Requirement	In compliance with ICAO Annex 14, Flight Crew shall be provided with sufficient runway visual information and lighting for a landing at the DA/H and with the minimum RVR.

Identifier	REQ-05.06.03-SPR-ALPV.1370
Requirement	In the event of loss of GNSS signals the navigation system shall not attempt to execute a missed approach procedure incorporating RF legs. If the procedure specifically implements an RF turn to meet requirements for terrain separation, then any aircraft flying the procedure shall be equipped with additional navigation capabilities (for example inertial) to complete the missed approach in absence of GNSS signals.

Identifier	REQ-05.06.03-SPR-ALPV.1380
Requirement	In the event of loss of GNSS signals known prior to the procedure, the procedure shall not be attempted

Identifier	REQ-05.06.03-SPR-ALPV.1390
Requirement	In the event the temperature is below the designated ICAO chart minimum, the operator shall be informed that the procedure may not be undertaken (e.g. via NOTAM) and the ADV-APV procedure shall not be executed.

3.1.1.3 Formalisation of mitigations identified during failure case analysis

Identifier	REQ-05.06.03-SPR-ALPV.2390
Requirement	The flight crew shall check that their trajectory remains free of conflict with terrain before undertaking a vector or direct-to during an ADV-APV procedure.

Identifier	REQ-05.06.03-SPR-ALPV.2400
Requirement	Both members of the flight crew shall ensure that an adjusted trajectory is correct in the event of a manual adjustment after the approach has been selected.

Identifier	REQ-05.06.03-SPR-ALPV.2410
Requirement	Both members of the flight crew shall ensure that the correct approach has been selected before undertaking the ADV-APV procedure.

Identifier	REQ-05.06.03-SPR-ALPV.2420
Requirement	Both members of the flight crew shall check that the ADV LPV procedure data in the FPLN match those of the published chart.

Identifier	REQ-05.06.03-SPR-ALPV.2430
Requirement	An ATC cross check shall be performed prior to issuing a vector or direct-to for an aircraft undertaking an ADV-APV procedure.

Identifier	REQ-05.06.03-SPR-ALPV.2440
Requirement	As per EASA AMC 20-27, ATCOs shall receive training specifically on the nature of the procedure and relationship with traffic.

3.1.1.4 Safety integrity requirements

Identifier	REQ-05.06.03-SPR-ALPV.3450
Requirement	The probability of aircraft nav system providing a wrong position estimation shall be no greater than $1x10^{-8}$ per flight.

Identifier	REQ-05.06.03-SPR-ALPV.3460
Requirement	The probability of aircraft nav system providing a wrong guidance instruction shall be no greater than $1x10^{-8}$ per flight.

Identifier	REQ-05.06.03-SPR-ALPV.3470
Requirement	The probability of a database loading error on the aircraft nav systems shall be no greater than $1x10^{-10}$ per flight.

Identifier	REQ-05.06.03-SPR-ALPV.0480
Requirement	The probability of a survey error in the procedure design shall be no greater than $1x10^{-9}$ per flight.

Identifier	REQ-05.06.03-SPR-ALPV.3490
Requirement	The probability of a procedure validation error shall be no greater than $1x10^{-5}$ per flight.

Identifier	REQ-05.06.03-SPR-ALPV.3500
Requirement	The probability of the procedure design being unsuitable for environment or aircraft type shall be no greater than $1x10^{-5}$ per flight.

Identifier	REQ-05.06.03-SPR-ALPV.3510
Requirement	The probability of the procedure design not being compliant with ICAO requirements shall be no greater than $1x10^{-5}$ per flight.

Identifier	REQ-05.06.03-SPR-ALPV.3520
Requirement	The probability of an AIP publication error shall be no greater than $1x10^{-5}$ per flight.

Identifier	REQ-05.06.03-SPR-ALPV.3530
Requirement	The probability of an LoA Type 1 or Type 2 error shall be no greater than $1x10^{-5}$ per flight.

3.1.2 Performance Requirements

The performance related requirements detailed in the OSED 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 RNP APCH Navigation Specification detailed in AMC-20-27 and AMC-20-28 (LPV) are envisaged. Note, 09.10 Technical Specification stated [5]:

'For the airborne side, it is considered that the applicable safety and performance requirements are:

The RNP APCH or Advanced RNP requirements until the FAP refer to AMC 20-27 for RNP APCH requirements (in particular the paragraphs 6.3 : accuracy, 6.4 : integrity and 6.5 : continuity of function) and to AC 20-138 for advanced RNP requirements (Appendix 3 : Advanced RNP Functions). The LPV requirements after the FAP refer to AMC 20-28 (in particular the paragraphs 6.3 : accuracy, 6.4 : integrity and 6.5 : continuity of function).'

Compliance of the functional analysis to these safety and performance requirements:

After the FAP, the aircraft is in LPV mode (see REQ-09.10-TS-FUNC.0006, REQ-09.10-TS-FUNC.0009, REQ-09.10-TS-FUNC.0013, REQ-09.10-TS-FUNC.0019) therefore the safety and performance requirements are covered by the "standard LPV" requirements (which are not in the scope of this document).

Before the FAP, the requirement REQ-09.10-TS-FUNC.0014 specifies that the aircraft has to comply with the RNP requirement.'

Details on the specifications which support the advanced APV approach are provided below:

- EASA AMC 20-27 provides the acceptable means of compliance for RNP Approach operations including APV BARO-VNAV operations [8].
- EASA AMC 20-28 provides the acceptable means of compliance for RNP Airworthiness Approval and Operational Criteria related to Area Navigation for Global Navigation Satellite System approach operation to Localiser Performance with Vertical guidance minima using Satellite Based Augmentation System [9].
- ICAO Doc 9613 on Performance Based Navigation covers the RNP as well as RF legs in Appendix 1 to Part C [10].
- FAA AC-90-105 on Approval Guidance for RNP Operations and Barometric Vertical Navigation also covers RF legs, in particular the requirements for RNP 1NM in Appendix 5 [11].
- FAA AC-20-138d on Airworthiness Approval of Positioning and Navigation Systems [12]
- EUROCAE ED-75C on minimum aviation system performance standards: required navigation performance for area navigation

An assessment of the requirements in the OSED was performed to determine whether specific performance requirements were required to complete the necessary traceability between the OSED operational requirements, INTEROP requirements, TS functional requirements and Validation Objectives, as per the following guidance in the Templates and Toolbox User Manual [3].

As the Advanced APV concept is an airborne-based procedure, many of the OSED requirements inherently relate to *required performance* to fulfil a specific operational requirement. Further, these OSED requirements have existing, established links to the project documentation mentioned above. Thus, rather than create superfluous performance requirements to link the OSED performance related requirements with the interoperability, functional requirements and validation objectives, an analysis was performed to determine whether any OSED requirements justified the creation of explicit [SPR] performance requirements.

The following performance requirements for the Advanced APV concept described in V3 OSED [5], along with their associated traceability, are described.

Identifier	REQ-05.06.03-SPR-ALPV.0360
Requirement	For the list of aerodromes capable for ADV-APV approach operations, the airspace concept shall take into consideration initial and intermediate segments composed of: 1. RNP straight and RF legs (ending at the FAP) unless the use of fly-by or fly-over waypoints has justification; 2. 1 NM or down to 0.3 NM
	Design of the airspace concept
	The goal is increased adherence to horizontal nominal paths.

Identifier	REQ-05.06.03-SPR-ALPV.0370
Requirement	For the list of aerodromes capable for ADV-APV approach operations, the final approach segment shall be an APV-SBAS (LPV) segment: 1. as short as 3nm in length (if not constrained by local environment),; 2. with a FAF/FAP located at or above 1000ft AGL.
	Design of the airspace concept
	The goal is maintained transition between modes and track/height conformance.

Identifier	REQ-05.06.03-SPR-ALPV.0380
Requirement	For the list of aerodromes capable for ADV-APV approach operations, for

	missed approach there shall be: 1. allowance of RNP straight and RF legs in the missed approach final phase; 2. an RNP value of 1 NM or down to 0.3 NM.
	Design of the airspace concept
	Avoidance of obstacles/terrain through increased adherence to paths.

Identifier	REQ-05.06.03-SPR-ALPV.0390
Requirement	For the list of aerodromes capable for ADV-APV approach operations, the procedure shall be designed to ensure the capture of the LPV glide-slope with a preceding continuous descent profile for a range of temperatures.
	Design of the airspace concept
	The goal is guarantee the capture of the glide slope, especially when coming from a CDA.

Identifier	REQ-05.06.03-SPR-ALPV.4010
Requirement	The aircraft shall be capable of allowing the Flight Crew to conduct an Advanced APV procedure compliant with the applicable Navigation Specification (RNP APCH), sufficient to perform approach operations to LPV minima with initial and intermediate segments with: 1. RNP values of 1 NM or 0.3 NM; 2. RNP straight and RF legs ending at the FAP, and; 3. CDA technique.
	Compliance with applicable Navigation Specifications
	The flight execution shall respect the RNP requirements of the RNP APCH operations down to LPV minima with segments with RNP values of 1 NM or 0.3 NM with RF legs ending at the FAP together with the CDA technique.

Identifier	REQ-05.06.03-SPR-ALPV.4151
Requirement	The aircraft shall be capable of allowing the Flight Crew to conduct an Advanced APV procedure compliant with the applicable Navigation Specification (RNP APCH) sufficient to perform the coded RNP Missed Approach with RNP values of 1NM, including the RF legs flown in LNAV mode.
	Compliance with applicable Navigation Specifications (Missed Approach)
	The Missed Approach RNP requirements shall be respected when flying the coded missed approach, including the RF legs flown in LNAV mode.

Identifier	REQ-05.06.03-SPR-ALPV.4170
Requirement	The aircraft shall be capable of allowing the Flight Crew to perform a stabilised final approach, where the Advanced APV includes RF-legs in the intermediate segment ending at the FAP.
	Stabilised final approach
	The final approach shall be stabilised even where the Advanced APV procedure includes an RF-turn direct to the FAP and avoid early capture of the LPV Final Approach Segment.

The traceability between the performance requirements identified above and the relevant project documentation is shown in Table 1, below.

OSED	SPR (Performance)	INTEROP	TS	VAL OBJ

OSED	SPR (Performance)	INTEROP	TS	VAL OBJ
REQ-05-06.03-OSED-ALPV.0010	REQ-05-06.03-SPR-ALPV.0010	REQ-05-06.03-INTEROP-ALPV.0010	REQ-09-10-TS-FUNC.0014	OBJ-05-06.03-VALP-0023.0190
An aircraft that is going to fly an Advanced APV procedure shall be able to perform RNP APCH operations down to LPV minima with segments with RNP values of 1 NM or 0.3 NM with RF legs ending at the FAP together with the CDA technique.	*The aircraft shall be capable of allowing the Flight Crew to conduct an Advanced APV procedure compliant with the applicable Navigation Specification (RNP APCH), sufficient to perform approach operations to LPV minima with initial and intermediate segments with:* *1. RNP values of 1 NM or 0.3 NM;* *2. RF legs ending at the FAP, and;* *3. CDA technique.*	*The aircraft shall provide the necessary navigation, flight plan management, guidance and control, performance monitoring and alerting and display and system functions to conduct RNP APCH operations down to LPV minima with segments with RNP values of 1 NM or 0.3 NM with RF legs ending at the FAP together with the CDA technique.*	*During RNP-LPV transition, when LPV modes engage, the RNP corridor requirements shall still be respected.*	*To assess that the aircraft is able to adhere to the flight path during the RNP part and during the approach, until the FAP.*
REQ-05-06.03-OSED-ALPV.0151	REQ-05-06.03-SPR-ALPV.0151	REQ-05-06.03-INTEROP-ALPV.0151	REQ-05-06.03-FUNC.0004	OBJ-05-06.03-VALP-0023.0200
The aircraft shall be capable to fly the RNP coded missed approach, including the RF legs, with an LNAV mode.	*The aircraft shall be capable of allowing the Flight Crew to conduct an Advanced APV procedure compliant with the applicable Navigation Specification (RNP APCH) sufficient to perform the coded RNP Missed Approach with RNP values of 1NM, including the RF legs flown in LNAV mode.*	*The aircraft shall provide the necessary navigation, flight plan management, guidance and control, performance monitoring and alerting and display and system functions to conduct the RNP coded missed approach, including the RF legs, with a LNAV mode.*	*The system shall enable the crew to use an appropriate lateral managed guidance mode to fly the lateral RNP flight path (including the missed approach, and with RF legs).*	*To assess that the aircraft is able to adhere to the flight path during the RNP part of the final phase of the missed approach*
REQ-05-06.03-OSED-ALPV.0170	REQ-05-06.03-SPR-ALPV.0170	REQ-05-06.03-INTEROP-ALPV.0170	REQ-05-06.03-FUNC.0013	OBJ-05-06.03-VALP-0023.0240
The aircraft shall be able to fly the ADV LPV with RF-turn into the FAP ensuring stabilized approaches.	*The aircraft shall be capable of allowing the Flight Crew to perform a stabilised final approach, where the Advanced APV includes RF-legs in the intermediate segment ending at the FAP.*	*The aircraft shall provide the necessary navigation, flight plan management, guidance and control, performance monitoring and alerting and display and system functions to conduct the ADV LPV with a RF-turn into the FAP ensuring stabilized approaches.*	*After LPV modes are manually armed by the crew, the transition towards LPV guidance modes shall be performed automatically by the guidance systems.*	*To assess that the aircraft is able to be stabilized after the transition from the RNP mode to the LPV mode.*

Table 1: Performance Requirements Traceability

It is important to note that the performance related requirements concerning 'expected benefits', produced to support project validation activities, were originally placed in the OSED as, at that time, no SPR document was available. Thus, the requirements on expected benefits are consolidated into the final version of the SPR and are included here with a unique SPR identifier.

Identifier	REQ-05.06.03-SPR-ALPV.5200
Requirement	The Advanced APV concept shall allow reducing the overall approach track miles, resulting in less fuel consumption and less CO_2 emission.
Title	Benefit: reduced track miles
Rationale	Thanks to the flexibility of trajectories through the combined use RF and TF legs with RNP values from 1 down to 0.3; thanks to a shorter FAS; and thanks to an RF turn directly linked to the FAP. This composition can allow the construction of shorter trajectories, e.g. when noise sensitive and terrain rich areas are to be considered. This favours shorter paths, especially for traffic arriving from opposite directions than the runway orientation compared to standard LPV that require a straight and aligned segment up to FAP.

Identifier	REQ-05.06.03-SPR-ALPV.5210
Requirement	The Advanced APV concept shall improve adherence to a defined flight path, increasing ground track predictability and repeatability.
Title	Benefit : improved adherence to the flight path
Rationale	Through the use of RF and TF legs with RNP values from 1 down to 0.3.

Identifier	REQ-05.06.03-SPR-ALPV.5215
Requirement	The Advanced APV concept shall allow concentrating noise distribution to specific non-sensitive areas.
Title	Benefit: improved adherence to the flight path
Rationale	Because of the flexibility and the increased adherence to horizontal nominal paths through the use of RF and TF legs with RNP values from 1 down to 0.3. RF turn defines a fixed turn trajectory, whereas TF/TF fly-by and fly-over transitions do not.

Identifier	REQ-05.06.03-SPR-ALPV.5220
Requirement	The Advanced APV concept shall improve the airport accessibility.
Title	Benefit: improved airport accessibility
Rationale	Because a procedure with RF and TF legs with (RNP values from 1 down to 0.3) before the turn to FAP can make it possible to construct LPV to a runway where a standard LPV cannot be constructed due to surrounding terrain. Also because the use of RNP navigation with RF turns in the missed approach final phase may allow to reduce the LPV minima where missed approach must confront terrain obstacles.

Identifier	REQ-05.06.03-SPR-ALPV.5225
Requirement	The Advanced APV concept shall keep or decrease the Flight Crew and ATC operational workload at aerodromes where all aircraft have to be radar vectored to final approach intercept.
Title	Benefit: keep or decrease Flight Crew and ATC operational workload.
Rationale	Because ATCO does not need to vector, and pilot does not need to follow vectors. However at busy aerodromes, where radar vectors are used to sequence traffic, the Advanced APV may increase ATC operational workload unless some new ATC functions are introduced.

Identifier	REQ-05.06.03-SPR-ALPV.5230
Requirement	The Advanced APV concept shall reduce CO_2 emissions (reduce fuel consumption) and noise on ground with respect to where current procedures do not allow flying CDA.
Title	Benefit:
Rationale	The increased repeatability and predictability of ground track may allow ATC to include CDA application where previously not possible with medium or high traffic. The procedure includes CDA technique till FAP. CDA technique leads to fly a higher profile and is performed with idle thrust (or near idle).

3.2 Information Exchange Requirements (IER)

[IER]

Identifier	Name	Content Type	Frequency	Safety Criticality	Confidentiality	Maximum Time of Delivery	Interaction Type	Free
IER-05.06.03-OSED-ALPV.0001	Request to fly RNAV Approach Procedure	<Voice>	Once per approach	<No Effect>	<Public>	<10 s	<One-way>	
IER-05.06.03-OSED-ALPV.0002	Clearance to fly RNAV Approach Procedure	<Voice>	Once per approach	<Major>	<Public>	<10 s	<Two-way dialogue>	
IER-05.06.03-OSED-ALPV.0003	Loss of GNSS/track keeping capability report	<Voice>	As required (event triggered)	<Major>	<Public>	<10 s	<Two-way dialogue>	
IER-05.06.03-OSED-ALPV.0004	ATC Instruction	<Voice>	As required (event triggered)	<Major>	<Public>	<10 s	<Two-way dialogue>	
IER-05.06.03-OSED-ALPV.0005	GNSS system problem report	<Voice>	As required (event triggered)	<Major>	<Restricted>	<10 s	<One-way>	
IER-05.06.03-OSED-ALPV.0006	Request for final approach track or relevant point report	<Voice>	Once per approach	<No Effect>	<Public>	<10 s	<One-way>	
IER-05.06.03-OSED-ALPV.0007	Final approach track or relevant point report	<Voice>	Once per approach	<Major>	<Public>	<10 s	<One-way>	
IER-05.06.03-OSED-ALPV.0008	Landing clearance	<Voice>	Once per approach	<Major>	<Public>	<10 s	<One-way>	
IER-05.06.03-OSED-ALPV.0009	Landing clearance acknowledgement	<Voice>	Once per approach	<Major>	<Public>	<10 s	<One-way>	
IER-05.06.03-OSED-ALPV.0010	Go-around report	<Voice>	Once per approach	<Minor>	<Public>	<10 s	<One-way>	
IER-05.06.03-OSED-ALPV.0011	Go-around acknowledgment	<Voice>	Once per approach	<Major>	<Public>	<10 s	<One-way>	
IER-05.06.03-OSED-ALPV.0012	Missed approach tactical instruction	<Voice>	Once per approach	<Major>	<Public>	<10 s	<Two-way dialogue>	

Table 2: IER layout

4 References and Applicable Documents

4.1 Applicable Documents

This SPR complies with the requirements set out in the following 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
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[4] EUROCONTROL ATM Lexicon
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4.2 Reference Documents

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[14]B.4.1 Performance Framework, edition 01.01.00, 25 Nov 2014

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

[19]SESAR Human Performance Reference Material
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[21]Performance Assessment Report (PAR) for OFA 02.01.01 Optimised 2D/3D Routes
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[29] OFA 02.01.01 Safety Plan, Edition 0.0.0, 04th December 2012

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[32]05.06.03-D36-V2-OSED- v00.01.01 30th May 2014

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[34]16.06.05 - Templates for application of the HP Reference Material - 00.01.01

[35]P05.06.03-D36-Advanced Procedures Identification Report (V2 OSED)

[36]P05.06.03-D23-Validation Plan of Advanced Procedures (VALP) (and its appendix : Human Performance Assessment Plan)

Appendix A Assessment / Justifications

A.1 Safety and Performance Assessments

The Safety Assessment and the Human Performance Assessment is provided in this Appendix (A). The Performance Assessment has been performed at OFA level in [21].

A.1.1 Safety assessment

The Safety Assessment Report [6] produced in support of the SPR is included in this Appendix (A).

A.1.1.1 Introduction

A.1.1.1.1 Background

A.1.1.1.1.1 OFA 02.01.01, Solution #51 and Project 5.6.3

Project 05.06.03 contributes to Operational Focus Area (OFA) 02.01.01 Optimised 2D/3D Routes and reports its results in Release 4 as part of SESAR Solution #51 Enhanced terminal operations with LPV procedures which consists of the following projects:

- 05.06.03: Approach Procedure with Vertical Guidance (APV)
- 09.09: RNP Transition to xLS (x=G, I or M)
- 09.10: Approach with Vertical Guidance APV

Project 05.06.03 is the operational project within the targeted SESAR Solution, and is tasked to develop the safety assessment for SESAR Solution #51.

The projects comprising OFA 02.01.01 are as follows; from SESAR PMP (02.00.00):

Operational Package	Sub Package	Operational Focus		Project Name	Coordinating Federating Projects	Other federating Projects for Consultation
PA C02 Efficient and Green Terminal Airspace Operations	Enhanced Route Structures	Optimised RNP Structures	05.07.04	Full Implementation of PRNAV in TMA	05.02 10.01.07	
		Point Merge in Complex TMA	05.07.04	Full Implementation of PRNAV in TMA	05.02 10.01.07	
	Improved Vertical Profiles	Approach Procedures with Vertical Guidance	05.06.03	QM-3 - Approach Procedure with Vertical Guidance (APV)	05.02 10.01.07	09.49
			09.09	RNP Transition to xLS (x = G I M)		
			09.10	Approach with Vertical Guidance APV		
		CCD			05.02 10.01.07	09.49
		CDA	05.06.02	QM-2 - Improving Vertical Profile	05.02 10.01.07	09.49
			10.09.04	CDA and CCD in high density traffic		
			09.40	Long-term CDA & Steeper Approach Airborne Architecture		

A.1.1.1.1.2 The two phases of project 5.6.3

Project 5.6.3 is divided into two phases:

1. LPV
2. Advanced LPV (ADV-APV)

In the first phase a Safety Assessment was conducted for the standard LPV, and where the scope was defined as:

The scope in terms of flight phases is defined in the APV-SBAS Safety Assessment Report (SAR), to cover an APV procedure from the acquisition of the Final approach path, until DA/DH or in the case of a missed approach it include the initial/intermediate part of the missed approach, as illustrated in figure 1. This is consistent with PANS-OPS definition of APV that states: *"The APV segment includes the final approach, the initial and the intermediate phases of the missed approach Segment"* (PANS-OPS, Vol II, Part III, Section 3, Chapter 5.1.1)

The Local Safety Assessments have the same scope as the SAR.

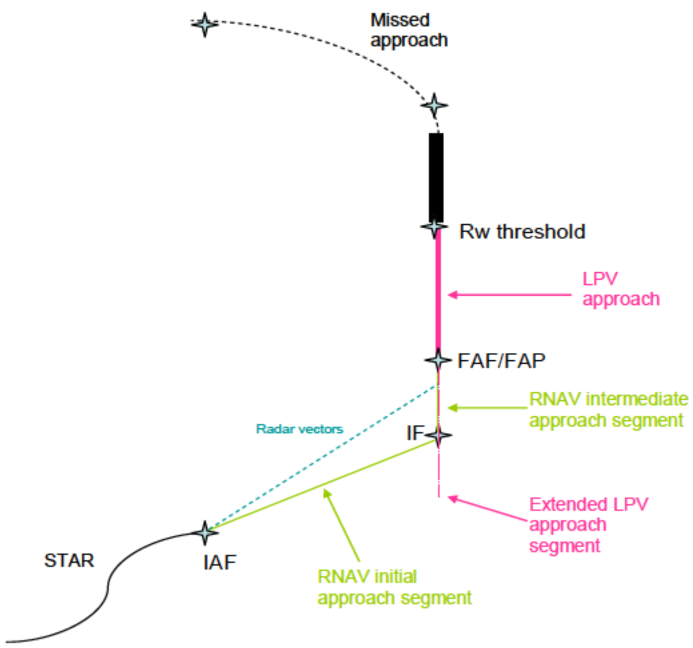
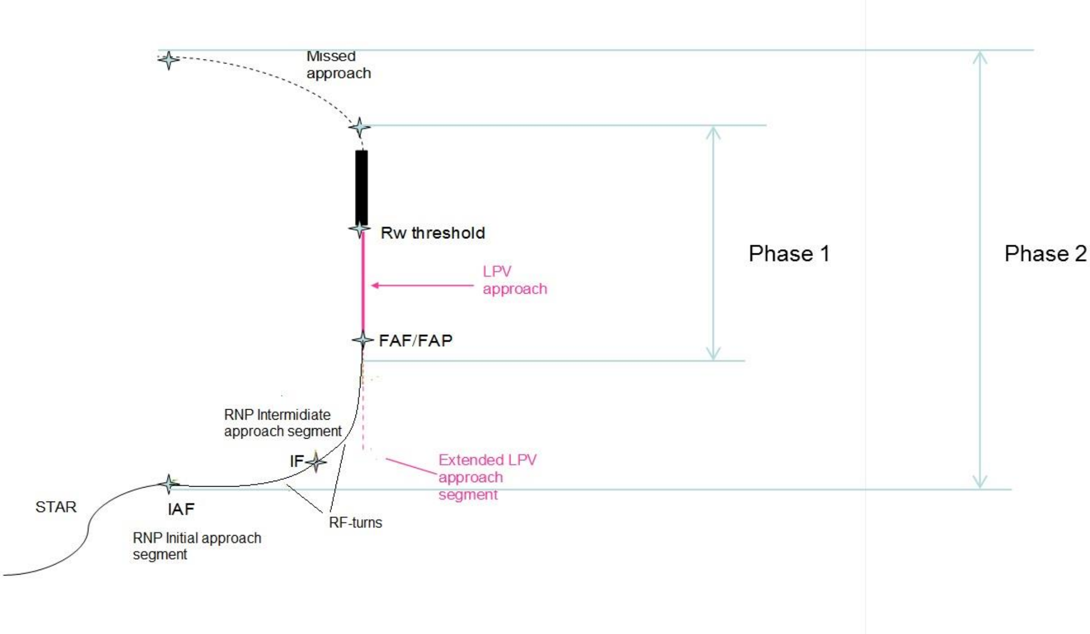


Figure 4-1: Interception of the LPV approach

This scope also corresponds with the scope of AMC 20-28 for APV-SBAS, stating (chapter 7): *"Functional criteria provided in this paragraph are those applicable to the LPV approach operation only. These criteria are therefore limited to the LPV Final Approach Segment and to the interception of the extended Final Approach Segment."*

Project Phase 1 scope as documented in the LPV Safety cases report

In the 2nd phase (ADV-APV) of the project the scope have been extended to also cover navigation and flight procedure from Initial Approach Fix, and until the completion of the missed approach segment. The increase in the flight phase scope between Phase 1 and Phase 2 can be illustrated as follows:



The Phase 2 of the ADV-APV including RF-turn

A.1.1.1.1.3 The changes between Phase 1 and Phase 2 (LPV and ADV-APV)

The changes within the **previous** LPV scope are:

- LPV requires a straight intermediate segment to FAP, whereas ADV-APV will allow the use of a Radius to Fix (RF) turn to the FAP (a change since SO#1 in the LPV SAR may be affected)

- LPV procedure design requires a level/flat portion of the intermediate segment to intercept the "glide path", while ADV will be designed without a level part in the intermediate segment (either a straight segment or a RF turn) (a change since SO#3 in the LPV SAR may be affected)

The change within the **new** added ADV-APV scope is:

- The introduction of Radius to Fix (RF) turns in segments from IAF to FAP, and in the final missed approach segment. The following figure from the ADV-APV OSED illustrates the concept:

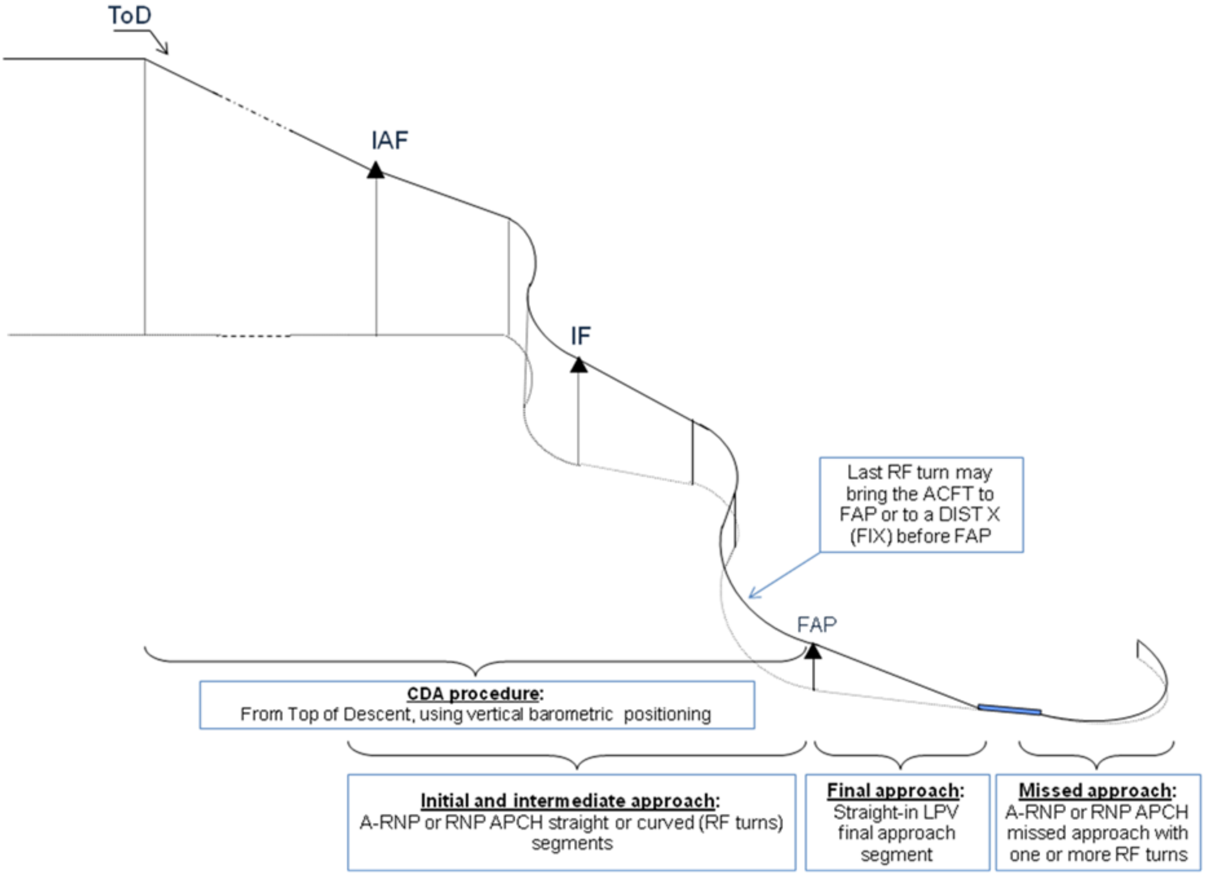
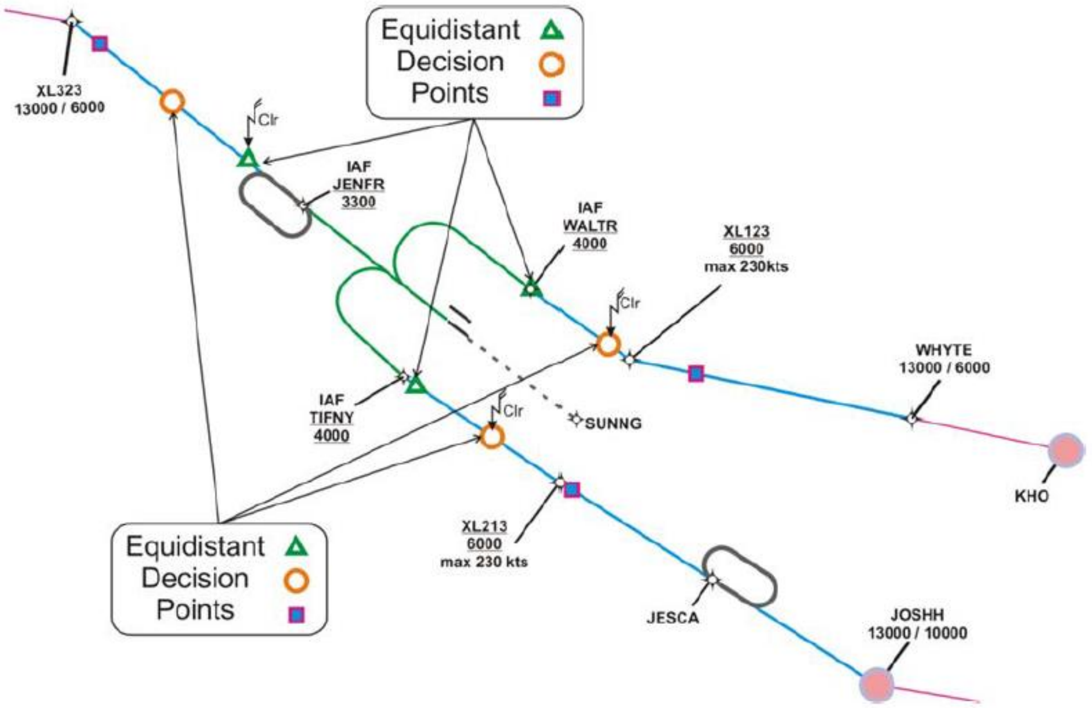


Figure 4-2: Illustration of the Advanced APV concept

A.1.1.1.1.4 ATS aspects not covered in the Phase 1 SAR

For a full description of the new operating methods, use cases and operational requirements for the Advanced APV concept (Phase 2), the reader should consult the OSED [5]. The following description is included to aid readability of the subsequent safety assessment material.

As the scope of ADV-APV includes the segments from Initial Approach Fix (IAF), there may be several different possible initial/intermediate approach procedures all ending at the same Final Approach Point (FAP). ATC need to perform sequencing of traffic arriving in conflict with each other, or solve conflicts with departing (or any other) traffic. The following figure taken from the ICAO PBN airspace concept manual Doc 9992, illustrates the situation with several approach procedures to the same runway. Not shown in this figure is the possible departure traffic crossing the arrivals (after inbounds have passed IAF) and is inside the scope of the Phase 2 assessment.



Possible ATC procedures and ATC criteria for airspace design – normal operations (which correspond to DOD sub-scenario 1C/Reference Scenario described in the OSED).

- An inbound flight shall be de-conflicted with other inbound traffic at IAF
  - A clearance to final approach is given before IAF, and no further radar heading instructions will be given.
  - Speed instruction may be given within the limits of the aircraft performance and in accordance with the published speed constraints (e.g. max speed during an RF leg).
  - The clearance does not contain any level limitations that would require the aircraft to level off.
- An inbound flight shall be de-conflicted with other traffic at IAF. In the event that this condition is not met, it is, where appropriate, the other traffic that has to be tactically instructed.
- Departure routes (e.g. SID) should be designed such that they do not cross the arrival traffic approach path (after IAF).
  - Unless the SID (and the ADV-APV procedures) is designed for departures to climb above arrivals.
  - Unless conflicts are resolved tactically for the departing traffic:
    - Departures are held on the ground.
    - Departures are radar vectored.

- Climb restrictions can be issued for departures (pass a WP above certain altitude) that solve a conflict.

Abnormal conditions are listed and assessed at a high level below (additionally, correspond to DOD sub-scenario 2C/Alternate Scenario in OSED). Note that their full assessment is contained in section A.1.1.3.5.

- In the event that a flight is not de-conflicted/sequenced (at IAF) the ATCO will have to issue tactical instructions in order to maintain separation. Such instructions include altitude restrictions, 'Direct to [waypoint]' instructions and/or radar vectors as required.

- If a conflict has to be resolved by radar vectors such that the RNAV route is not followed, the aircraft/crew will have to be able to discontinue RNAV and follow radar vectors. The aircraft/crew will have to be able to intercept final approach from radar vectoring.

- In the event that a flight cannot execute the procedure due to e.g. weather (CB in the path), an alternative approach procedure will have to be selected. If no alternative procedure can be selected (including a radar vectored approach to final) the flight will have to hold until the conditions change or divert to alternate runway or aerodrome.

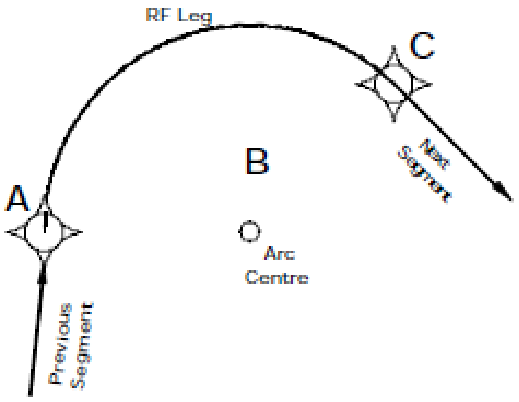
A.1.1.1.1.5 CFIT aspects not covered in the Phase 1 SAR

The Phase 1 SAR assessed the flight from FAP to DA/H, or to the initial missed approach. The Phase 2 ADV-APV includes the so-called "RF turns" in initial, intermediate or final missed approach segment.

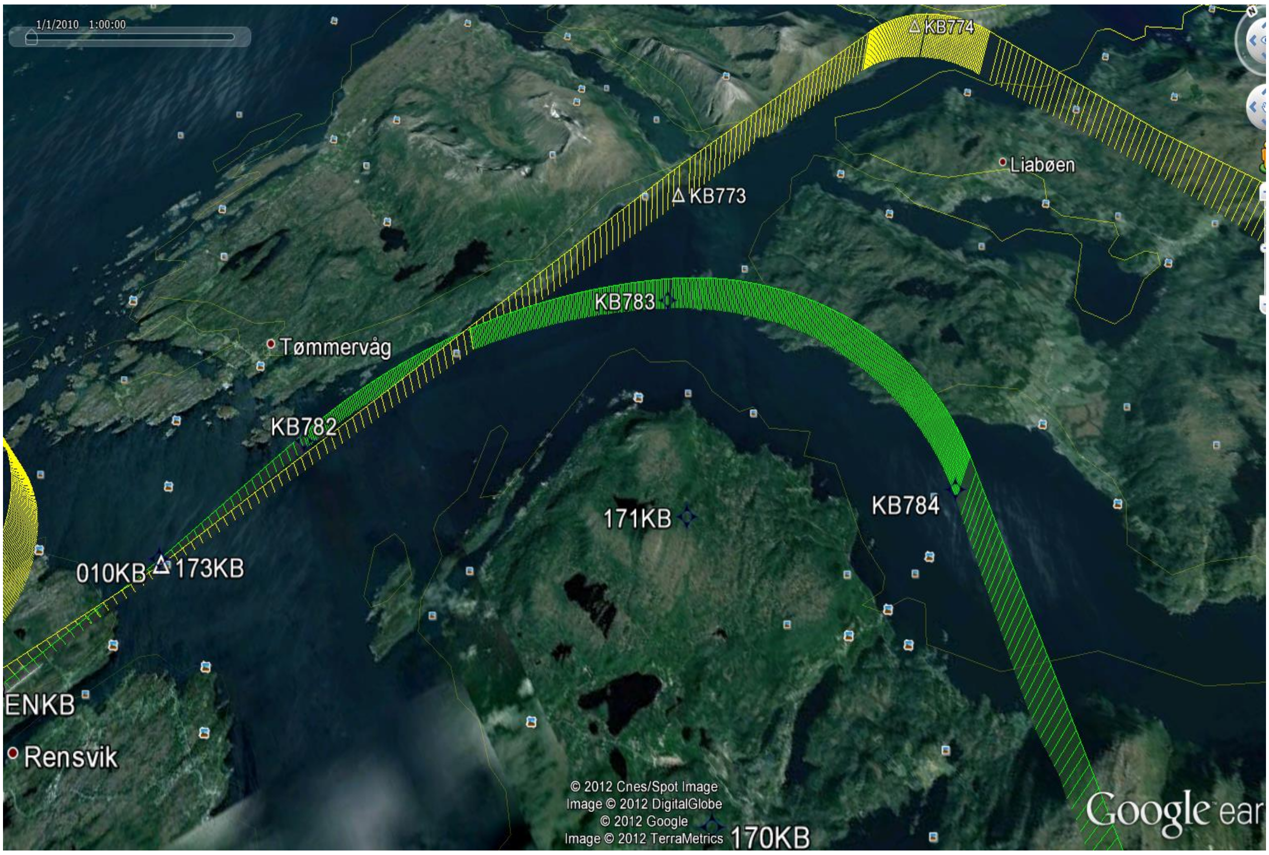
Guidance Material for the Design of Terminal Procedures for Area Navigation (DME/DME, B-GNSS, Baro-VNAV & RNP-RNAV)

RF

The constant radius arc to a fix , or RF, segment is a circular path about a defined turn centre that terminates at a waypoint. The beginning of the arc segment is defined by the terminating waypoint of the previous segment. The waypoint at the end of the arc segment, the turn direction of the segment and the turn centre are provided by the navigation database. The radius is computed by the RNAV system as the distance from the turn centre to the termination waypoint. A single arc may be defined for any turn between 2° and 300°. (Required for RNP-RNAV but NOT for P-RNAV)



A possible ADV-APV (green) compared to a LPV (yellow) may be illustrated as follows.



In the flight phases where the RF turn is used, the aircraft may be at an altitude lower than the minimum sector (safe) altitude (MSA), i.e. might be lower than the terrain. Furthermore, RF may be specifically used by procedure designers as a tool for clearing obstacles which would prohibit standard LPV implementation. In consequence, one of the primary safety concerns for such a procedure is the possibility that the navigation subsystem deviates the aircraft from the selected track in collision with the terrain. The Phase 1 SAR only considered this in the final approach phase, but the Phase 2 assessment needed to assess this for the increased scope. It should be mentioned that RNP-AR procedures have been developed and used exactly for these situations. The ADV-APV OSED assumes that the procedure made is not an RNP-AR.

A.1.1.1.2 General Approach to Safety Assessment

A.1.1.1.2.1 A Broader approach

The safety assessment is conducted as per the SESAR Safety Reference Material (SRM) which itself is based on a twofold approach:

- A success approach which is concerned with the safety of the OFA operations in the absence of failure within the end-to-end OFA System
- A conventional failure approach which is concerned with the safety of the OFA operations in the event of failures within the end-to-end OFA System.

Together, the two approaches lead to Safety Objectives and Safety Requirements, which set the minimum positive and maximum negative safety contributions of the OFA System.

A.1.1.1.3 Scope of the Safety Assessment

The scope of this Safety assessment is the concept described in chapter 1.1 and in the OSED [5] that have been developed by project 5.6.3. As mentioned, the project is divided into two phases – Phase 1 and Phase 2 – where Phase 2 builds on the work performed in Phase 1 in developing an Advanced [APV] procedure.

This version of the safety assessment specifically covers changes that result from Phase 2. It does not cover an assessment of the aspects which were covered by the Phase 1 assessment *and* which have not been impacted by the concept development in Phase 2.

Previous versions of the safety assessment have input to the Validation Plan. This version of the safety assessment is based upon the completed V3 OSED [5] and related validation results [33], i.e. the completed project documentation set excluding SPR (main body of this document), which this safety assessment was performed for.

This version of the safety assessment includes those parts of the failure case analysis which have been completed in Phase 1 and are still relevant in Phase 2. There are a number of operational hazards which have been identified specifically for Phase 2. These were fully assessed during a workshop conducted in Madrid on 18th May 2015. Fault trees associated with the contributions to the operational hazards were assessed and updated; these are included in Section A.1.1.3.6 in this submission.

A.1.1.1.4 Layout of the Document

In chapter 2 of this report, the safety specification at the OSED level is documented, through the setting of the Safety Criteria, the identification of the pre-existing hazards, and the mitigation process in abnormal and normal conditions of the system. System-generated hazards are identified towards the end of this chapter, including the derivation of the safety objectives associated with these hazards. Functional and performance safety objectives are also specified in this chapter.

In chapter 3 the safety requirement process is documented and the derived safety and performance requirements are specified for normal and abnormal conditions.

Chapter 4 deals with the safe design at the physical level. This is considered to be outside the scope of this (operational) project. The physical level will be addressed during the related system project(s) and the local implementation.

A.1.1.2 Safety specifications at the OSED Level

A.1.1.2.1 Scope

This section addresses the following activities:

- Description of the key properties of the Operational Environment that are relevant to the safety assessment – section 2.2
- Setting of the Safety Criteria (from the OFA Safety Plan, Reference [29]) – sections 2.3 and 2.4
- Identification of the pre-existing hazards that affect traffic in the OFA relevant operational environment (airspace, airport, terrain, etc.) and the risks of which operational services provided by the OFA may reasonably be expected to mitigate to some degree and extent – section 2.5
- Comprehensive determination of the operational services that are provided by the OFA to address the relevant pre-existing hazards and derivation of Safety Objectives (success approach) in order to mitigate the pre-existing risks under normal operational conditions – section 2.6
- Assessment of the adequacy of the operational services provided by the OFA under abnormal conditions of the Operational Environment – section 2.7
- Assessment of the adequacy of the operational services provided by the OFA in the case of internal failures and mitigation of the system-generated hazards (derivation of Safety Objectives (failure approach)) – section 2.8
- Assessment of ADV-APV operations on adjacent airspace or neighbouring ATM systems – section 2.9
- Achievability of the SAfety Criteria (SAC) – section 2.10
- Validation & verification of the safety specification – section 2.10

A.1.1.2.2 ADV-APV Operational Environment and Key Properties

A.1.1.2.2.1 Airspace Structure and Boundaries

The approach navigation and associated instrument flight procedure will normally take place in Terminal airspace transiting to an aerodrome control zone. The neighbouring airspace if affected, should allow for continuous descent operation, as this is part of the concept in ADV-APV.

A.1.1.2.2.2 Types of Airspace – ICAO Classification

Terminal airspace and aerodrome control space are typically Class C and D airspace, while an aerodrome traffic information zone is Class G airspace. The en-route part of the airspace is typically class A or class C.

A.1.1.2.2.3 Airspace Users – Flight Rules and Meteorological conditions

Aircraft flying ADV-APV procedures will be any type of aircraft suitably equipped and approved for this type of instrument flight procedure. No restriction on what type of operation (e.g. commercial or private) will be considered.

It should be assumed that the aircraft is operating under Instrument Meteorological Conditions, and as such must be flying under instrument flight rules during the initial, intermediate, final and missed approach segments. This environment condition must be properly considered in the Safety Assurance activity.

A.1.1.2.2.4 Traffic Levels and complexity

The ADV-APV procedure can be used in any traffic levels and complexity. However, using the procedure in high traffic levels may prove difficult when implemented in a mixed equipage environment. As stated in the OSED, the Reference Scenario (where expected benefits will be maximized) is based on a low density terminal environment, consistent with DOD sub-scenario 1C.

An Alternate Scenario, based on 100% equipage and DOD sub-scenario 2c, has been assessed for ATC operational feasibility in a high density terminal environment.

There may be several ADV-APV procedures to the same runway (from different IAF) merging at IF or FAF/FAP. Sequencing traffic at aerodromes with a high traffic load will require a sequencing concept, as shown in EXE-05.06.03-VP-792 where all traffic is sequenced at IAF (as opposed to a more traditional concept where traffic is sequenced onto final approach by radar vectoring).

A.1.1.2.2.5 Aircraft ATM capabilities

The Reference Scenario is based on a mix of aircraft with different capabilities. Only a few aircraft may be capable of flying the ADV-APV procedure, and there may be several other approach procedures to the same runway.

A.1.1.2.2.6 Terrain Features - Obstacles

One of the benefits for ADV-APV is that it allows the implementation of LPV final approach segment where terrain would normally prevent standard LPV from being implemented. The ADV-APV procedure may be used in mountainous environments where the altitudes flown from IAF to FAF may be lower than the surrounding terrain and as such it could be lower than the Minimum Safe Altitude (MSA).

Also for the missed approach segment, terrain may also exist and the missed approach procedure must therefore be designed to avoid terrain.

Presence of terrain which is higher than the altitude the aircraft is flying at when navigating the initial and intermediate approach segment (or the missed approach segment), will be a key factor with regards to the CFIT Hazard for this ADV-APV operation.

Also in non-mountainous terrain there can be an obstacle rich environment which creates a safety concern with regards to obstacle infringement.

These environment conditions must be properly considered in the Safety Assurance activity.

A.1.1.2.2.7 CNS Aids

Navigation services may be provided by GNSS (Core constellation & EGNOS) alone. Precision or non- precision navigation aids may also exist for the aerodrome.

Communication is assumed to be VHF voice, or a combination of VHF voice and data-link.

A.1.1.2.2.8 ATC Separation Minima

Separation minima will depend up on the surveillance capability in the airspace. If radar control is applied in the airspace, different separation minima will exist compared to procedural control.

A.1.1.2.2.9 PBN Navigation specifications

ICAO has issued a PBN Manual, currently issued as fourth edition [10]. The PBN Manual with its Navigation specification description can be seen as a key property in the operational environment.

The PBN Manual is divided in two volumes. Volume I is titled "Concept and implementation guidance", while Volume II is titled "Implementing RNAV and RNP Operations".

A future implementation of the ADV-APV concept will, in PBN terms, be a ***Navigation application****;*

> ***Navigation application*.** The application of a navigation specification and the supporting NAVAID infrastructure, to routes, procedures, and/or defined airspace volume, in accordance with the intended airspace concept.
> [ICAO PBN Manual 4th edition]

Such an implementation should follow the guidance of the ICAO PBN Manual. This means that ideally the ADV-APV concept development should also follow the guidance of the PBN Manual.

The ADV-APV OSED as developed by project 5.6.3 can be regarded as a part of an **"Airspace Concept"**, and a "Navigation Application".

> ***Airspace concept*.** An airspace concept describes the intended operations within an airspace. Airspace concepts are developed to satisfy explicit strategic objectives such as improved safety, increased air traffic capacity and mitigation of environmental impact etc. Airspace concepts can include details of the practical organization of the airspace and its users based on particular CNS/ATM assumptions, e.g. ATS route structure, separation minima, route spacing and obstacle clearance.
> [ICAO PBN Manual advance 4th edition]

The selection of particular Navigation specification should then be made that is the most suitable for the Navigation application for a particular Airspace concept.

> ***Navigation specification***. A set of aircraft and aircrew requirements needed to support Performance-based Navigation operations within a defined airspace. There are two kinds of navigation specification:
>
> <u>RNAV specification:</u> A navigation specification based on area navigation that does not include the requirement for on-board performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.
>
> <u>RNP specification:</u> A navigation specification based on area navigation that includes the requirement for on-board performance monitoring and alerting, designated by the prefix RNP, e.g. RNP 4, RNP APCH.

> Note: The Performance-based Navigation Manual (Doc 9613), Volume II, contains detailed guidance on navigation specifications.
> [ICAO PBN Manual advance 4th edition]

According to the PBN Manual the choice of Navigation specification will also take into account the safety aspect. Volume II of the PBN Manual gives detailed implementation guidance on the different Navigation Specifications. Each Navigation Specification has parameters defined as System Performance which also includes a severity classification of navigation system integrity (malfunction) and continuity (loss of function).

Different Navigation Specifications have different classification of continuity/loss of function, and a choice of Navigation Specification should ensure that the assumed severity of a loss of function situation is matching the safety assessment severity classification of such a situation.

A.1.1.2.3 Airspace Users Requirements

From OSED [5] Chapter 2.2.5:

Novelty 1: Combined use of RNP, RF turns and CDA:

- **Reduce track miles**, **resulting in less fuel consumption and less CO2 emission**, through the combined use RF and Track-to-Fix (TF) legs with RNP values from 1 down to 0.3. This composition can allow the construction of shorter trajectories, e.g. when noise sensitive and terrain rich areas are to be considered. This favours shorter paths, especially for traffic arriving from opposite directions than the runway orientation compared to standard LPV that require a straight and aligned segment up to FAP.
- Because of the increased adherence to horizontal nominal paths through the use of RF and TF legs with RNP values from 1 down to 0.3:
  - **increase ground track predictability and repeatability** for air traffic controllers and pilots,
  - **concentrate noise distribution to specific non-sensitive areas** when applicable. In case the airport is not noise-sensitive, full focus on optimised routing (fuel/CO2) should be prioritised, because a RF turn defines a fixed turn trajectory, whereas TF/TF fly-by and fly-over transitions do not, and
  - **fly very optimised CDA descent profiles** for each aircraft and probably **avoiding level flying** because distance to runway is known very accurately.
- **Increase the airport accessibility**, because a procedure with RF and TF legs with (RNP values from 1 down to 0.3) before the turn to FAP can make it possible to construct LPV to a runway where a standard LPV cannot be constructed due to surrounding terrain.
- Maintain or **decrease the flight crew and ATC operational workload**, compared to current operations, at aerodromes where all aircraft have to be radar vectored to final approach intercept, because ATCO does not need to vector, and pilot does not need to follow vectors. However, at busy aerodromes where radar vectors are used to sequence traffic, the Advanced APV may increase ATC operational workload unless some new ATC functions are introduced.
- Provide the benefits of curved approaches with RNP down to 0.3, **without the cost and burden** of the specific aircraft and operational qualification and crew training required for **RNP AR operations.**
- Fly continuously CDA technique (idle or quasi idle engine), resulting in:

   – **Reduced CO2 emissions and noise on ground** through the flight of a higher profile and excessive thrust settings (at level-offs) at low altitude.

   – **Reduced fuel consumption and noise** based on a constant Idle (or near Idle) thrust, because ATC does not clear the aircraft to particular level-off at low altitudes, and the instrument flight procedure does not contain any level restrictions.

Novelty 2: RF turn directly linked to final approach point:

- **Reduce track miles**, where possible, resulting in less fuel consumption and less CO2 emission, through the use of a RF turn directly to FAP. This favours shorter paths, especially for traffic arriving from opposite directions than the runway orientation compared to standard LPV that require a straight and aligned segment up to FAP.
- Increase the **airport accessibility**, because a procedure with RF turn to FAP (especially a RF turn with RNP 0.3) can make it possible to construct LPV to a runway where a standard LPV cannot be constructed due to surrounding terrain.
- Provide the benefits of curved approaches onto a short precision-type final approach segment, **without the cost and burden of** the specific aircraft and operational qualification and crew training required for **RNP AR operations**.

Novelty 3: Shortest possible final approach segment:

- **Reduce track miles**, where possible, **resulting in less fuel consumption and less CO2 emission**, especially in combination with a RF turn directly to FAP. This favours shorter paths, especially for traffic arriving from opposite directions than the runway orientation compared to standard LPV that require a straight and aligned segment up to FAP.

Novelty 4: RF turns in the final phase of the missed approach:

- Increase the **airport accessibility**, because with the use of RF turns (especially with low RNP value) can make it possible to reduce the LPV minima where the missed approach must confront terrain obstacles.
- Through the better adherence to horizontal nominal paths with the use of RF and TF legs:
   – **Increase ground track predictability and repeatability for air traffic controllers and pilot.**
   – **Concentrate noise distribution to specific non-sensitive areas** when applicable. In case the airport is not noise-sensitive, full focus on optimised routing (fuel/CO2) should be prioritised.

A.1.1.2.4 Safety Criteria

In addition to the six safety criteria from the LPV phase of the project, six new Safety Criteria have been identified for the ADV-APV.

A.1.1.2.4.1 Project Phase 1 – LPV Safety Criteria

In Phase 1 of the project, a safety assessment of LPV was performed. In the SAR for LPV assessment, CFIT SAC were defined as follows:

* For baseline situation where the Runway end is an ILS Cat I approach (Baseline#1):

SAC#01a: The risk of Controlled Flight Towards Terrain with LPV approach at airports where ILS CAT-1 is operated shall not increase.

* For baseline situation where the Runway end is a conventional non-precision approach (Baseline#2):

SAC#01b: The risk of Controlled Flight Towards Terrain with LPV approach at airports currently operating conventional NPA shall decrease 50 fold.

Also, Safety Criteria applicable for the Landing Accident were defined as follows:

*For baseline situation where the Runway end is an ILS Cat I approach (Baseline#1):

SAC#02a: The risk of runway overrun and/or hard landing due to LPV approach (unstable) at airports where ILS CAT-1 is operated shall not increase.

SAC#03a: The risk of runway undershoots due to LPV approach at airports where ILS CAT-1 is operated shall not increase.

*For baseline situation where the Runway end is a conventional non-precision approach (Baseline#2):

SAC#02b: The risk of runway overrun and/or hard landing due to LPV approach (unstable) at airports currently operating conventional NPA shall decrease 50 fold.

SAC#03b: The risk of runway undershoots due to LPV approach at airports currently operating conventional NPA shall decrease 50 fold.

These SAC are for the LPV final approach only. Mid-air collision and wake turbulence accident were assumed to not be affected and no SAC developed.

A.1.1.2.4.2 Project Phase 2 – ADV-APV Safety Criteria

The safety criteria for phase two of the project were divided into three different categories: Controlled Flight Into Terrain (CFIT), Mid Air Collision in TMA (MAC-TMA), airspace and landing accidents due to mainly non-stabilized approach criteria.

A.1.1.2.4.2.1 Safety criteria for ADV-APV with regard CFIT

In Phase 2 (ADV-APV) of the project, the scope is extended from Initial Approach Fix covering also the initial and intermediate approach segments and the final missed approach segment. The SAC from Phase 1 are still applicable.

However, the following Safety criteria for ADV-APV with regard to Controlled Flight Toward Terrain have been set:

SAC#4 : There shall be no increase of Controlled Flight Toward Terrain (CFTT – CF4) during final approach with ADV-APV compared to LPV.

The ADV-APV final approach segment will be the LPV. It should be almost identical compared with Phase 1, although the ADV-APV do not necessary use a straight and level segment when transitioning to final approach segment, and the final segment may be shorter.

SAC#5 : There shall be no increase of Controlled Flight Toward Terrain (CFTT – CF4) during initial and intermediate approach with ADV-APV compared to current* initial and intermediate approach navigation.

This covers the added scope ahead of final approach. Reference to e.g NPA or CAT-1 is not relevant in these flight phases.

SAC#6 : There shall be no increase of Controlled Flight Toward Terrain (CFTT – CF5) during Missed approach with ADV-APV compared to current* missed approach navigation.

The SAC #5 and #6 are for CFIT in the flight phases that Phase 1 did not cover. In mountainous terrain, the aircraft may be at an altitude lower than surrounding terrain (lower than MSA) when navigating the initial and intermediate approach segments. Also during missed approach, the aircraft may be at an altitude lower than surrounding terrain.

* current navigation refers to the different navigation specifications used currently in these flight phases. A specification may also be RNAV.

A.1.1.2.4.2.2 Safety criteria for ADV-APV with regard to Mid Air Collisions

As the ADV-APV also covers flight phases where ATC normally issue heading, level, and speed instructions in order to sequence flights to final approach, and also to separate arriving traffic from departing traffic (any traffic) a Safety Criterion for MAC is also appropriate:

SAC#7 : There shall be no increase of imminent infringement (MF5-9)[1] during initial and intermediate approach with ADV-APV compared to current initial and intermediate approach navigation.

For current (non-ADV-APV) the Tactical Conflict Resolution barrier ATC may use radar vectoring and level flight clearances. For a flight according to ADV-APV, ATC is limited in how to perform the Conflict management, but the barrier efficiency up to MF5-9 needs to be maintained.

As the ADV-APV also covers missed approach and also contingency procedures, a further Safety Criterion for MAC is required:

SAC#8 : There shall be no increase of imminent infringement (MF5-9) during missed approach or contingency procedures with ADV-APV compared to current missed approach navigation and contingency.

ADV-APV implementation at an aerodrome may change the number of different missed approach procedures and contingency procedures that exist for the aerodrome. The barrier efficiency for this needs to also be maintained.

[1] MF5-9 refers to a specific barrier in the Accident Incident model [31]

A.1.1.2.4.2.3 Safety criteria for ADV-APV with regard to landing accident

The LPV SAR also had safety criterion for landing accident, as a flight final approach influence the outcome of the landing. A runway excursion / overrun or hard landing may be the effect of a non-stabilized approach. Landing short of the runway will be a CFIT situation.

SAC#9 : The likelihood of Runway over-run and/or hard landing (non-stabilized) due to ADV-APV shall not increase compared to LPV.

One of the objectives with ADV-APV is to have a shorter final approach segment and continuous descent onto FAP and transit from RF turn onto FAP. The barriers ensuring that the flight is stable in speed, trajectory and configuration need to be maintained.

A.1.1.2.5 Relevant Pre-existing Hazards

From Guidance F.2.2 of Reference [26], a list of possible pre-existing hazards for Terminal Area is provided. The relevant pre-existing hazards that the OFA operational services have to mitigate in the relevant operational environment have been identified to be:

Hp#1 : a situation in which the intended trajectories of two or more aircraft are in conflict

Hp#2 : a situation where the intended trajectory of an aircraft is in conflict with terrain or an obstacle

Hp#3: a situation in which the aircraft is not stabilized on the nominal final approach path

By definition, these hazards exist in the operational environment before any form of de-confliction (from airspace design, through planner and tactical controller intervation, to safety nets) has taken place. It is therefore the primary purpose of the relevant OFA operational services to mitigate them.

Penetration of restricted airspace has not been identified as relevant. There may of course in theory also be restricted airspace in the TMA, but ADV-APV concept is not dealing with how restricted airspace is avoided.

Wake vortex encounters has not been identified as relevant, as ADV-APV will not influence the distance spacing of aircraft in the air and the time-wise spacing of aircraft landing and taking off.

Encounters with adverse weather in mountainous terrain, on the other hand, might be identified as relevant.

A.1.1.2.6 Mitigation of the Pre-existing Risks – Normal Operations

A.1.1.2.6.1 Operational Services to Address the Pre-existing Hazards

In this chapter the operational services that are provided in the operational environment are identified and referenced to the pre-existing hazards defined in the chapter above.

ID	SERVICE OBJECTIVE	PRE-EXISTING HAZARDS

Provide Navigation service to aircraft during the approach and missed approach segments		
SPT1	Separate aircraft from terrain/obstacles during the initial/intermediate approach	HP#2
SPT2	Separate aircraft from terrain/obstacles during the final approach	HP#2
SPT3	Separate aircraft from terrain/obstacles during the missed approach part	HP#2
AFA	Allow acquisition of the Final approach path	HP#2, HP#3
LFA	Allow landing at DA/DH	HP#2 HP#3
Provide Air Traffic Service during the approach (initial, intermediate and final) and missed approach (Air Traffic Control in controlled airspace and Air Traffic Information Service in uncontrolled airspace)		
SAD	Establish separation between arrival flows and departing flows (including missed approach) in the particular environment	Hp#1
SP1	Maintain arrival flow separation	Hp#1
SP2	Maintain aircraft separation during the approach (initial, intermediate, final and missed segments)	Hp#1

Table 4-1: Air Navigation Service (ANS) and Pre-existing Hazards

A.1.1.2.6.2 Derivation of Safety Objectives (Functional & Performance – success approach) for Normal Operations

In this chapter the operational services provided in the defined flight phase are related to the correct AIM barrier, and to the safety objectives found in Table 4-2.

Ref	Phase of Flight / Operational Service	Related AIM Barrier	Achieved by / Safety Objective [SO xx]
1	Approach /Navigation	CFIT B5: Pilot Trajectory Management	SO 001, SO004,
2	Approach /Navigation	CFIT B6: FMS/RNAV/Flight Control Management	SO 002, SO 003, SO 006, SO 007,
3	Approach /Navigation	CFIT B7: ATC Trajectory Management	SO 005
4	Approach /Navigation	CFIT B8: Route/Procedure design and publication	SO 001, SO 002, SO 008
7	Approach /Air Traffic Service	MAC-TMA B10: Traffic	SO 009

		Planning and Synchronisation	
8	Approach /Air Traffic Service	MAC-TMA B6: Crew/AC Induced Conflict Management	SO011
9	Approach /Air Traffic Service	MAC-TMA B7: Plan Induced Conflict Management	SO010
10	Approach /Air Traffic Service	MAC-TMA B8: ATC Induced Conflict Management	SO 009

Table 4-2: Operational Services & Safety Objectives (success approach)

ID	Description	Related SAC
SO 001	Approach procedure shall be designed to prevent loss of separation with obstacles, terrain or other departing or arriving aircraft	SAC#7
SO 002	Aircraft shall conform laterally to the defined ADV-APV route segments including RF legs	SAC#5 SAC#6
SO 003	Aircraft shall conform vertically (not lower that the published minimum altitudes) to the defined ADV-APV route segments, also when performing CDO	SAC#5 SAC#6
SO 004	Aircraft crew procedure shall be designed for monitoring the trajectory laterally and vertically to prevent loss of separation with obstacles and/or terrain	SAC#5 SAC#6
SO 005	ATCO procedures shall be designed for monitoring the trajectory laterally and vertically to prevent loss of separation with obstacles and/or terrain	SAC#7 SAC#8
SO 006	Aircraft shall change mode to LPV from lateral navigation (LNAV) at a defined point	SAC#4
SO 007	Aircraft shall decelerate before FAP so that an stabilized approach can be ensured	SAC#4 SAC#9
SO 008	A missed approach procedure shall be designed to prevent loss of separation with obstacles and/or terrain	SAC#6
SO 009	Arrival traffic flows shall be de-conflicted at IAF with other traffic	SAC#7
SO 010	Arrival traffic shall be sequenced with other arrival traffic at IAF (no later than)	SAC#7
SO 011	The aircraft shall be able to fly as instructed, if ATC needs arrival traffic to	All

ID	Description	Related SAC
	discontinue ADV-APV	

Table 4-3: List of Safety Objectives (success approach) for Normal Operations

A.1.1.2.6.3 Analysis of the Concept for a Typical Flight

From the ADV-APV OSED [28] Use Case 1.1 the following additional SO have been identified:

ID	Description	Related SAC
SO 012	Aircraft shall be properly equipped and approved for ADV-APV	All
SO 013	Flight crew shall be properly trained and approved for ADV-APV	All
SO 014	ATCO shall be properly trained for ADV-APV	All

Table 4-4: Additional Safety Objectives (success approach)

A.1.1.2.7 ADV-APV Operations under Abnormal Conditions

The purpose of this section is to assess the ability of the OFA to work through (robustness), or at least recover from (resilience) any abnormal conditions (i.e. external to the OFA System), that might be encountered relatively infrequently.

A.1.1.2.7.1 Identification of Abnormal Conditions

In identifying abnormal conditions which are external to the system, we must look at which element belongs to the system and which element is in the environment.

Four components have been identified as environment parts to be assessed;

- Communication
- Surveillance
- Adverse Weather
- Aerodrome
- GNSS

Communication is a vital part of the air traffic service. The abnormal conditions can originate from the air to ground segment or the ground to air segment. The two situations are very different in nature and severity.

The air to ground segment failure, usually affects only one plane. The loss or partial loss (stuck mic etc.) of communication from one aircraft does not necessarily affect more than one aircraft. The effect that it has on this particular aircraft depends upon many different parameters; the traffic picture, where the aircraft is, what its intention was and so on. For ATC, however, this is a situation that is dealt with more frequently, namely the loss or partial loss of ground to air communication. This could affect one or more aircraft at the same time.

The situation is not seen to be different than how communication loss or partial loss is managed today.

This results in assumption A002 (which is recorded in annex **Error! Reference source not found.**).

The partial or total loss of the Surveillance function is not seen as any different as it is today. A total loss of the surveillance function will lead to a reduction and in the end a halt of the flow of traffic into and out of the airspace that is affected of the problem, and alternatively the use of procedural control of air traffic.

The situation is not seen to be different than how surveillance loss or partial loss today is managed today.

Temporary closure of an aerodrome due to winter operation, runway change, situations that are not part of the day to day operation of an aerodrome, are not seen as any different to today.

Adverse weather will affect the aircraft flying ADV-APV procedures as it will today. The difference is that there might not be any possible way of deviating around weather flying ADV-APV since the aircraft must follow the procedure very accurately, in order to not infringe the obstacle plane. Adverse weather can also be different inside a mountainous area. The rate of change of the weather, especially wind, can be dramatically different in mountainous areas compared to non-mountainous areas. When the aircraft is within the mountainous area, and restricted to follow the procedure, there is a difference in that situation, compared with today, where there is not flight within confined space inside a mountain range, unless flying RNP-AR.

Change of wind and wind velocity also make a specific challenge in ADV-APV procedures. The RF-turn mixed with an optimized CDO will be governed by how, where and how much wind there is. Again the aircraft must follow the procedure very accurately, in order to not infringe the obstacle plane.

Based on the above rationale, adverse weather (including change of wind and wind velocity) is considered further for mitigation of risk.

For more information see OSED chapter 4.3.3.

As the GNSS segment is outside of scope of the project, a failure in GNSS is considered an abnormal condition. It would lead to the procedure not being able to be executed. Loss of GNSS could occur over a short period (leading to an abandoned procedure, which is then able to conduct the missed approach, with part of the missed approach utilising an RF turn, by which point GNSS availability is restored). If the loss of GNSS is for an extended period then, in the worst case this could be during the execution of a missed approach including an RF leg.

Based on the above rationale, loss of GNSS is considered further for mitigation of risk.

A.1.1.2.7.2 Potential Mitigations of Abnormal Conditions

Shown in Table 4-5 the abnormal condition and the assessed immediate operational effect, together with the possible mitigations of the safety consequence of the operational effect with a reference to the new safety objective described in Table 4-6 below. The mitigation of the Surveillance, Communication and the Aerodrome

Ref	Abnormal Conditions	Operational Effect	Mitigation of Effects / [SO xx]
1	Adverse WX in mountainous area where the defined procedure is located	No possibility of deviating around WX, resulting in the aircraft flying into adverse WX.	Restricting the use of the procedures to a set of specific weather conditions, or within some specific weather parameters. SO 015
2	Loss of GNSS	Approach procedure cannot be conducted. Missed approach, which includes an RF leg cannot be executed.	Procedure should not be utilised in the absence of GNSS. Additionally the aircraft will need to be able to complete the missed approach via additional navigation means should GNSS be lost during a missed approach RF leg.

Table 4-5: Additional Safety Objectives (success approach) for Abnormal Conditions

ID	Description	Related SAC
SO 015	ADV-APV shall be commenced only when specific (favourable) weather condition prevails.	SAC#4 SAC#5 SAC#6
SO 029	ADV-APV shall be commenced only when GNSS is available.	SAC#4 SAC#5 SAC#6
SO 030	Aircraft conducting an ADV-APV procedure which incorporates an RF leg to meet requirements for separation from terrain.	SAC#4 SAC#5 SAC#6

Table 4-6: List of Safety Objectives (success approach) for Abnormal Operations

A.1.1.2.8 Mitigation of System-generated Risks (failure approach)

A.1.1.2.8.1 Identification and Analysis of System-generated Hazards

From the analysis of the above description of the OFA operational services and by considering, for each safety objective (from the success approach above), what would happen if the objectives were not satisfied (i.e. negate the safety objectives derived with the success approach), the following OFA system-generated hazards have been identified:

1. Failure to laterally follow the defined route segment as provided by the procedure

2. Failure to vertically follow the defined route minimum altitudes (MOCA) as provided by the procedure

3. Failure to fly the approach stabilized/ Flying a non-stabilized approach

4. Failure to change mode from ADV-APV (LNAV+CDO /RF-turn) to LPV

5. Failure to laterally follow the defined missed approach route segment as provided by the procedure

6. Failure to properly sequence traffic arriving from different IAF (different approach procedures) such that separation will be lost if no further tactical intervention is performed

7. Failure to properly space aircraft using the same approach procedures such that separation will be lost during the RF-turn or if an aircraft is catching up on the same approach

8. Failure to properly manage traffic (any other traffic) that have a route that crosses the approach procedure route such that separation may be lost

9. Failure to properly manage separation of an aircraft executing a missed approach with other traffic

10. Failure to properly manage separation of an aircraft executing a company contingency procedure (the contingency procedure required in accordance with EASA AMC 20-28)

A.1.1.2.8.1.1 Failure to laterally follow the defined route segment as provided by the procedure

This hazardous situation can be caused by several elements; aircraft, air crew, Navigation Service, Aeronautical Information Service, and other handling of navigation data. If the route segment has a purpose to separate the aircraft from other traffic, (including restricted airspace), the lateral deviation may cause loss of traffic separation – however, it is assumed here that the route will not have this purpose. Nevertheless, the route is assumed to have a purpose of ensuring terrain separation. When assessing the severity of this hazard, IMC condition and terrain/obstacles have to be assumed to be present. Applying procedure design criteria ensure terrain/obstacle separation when the Hazard does not occur, but that does not take into account the failure situation the hazard describes. The severity of the described situation will vary significantly between different aerodromes depending on the surrounding terrain and obstacles. If there is no terrain or obstacles in the vicinity, a lateral deviation will have only a minor safety effect. However, if the route is placed such as to avoid terrain or obstacles, a lateral deviation will be a much more severe situation. Due to this, this Hazard is split into two, according to the two aerodrome environments. One environment is non-mountainous and no obstacles, and the other is mountainous and/or obstacle rich. So far, no clear definition to distinguish the two environments has been established, but one suggestion to distinguish between them could be the PANS-OPS definition (Volume II Part I Chapter 1 page I-1-1-6) which can be used to indicate a mountainous environment. This would indicate the classification of an obstacle, and therefore where a Hazard is induced. Any type of obstacle, terrain or man-made, which would dictate an action from either the crew or the ATCO, should be considered. It is recommended that in detailed safety assessments of specific procedure implementations, more detailed analysis of the terrain environment is considered.

Using the Risk Classification Scheme from the SRM guidance [26], a lateral deviation in a non-mountainous (and no obstacles) environment will be less severe than the lowest CFIT severity class, CFIT-SC3(b) (“A situation where a controlled flight towards terrain is prevented by pilot tactical CFIT resolution (flight crew monitoring)”). Assessing the severity to be less than CFIT-SC3(b), there will be no need to specify a quantitative integrity Safety objective for the Hazard, as in such a situation the probability of a deviation resulting in flight toward terrain is very low. A lateral deviation which does not result in flight toward terrain would not be a hazard in the context of CFIT. Therefore the hazard has been set to a situation where the flight is commanded toward terrain, and assessed as CFIT-SC3(b).

Using the Risk Classification Scheme for the situation that the environment is mountainous (or obstacles exists) it is evident that the obstacle clearance could be lost, and the severity category will be CFIT-SC2. Initially it was considered that the severity could be bordering to CFIT-SC1 if the procedure has been specifically implemented to enable approaches near terrain/obstacles. However this was not considered credible, as there is no situation whereby protection limits are so small that airborne avoidance (e.g. TAWS) does not have time to intervene. If a procedure with such limited buffers were designed, it would not be allowed by ICAO PANS-OPS. Therefore the worst credible situation is CFIT-SC2.

The use of RF-turn is also contributing to the consequential severity. A loss of aircraft navigation function (system failure, GNSS signal failure or interference) is more likely to result in lateral deviation in a turn, than for a straight segment where maintaining heading will be possible and therefore reducing the lateral deviation. High airborne centre-line integrity through compliance with standards is therefore required for RF-turn.

The justification to divide this Hazard into two, based on the aerodrome environment is to not put too strong Safety Objective on situations where it is not deemed necessary (i.e. less mountainous environments and obstacle-free zones).

A.1.1.2.8.1.2 Failure to vertically follow the defined route minimum altitudes (MOCA) as provided by the procedure

Most aircraft today have a way of managing the vertical energy state during descent. All pilots learn to manage and supervise the descent profile for its aircraft manually. In modern large aircraft the management is typically achieved through a Flight Management Computer (FMC), while smaller type aircraft have a less sophisticated type of computer, and in some cases small light aircraft where the pilot will use established rule of thumb to manage the vertical path.

In a CDA/CDO the aircraft vertical management computer (Flight Management Computer) will optimize the vertical profile the aircraft must follow, considering the Flight Plan altitude and speed constraints. For a CDO, there is no general defined vertical route that is valid for all aircraft types or groups. For a specific procedure, the MOCAs in that procedure will protect all aircraft flying the procedure from infringement of obstacles. The hazard in this case is related to the pilot or the FMC (failure) to follow correctly the vertical defined profile and then respect the MOCAs in the procedure. If the aircraft continues below the MOCA, there will be an obstacle clearance infringement, and according to the SRM guidance [26] “A situation where an imminent CFIT is prevented by ATC CFIT avoidance” which is classified as CFIT-SC3(a). It is considered that this hazard is no different than current approaches today. When the crew detects the situation, they will stop the descent and start a climb or initiate a go-around as a result of this situation.

If each aircraft flying the procedure shall adhere to CDO optimized paths, there will not be two identical paths, (due to difference in aircraft weight, wind, pressure and temperature), giving ATC a difficult job to effectively manage the traffic in the vertical plane (both for arrival and departure), but they can, and are today, monitoring the conformance of aircraft staying above the MOCA for procedures in use.

A.1.1.2.8.1.3 Failure to fly the approach stabilized/ Flying a Non-stabilized approach

Three essential parameters need to be stabilized for a safe approach:

- Aircraft Track;
- Flight path angle; and
- Airspeed

If any one of these parameters is out of tolerance, and the approach is continued, an approach or landing accident may happen. It is shown that a non-stabilized approach has a casual factor in 40% of all approach and landing accidents.[2]

Since the aircraft track and flight path angle will constantly be changing in an RF-turn, the question will then be if there is a higher probability of having a non-stabilized approach as a result? A typical operational effect of a non-stabilized approach will be to call-out and correct the exceeded parameter, competency that will allow for a go-around, and only continue the landing if it can be determined that it will be safe to continue.

If the procedure is very challenging, there is a possibility that the pilot will have increased workload in the last part of the procedure, namely the approach phase, especially when familiarising with the procedure. If this pilot is task saturated, the possibility of a non-stabilized approach is higher than normal.

Provided the aircraft FMS provides the pilots with indication of correct vertical profile in relation to distance to go (aircraft energy level using altitude, airspeed, wind and aircraft weight), the crew will have possibility to avoid non-stabilized approaches through energy management of the aircraft.

It is noted that energy management is more challenging to pilots on curved paths than straight paths as they are typically not as familiar with them. This will especially be the case with the coupling of a CDO (which also impacts aircraft energy management compared to current operations). These issues are principally treated through training and familiarisation.

The classification of this hazard is not quantified, as the lowest severity class CFIT-SC3(b) was assessed to be too severe for this situation. However the objective should be that this hazard occurrence should be no more frequent for ADV-APV compared to other approaches.

A.1.1.2.8.1.4 Failure to change mode from ADV-APV (LNAV+CDO /RF-turn) to LPV

When flying an approach to land, the aircraft should transition from the navigation modes “LNAV/VNAV” to the final approach “LPV” mode, when the aircraft is within some specified approach parameters. The avionics in aircraft today (may) require the crew to manually change or arm the mode from lateral & vertical navigation modes to the final approach mode, which again changes the configuration of the auto flight system. If this change does not happen, the aircraft will continue in lateral & vertical navigation modes, and the auto flight system will be guided according to that mode. The effect of this could be that the aircraft does not capture the LPV Final Approach Segment, and will continue the approach without it. That will put both the crew and the aircraft in the wrong “configuration” for landing, with a potential go-around situation, or worse, ending up with a non-stabilized approach. See the above discussion on non-stabilized approach.

For the ADV-APV concept, the lateral navigation includes a potential RF-turn, together with a CDO, directly linked to the LPV final approach segment. The final approach mode “LPV” must engage only following criteria to avoid unexpected early capture of the LPV final approach segment by-passing the upstream turn. When these criteria are met, the aircraft will then be flying the final approach as

[2] Source: Flight Safety Foundation Flight Safety Digest Volume 17 & 18 – November 1998 / February 1999

defined. It is assessed that this hazard is no different for ADV-APV approaches than for approach types of today.

High airborne avionics integrity through compliance with standards is therefore required.

The classification of this hazard is the lowest severity class CFIT-SC3(b), based on the worst credible case that the flight crew could fail to recognise that there should have been a change from LNAV/VNAV to LPV. This could lead to a degradation of navigation accuracy and in cases of extreme degradation the potential loss of separation with terrain (or at least the safety margin).

A.1.1.2.8.1.5 Failure to laterally follow the defined missed approach route segment as provided by the procedure

In addition to the rationale provided in A.1.1.2.8.1.1 for the main procedure, this situation is slightly worse than in the initial phase, as missed approach can be performed due to aircraft failures (engine failure etc.). However, conversely, the aircraft might have a higher speed and is already climbing and therefore moving away from the obstacle.

Minima for the approach may depend on the missed approach climb requirements. By having RF legs during missed approach (final segment) the minima for the approach may be lower than for a conventional approach. The inability to follow lateral track due to system failures must therefore be carefully assessed for all these approaches/missed approaches.

The severity classification is the same as deviation between IAF and FAP.

A.1.1.2.8.1.6 Failure to properly sequence traffic arriving from different IAFs (different approach procedures), such that separation will be lost if no further tactical intervention is performed

The sequencing of traffic is instrumental in air traffic services, so that it can provide efficient, expeditious and safe flow of aircraft. The optimum sequencing of the traffic is dependent upon the separation criteria which are applied in the airspace. In a given airspace, there will typically be more than one approach procedure so that an optimum flow of aircraft can be achieved. ATC will use the sequencing of traffic from different procedures to optimize the flow of traffic into and out of a given airspace, and in such airspace ATC will use radar and/or radar vectors to achieve this if necessary. When radar and/or radar vectors are not an option, procedure control can be utilized to achieve the same result, but with the penalty of an increase in separation, and thereby a less efficient service.

The hazard manifests itself in that if ATC do not issue any tactical interventions other than speed control after IAF, the risk of losing separation between two aircraft on procedures converging from two different IAFs is obvious.

The severity differs for situations where radar vectoring, and/or ‘Direct to’ instructions can be performed and situations where radar vectoring, and/or ‘Direct to’ instructions cannot be performed. Minimum Vectoring Altitude for the aerodrome may restrict the vectoring possibility.

This would lead to a severity classification of MAC-SC4a (MAC RCS from the SRM guidance [26]). The Tactical Conflict Resolution barrier will be weaker than normal. This should be taken into account when designing the airspace functions.

A.1.1.2.8.1.7 Failure to properly space aircraft using the same approach procedures such that separation will be lost during

the RF-turn or if an aircraft is catching up on the same approach

ATC systems of today have different types of conflict alert algorithm, but they all use slant range for calculating separation criteria. For ADV-APV procedures, RF-turn is a novelty for the concept. If two or more aircraft are cleared to use the same procedure assuming that the separation criteria are obeyed, there could be a loss of separation between two aircraft following each other in the RF-turn, just because the ATC system does not take into account the track distance between the aircraft, instead it uses the slant range between them. This will lead to a “loss of separation” alarm. This is per Doc 4444 for loss of separation situation.

The second part of the hazard originates from different speed between two aircraft. As said before, the airspeed for two different aircraft may vary significantly. Dependent upon the weight, wind, air pressure and temperature, aircraft CDO calculation may result differently, and therefore the speed for which the aircraft is intended to hold may differ. If the speed between two aircraft on the same approach is different, the tactical solution is to apply speed control. If speed control is applied during the approach, the optimum descent path of the aircraft will be affected (provided the speed restriction is not known prior to the TOD).

The severity classification of this hazard will then by nature be divided into two:

- firstly where the RF-turn there are very little airspace or terrain limitations it will not have any direct impact at all. Although alerting will need to be by exception (i.e. regular false alarms are not a safety enhancement);
- secondly as a result of a planned conflict, and by definition from MAC RCS from the SRM guidance [26], it would constitute as a MAC-SC4b.

A.1.1.2.8.1.8 Failure to properly manage traffic (any other traffic) that has a route that crosses the approach procedure route such that separation may be lost

In a fully optimized Continuous Descent Operation, ATC should not interfere with the vertical or the horizontal trajectory of the aircraft, so once the aircraft has started on the descent to the LPV approach it will follow this optimized path. It is clear that if the complexity and density of the airspace and traffic is high, the demand for accurate planning of arrival and departure will be higher than it is today. Even for a less complex airspace and lower traffic volumes, the need for accurate planning will be higher than it is today.

One way of mitigating this situation is by holding departing traffic longer on the ground, so that the picture will be less complex for the ATC to manage. Airspace design around airports is essential for the optimum management of departing and arriving traffic. Departure and arrival routings should be constructed so as to allow aircraft to follow a best possible optimal lateral and vertical profile, and at the same time being separated to avoid conflicts.

If the planning process leads to a planned conflict, it will constitute to a MAC-SC4b classification.

A.1.1.2.8.1.9 Failure to properly manage separation of an aircraft executing a missed approach with other traffic

The missed approach segment of the ADV-APV concept can contain a RF-turn if needed. The RF-turn in the missed approach segment is what separates the ADV-APV with a conventional missed approach. All missed approaches will affect the way ATC is conducting traffic management. For a conventional missed approach, the ATC will plan for a missed approach so that the next approaching or departing aircraft will not constitute an added element of unpredictability. Usually this will not constitute a problem as long as each aircraft is following the missed approach procedure, and tactical intervention can be made to other aircraft (the next approach or departing aircraft).

As stated in the OSED, the novelty for designing a RF-turn in the final segment of a missed approach may come from the motivation of having lower approach minima, better efficiency (i.e. shorter track-miles), a safer track in obstacle rich environments, and for avoiding other arriving or departing traffic. ATC will not be able to give any radar vectoring in this case (RF-turn missed approach), which will restrict the options an air traffic controller have to make tactical interventions. This means that the controller must increase the separation between other potential conflicting aircraft to contain the same safety level as a conventional missed approach.

This is concerned with planning and managing the traffic into and out of a given airspace. According to the classification scheme this constitutes to a MAC-SC4b.

A.1.1.2.8.1.10 Failure to properly manage separation of an aircraft executing a company contingency procedure (the contingency procedure required by AMC 20-28)

According to AMC-20-28 (Annex II to ED Decision 2012/014/R of 17/09/2012) Annex 3 chapter 2 “Abnormal Procedures”, “In case of a complete RNAV guidance loss during the approach, the crew must follow the operator defined contingency procedure.” In this case a complete loss of RNAV guidance is classified as a major failure condition, and the consequence for the aircrew is to initiate a go around according to the company contingency procedure. For ATC, the only type of missed approach procedures that are known, and available, are the published missed approach procedures. The point or time at which the contingency is executed will affect the controller’s ability to manage such a procedure. This could result in a loss of separation due to the unpredictability aspect of a contingency procedure. The RF-turn may induce extra workload for both the pilot and the controllers, so there is a higher probability that the controller will lose situational awareness and in turn affect the management of separation between aircraft executing contingency procedures and other aircraft in the same airspace.

In addition, a contingency procedure in relation to engine failure during take-off is defined by the operator, and may not be known by ATC. In this situation the ATC controllers may not be fully aware of the intentions of the crew, therefore possibly jeopardizing separation criteria to other traffic.

This will constitute to a MAC-SC3 classification.

A.1.1.2.8.1.11 Summary of hazards

The following table summarises the analysis described above:

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
Hz001a	Failure to laterally follow the defined route segment as provided by the procedure in non-mountainous and obstacle free environment resulting into controlled flight toward terrain Non-mountainous environment could be defined by a change in elevation of less than 3000 feet in 10 nm	SO 001 SO 002 SO 004	Assumption: No conflict with protected areas, and procedure not design to separate from other traffic/sectors There will be terrain and obstacle separation. Traffic separation may be affected If RNP has been used to separate with traffic inside special airspace areas , the consequence can also be conflict with other traffic / airspace infringement Flying RNP in non-obstacle environment, the severity is low.	Go around, with contingency procedures, TAWS, CRM, procedures,	CFIT-SC-3b or less
Hz001b	Failure to laterally follow the defined route segment as provided by the procedure in mountainous or obstacle environment resulting into controlled flight toward terrain Mountainous environment could be	SO 001 SO 002 SO 004	Separation with terrain can no longer be assured.	Go around, with contingency procedures, TAWS, CRM, procedures, The flight crew must initiate a contingency procedure. This procedure will include a climb	CFIT-SC-2

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
	defined by; by a change in elevation of more than 3000 feet in 10 nm			to or above MSA in the sector using a method that giving best chances (using all available means) for terrain separation. If the aircraft navigation system is no longer able to provide the required navigation guidance of the selected procedure (ex RF-turn), other means to navigate away from terrain must exist, for example a turn to follow a track to ensure terrain separation. Risk mitigation in the form of preventing the hazard occurrence could be needed. RNP-AR is used in similar environment, and RNP-AR mitigation means could be used.	
Hz 002	Failure to vertically follow the defined route minimum altitudes (MOCA)as provided by the procedure resulting into controlled flight toward terrain	SO 001 SO 003 SO 004	The operational effect is that separation with terrain will no longer be guaranteed. There is also a possibility of confusion in the situational awareness picture for the pilots, which might lead to a high workload	Go around, with contingency procedures, TAWS, CRM, procedures	CFIT-SC3a

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
			in cockpit. The hazard is related to the CDO concept, and not to the navigation service, since the CDO is based on barometric altitude and vertical navigation calculation performed by the aircraft on board FMS Can sometimes go below the optimum profile given by the FMS, but never below defined minimum altitudes Considered to be no different than other current approaches. Will stop decent and climb.		
Hz 003	Failure to fly the approach stabilized/ Flying a Non-stabilized approach	SO 007	The operational effect is that the aircraft and crew will not be in the correct operational state, according to procedures, with a higher work load for both the flight crew and the air traffic controller(s) as a consequence	Possible go around.	Not quantified (Lower than CFIT-SC-3b)

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
Hz 004	Failure to change mode from ADV-APV (LNAV+CDO /RF-turn) to LPV	SO 006	The operational effects of this will be that the approach will either be abandoned or it will be continued. The flight crew may fail to recognize that there should have been a change from LNAV|VNAV to LPV so that the procedure is flown and continued in LNAV|VNAV. The effect of that is a degradation of navigation accuracy. The pilot will stop the descent, and then must decide whether to re-intercept or go-around As today with ILS.	Go around	CFIT-SC-3b The severity of abandoning the approach at FAP or delayed until DA, will be low and will be the same as doing a missed approach due to insufficient visibility for a landing
Hz005a	Failure to follow laterally the defined missed approach route segment as provided by the procedure <u>in non-mountainous</u> environment resulting into controlled flight toward terrain	SO 001 SO 002 SO 008 SO 011	If the aircraft reaches MSA before the final missed approach segment, the operation effect will only be that conflict with other traffic may occur.		CFIT-SC-3b

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
Hz005b	Failure to follow laterally the defined missed approach route segment as provided by the procedure in mountainous environment resulting into controlled flight toward terrain	SO 001 SO 002 SO 008 SO 011	As with the failure to follow the RF-turn in the initial and intermediate approach segments, the operational effects will be that separation with terrain is no longer ensured. If a missed approach is initiated due to a situation during final approach where the capability to perform the required navigation is lost, the operational effect will still be a go around, but on the basis that the crew can navigate with other means. This will also result in this Hazardous situation, but the probability that the severity will be high, is also higher Slightly worse than in the initial phase, as missed approach can be performed due to aircraft failures (engine failure etc.). Margins are increased procedurally.		CFIT-SC2
Hz 006	Failure to properly sequence traffic arriving from different IAF (different	SO 009	The severity differs for situation where radar	Radar vectoring procedures and proficiency. Avionics that	MAC-SC4a.

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
	approach procedures) such that separation will be lost if no further tactical intervention is performed	SO 010	vectoring, and/or 'Direct to' instructions can be performed and situation where radar vectoring, and or 'Direct to' instructions cannot be performed. Minimum Vectoring Altitude for the aerodrome may restrict the vectoring possibility.	handle ADV-APV discontinuation and reversion to heading and LPV intercept from heading.	
Hz 007	Failure to properly space aircraft using the same approach procedures such that separation will be lost during the RF-turn or if an aircraft is catching up on the same approach	SO 009 SO 010	The operational effect of lost separation criteria in the RF-turn, will be that the ATC system will administer a warning. The STCA systems use slant range, not radius. Must be verified from ATC point of view.	Apply speed control. The geometry of a turn is such that separation will not continue to decrease in the turn.	MAC-SC4b
Hz 008	Failure to properly manage traffic (any other traffic) that have a route that crosses the approach procedure route such that separation may be lost	SO 009 SO 010	*The tactical conflict should be solved by instructing the all "types" of traffic.*	Mitigation can be to hold departure on ground until the conflict is resolved, to design SID that takes the departing traffic outside the inner part of the STAR, or to ensure vertical separation or radar vector of the departing traffic. All this is mitigating the	MAC-SC4b

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
				cause	
Hz009	Failure to properly manage separation of an aircraft executing a missed approach with other traffic.	SO 008 SO 011	Causes can be that there are many MA depending on the procedure ADV or something else A missed approach is slightly worse to predict than an arrival versus a departure, as the missed approach may not be able to comply.	ATS local instructions take into account the different MA that exists.	MAC-SC-4a
Hz010	Failure to properly manage separation of an aircraft executing a company contingency procedure (the contingency procedure required by AMC 20-28	SO 008 SO 011	Contingency procedures may be different than official MA procedures, and may not be known by ATC	ATS must be aware of the different contingency procedures	MAC-SC-3

Table 4-7: System-Generated Hazards and Analysis

No additional safety objectives (functionality and performance) were identified as a result of the system generated risks.

A.1.1.2.8.2 Derivation of Safety Objectives (integrity/reliability)

Below the integrity and reliability based SO based on the Hazards in Table 4-7, and based on the proposed severity classification.

The SESAR guidance [26] proposes a modification factor to take into account of the Number of aircraft exposed to the operational hazard. This has not been used for any situation in this assessment, as in all cases there is one aircraft, or one incident which is the subject of the hazardous situation, and therefore there is no justification for using a modification factor other than 1.

MTFoO = Maximum Tolerable Frequency of Occurrence, for CFIT hazards this is per flight, whereas for MAC hazards the frequency is defined per flight hour. Again this is directly taken from SESAR guidance [26].

Severity Class	***Hazardous situation***	***Operational Effect***	***MTFoO [per flgt]***	***# Haz***	***Max tolerable frequency of Hazard occurrence (/flt)***
CFIT-SC1	A situation where an imminent CFIT is not mitigated by pilot/airborne avoidance and hence the aircraft collides with terrain/water/ obstacle	CFIT Accident (CF2) Near CFIT (CF2a)	1e-8	5	2e-9
CFIT-SC2	A situation where a near CFIT is prevented by pilot/airborne avoidance	Imminent CFIT (CF3)	1e-6	10	1e-7
CFIT-SC3a	A situation where an imminent CFIT is prevented by ATC CFIT avoidance	Controlled flight towards terrain (CF4)	1e-5	50	2e-7
CFIT-SC3b	A situation where a controlled flight towards terrain is prevented by pilot tactical CFIT resolution (flight crew monitoring)	Flight towards terrain commanded (CF5-8)	1e-5	50	2e-7

Table 4-8. CFIT Safety Objective classification scheme. Based on SRM [26] appendix E.

Severity Class	***Hazardous situation***	***Operational Effect***	***MTFoO [per fh]***	***# Haz***	***Max tolerable frequency of Hazard occurrence (/flt)***

Severity Class	Hazardous situation	Operational Effect	MTFoO [per fh]	# Haz	Max tolerable frequency of Hazard occurrence (/flt)
MAC-SC1	A situation where an aircraft comes into physical contact with another aircraft in the air.	Accident - Mid air collision (MF3)	1e-9	1	1e-9
MAC-SC2a	A situation where an imminent collision was not mitigated by an airborne collision avoidance but for which geometry has prevented physical contact.	Near Mid Air Collision (MF3a)	1e-6	5	2e-7
MAC-SC2b	A situation where airborne collision avoidance prevents near collision	Imminent Collision (MF4)	1e-5	10	2e-6
MAC-SC3	A situation where an imminent collision was prevented by ATC Collision prevention	Imminent Infringement (MF5-8)	1e-4	25	4e-6
MAC-SC4a	A situation where an imminent infringement coming from a crew/aircraft induced conflict was prevented by tactical conflict management	Tactical Conflict (crew/aircraft induced) (MF6.1)	1e-3	30	3.3e-5
MAC-SC4b	A situation where an imminent infringement coming from a planned conflict was prevented by tactical conflict management	Tactical Conflict (planned) (MF5.1)	1e-2	30	3.3e-4
MAC-SC5	A situation where, on the day of operations, a tactical conflict (planned) was prevented by Traffic Planning and Synchronization.	Pre tactical conflict (MF5.2)	1e-1	100	1e-3

Table 4-9 MAC Safety Objective classification scheme. Based on SRM [26] appendix E.

Based upon the Table 4-8. and 10 above, the classification of each hazard's maximum tolerable frequency occurrence will then be as shown below:

ID	Safety Objectives	Hz ID
SO 016	The probability of not laterally follow the defined route segment as provided by the procedure in non-mountainous environment resulting into controlled flight toward terrain shall be less than 2 $x10^{-7}$ per Approach (CFIT-SC-3b severity class)	Hz 001a
SO 017	The probability of not laterally follow the defined route segment as provided by the procedure in mountainous or obstacle environment resulting into controlled flight toward terrain shall be less than 1 $x10^{-7}$ per Approach (CFIT-SC-2 severity class)	Hz 001b
SO 018	The probability of not vertically follow the defined route minimum altitudes (MOCA) as provided by the procedure resulting into controlled flight toward terrain shall be less than 2 $x10^{-7}$ per Approach [CFIT-SC-3a]	Hz 002
SO 019	The probability of not being able to perform a stabilized approach shall not increase for ADV-APV compared to LPV [This is not quantitative, as the severity is lower than CFIT-SC3b defined in the AIM based RCS model, and by such is not defined to be quantitative. The objective is still to limit non-stabilised approach occurrences to the current level, and has been quantified on a bottom up process]	Hz 003
SO 020	The probability of not being able change mode from LNAV to LPV shall be less than 2 $x10^{-7}$ per Approach (CFIT-SC-3b)	Hz 004
SO 021	The probability of not laterally follow the defined missed approach route segment as provided by the procedure in non-mountainous environment resulting into controlled flight toward terrain shall be less than 2 $x10^{-7}$ per Approach (CFIT-SC-3b)	Hz 005a
SO 022	The probability of not laterally follow the defined missed approach route segment as provided by the procedure in mountainous or obstacle environment resulting into controlled flight toward terrain shall be less than 1 $x10^{-7}$ per Approach (CFIT-SC-2 severity class)	Hz 005b
SO 023	The probability of not properly sequence traffic arriving from different IAF (different approach procedures) such that separation will be lost if no further tactical intervention is performed shall be less than 3.3 $x10^{-5}$ per flight hour (MAC-SC-4a severity class)	Hz 006
SO 024	The probability of not properly space aircraft using the same approach procedures such that separation will be lost during the RF-turn or if an aircraft is catching up on the same approach shall be less than 3.3 $x10^{-4}$ per flight hour (MAC-SC-4b severity class)	Hz 007
SO 025	The probability of not properly manage traffic (any other traffic) that have a route that crosses the approach procedure route such that separation may be	Hz 008

	lost shall be less than 3.3 x10^{-4} per flight hour (MAC-SC-4b severity class)	
SO 026	The probability of not managing separation of an aircraft executing a missed approach with other traffic shall be less than 3.3 x10^{-5} per flight hour (MAC-SC-4a severity class)	Hz 009
SO 027	The probability of not managing separation of an aircraft executing a company contingency procedure with other traffic shall be less than 4 x10^{-6} per flight hour (MAC-SC-3 severity class)	Hz 010

Table 4-10: Safety Objectives (integrity/reliability)

A.1.1.2.9 Impacts of ADV-APV operations on adjacent airspace or on neighbouring ATM Systems

The CDO concept will impact adjacent airspace since the TOD position may be located well inside the adjacent airspace. If it does not take into consideration that aircraft utilizing CDO may require more airspace than conventional descents, it may cause conflicts later in the procedure.

ID	Description	Related SAC
SO 028	Adjacent airspace shall be designed so it will not negatively affect the use of CDO in ADV-APV airspace	SAC#7

Table 4-11: Additional Safety Objectives (functionality and performance) for Compatibility

A.1.1.2.10 Achievability of the SAfety Criteria

See section A.1.1.3.7.

A.1.1.2.11 Validation & Verification of the Safety Specification

In the process in deriving the Safety Objectives, two workshops were arranged; the first (WS1) in Eurocontrol Brétigny with safety experts and ATC/PANS OPS procedure design experts, while the second workshop (WS2) was in Oslo. This was arranged with airspace users for the purpose of identifying the severity of the hazards and analysing the hazards themselves.

The results of both WS1 and WS 2 were distributed for participant internal review and comments.

There was also a formal review with the wider project members after each update of the document. All comments from the reviews have been addressed through the document updates.

The following list provides the name and role of project members and airspace users:

Bruno Rabiller / EUROCONTROL	Project 16.6.1 Safety Expert
Hans Christian Erstad/NORACON	Project Member/Safety Expert
Harald Roen/NORACON	Project Member/Safety Expert
Jean-Yves Bain/Thales	Project member
De Andrés Díaz, Javier /ENAIRE	Project member
Salvatore Carotenuto /ENAV	Project member

César Pérez Arana / ENAIRE	Project member
Terence Ngai / NATS	Project member
Patrice Rouquette / Airbus	Project member
Klaus-Peter Sternemann / AOPA Germany	Pilot
Ingolf Tischoff / tuifly	Pilot B737
Sigmund Lockert /CHC – EHA	Pilot helicopter S92
Serge Lebourg / EBBA	Safety Expert Dassault Aviation
Andreas Linnér, / NOVAIR	Pilot A321

Table 4-12: Reviewers of original safety objectives

Following the subsequent safety analysis, the safety objectives were revisited and have been adapted. This took place over the course of a workshop (21st April 2015) and web conference (8th June 2015) involving project members and WP16.6.1 representatives. These were then reviewed as part of this document review process, by the following:

De Andrés Díaz, Javier /ENAIRE	Project member
César Pérez Arana / ENAIRE	Project member
Miguel Capote Fernandez / INECO	WP16.6.1 Safety Expert
Raquel Chinea Delgado / INECO	WP16.6.1 Safety Expert
Andrew Burrage / Helios (NORACON)	Interim SPR task lead
Philip Church / Helios (NORACON)	Safety and concept Expert
Glen Smith / Helios (NORACON)	Safety Expert

A.1.1.3 Safe Design at SPR Level

A.1.1.3.1 Scope

Based on the safety assurance activities defined in the safety plan, the following section addresses the following activities with regard to the ADV-APV concept:

- A description of why a functional model is not required within the context of this project – Section 3.2
- A description of the SPR level model of the ADV-APV system including identification of aircraft and ground based elements in addition to external entities – Section 3.3
- The derivation, from the Functionality and Performance Safety objectives, of the Functional Safety Requirements (success approach) for the ADV-APV SPR level design. This includes a mapping onto the related SPR model level elements – Section 3.3.3
- Analysis of the operation of the SPR level design under normal operational conditions – Section 3.4
- Analysis of the operation of the SPR level design under abnormal operational conditions (such as extreme inclement weather) – Section 3.5
- Design Analysis and justification that the SAfety Criteria will be satisfied on implementation – Section 3.6 and 3.7.

- Realism of the SPR level ADV-APV design – Section 3.8
- Validation and verification of ADV-APV concept operations – Section 3.9

A.1.1.3.2 The 02.01.01 OFA Functional Model

The Functional Model is a high level, abstract representation of the OFA System functionality that describes what safety-related functions are performed and the data that is used by, and produced by those safety functions. This model facilitates the bridging between the OSED level and the SPR level for OFA where a high level of abstraction is necessary because for instance the concept is not sufficiently mature to decide if the function will be supported by a machine based function or by human.

The ADV-APV SBAS OFA has reached a level of maturity where this intermediate Model is not required. Therefore the Functional Model activity has been bypassed in this safety assessment and instead the SPR-level model has been developed directly. This is consistent with the approach taken in Phase 1 of the project.

A.1.1.3.3 The 02.01.01 OFA SPR-level Model

The SPR-level Model in this context is a high-level architectural representation of the project system design that is entirely independent of the eventual physical implementation of the design. The SPR-level Model describes the main human tasks, machine functions and airspace design. In order to avoid unnecessary complexity, human-machine interfaces are not shown explicitly on the model – rather they are implicit between human actors and machine-based functions. This is also the case for procedural elements, which implicitly represented within the human actors (who implement said procedures).

The following definition of the terms used in the logical SPR model is presented below.

Term	Definition	Where defined
ATM/ANS	ATM/ANS” shall mean the air traffic management functions as defined in Article 2(10) of Regulation (EC) No 549/2004, air navigation services defined in Article 2(4) of that Regulation, and services consisting in the origination and processing of data and formatting and delivering data to general air traffic for the purpose of safety-critical air navigation;	Regulation EC No 1108/2009
AIS	aeronautical information service’ means a service established within the defined area of coverage responsible for the provision of aeronautical information and data necessary for the safety, regularity, and efficiency of air navigation;	EC Regulation 549/2004
ANS	‘air navigation services’ means air traffic services; communication, navigation and surveillance services; meteorological services for air navigation; and aeronautical information services;	EC Regulation 549/2004
ANSP	‘air navigation service providers’ means any public or private entity providing air navigation services for general air traffic;	EC Regulation 549/2004
ASM	‘airspace management’ means a planning function with the primary objective of maximizing the utilization of available airspace by dynamic time-sharing and, at	EC Regulation 549/2004

	times, the segregation of airspace among various categories of airspace users on the basis of short-term needs;	
AFTM	'air traffic flow management' means a function established with the objective of contributing to a safe, orderly and expeditious flow of air traffic by ensuring that ATC capacity is utilized to the maximum extent possible, and that the traffic volume is compatible with the capacities declared by the appropriate air traffic service providers;	EC Regulation 549/2004
ATM	'air traffic management' means the aggregation of the airborne and ground-based functions (air traffic services, airspace management and air traffic flow management) required to ensure the safe and efficient movement of aircraft during all phases of operations;	EC Regulation 549/2004
ATS	'air traffic services' means the various flight information services, alerting services, air traffic advisory services and ATC services (area, approach and aerodrome control services);	EC Regulation 549/2004
ATC	'air traffic control (ATC) service' means a service provided for the purpose of: (a) preventing collisions: — between aircraft, and — in the manoeuvring area between aircraft and obstructions; and (b) expediting and maintaining an orderly flow of air traffic;	EC Regulation 549/2004
COM	'communication services' means aeronautical fixed and mobile services to enable ground-to-ground, air-to - ground and air-to-air communications for ATC purposes;	EC Regulation 549/2004
MET	'meteorological services' means those facilities and services that provide aircraft with meteorological forecasts, briefs and observations as well as any other meteorological information and data provided by States for aeronautical use;	EC Regulation 549/2004
SUR	'surveillance services' means those facilities and services used to determine the respective positions of aircraft to allow safe separation;	EC Regulation 549/2004
ASD	Airspace structures and flight procedures shall be properly designed, surveyed and validated before they can be deployed and used by aircraft.	EC Regulation 1108/2009

A.1.1.3.3.1 Description of SPR-level Model

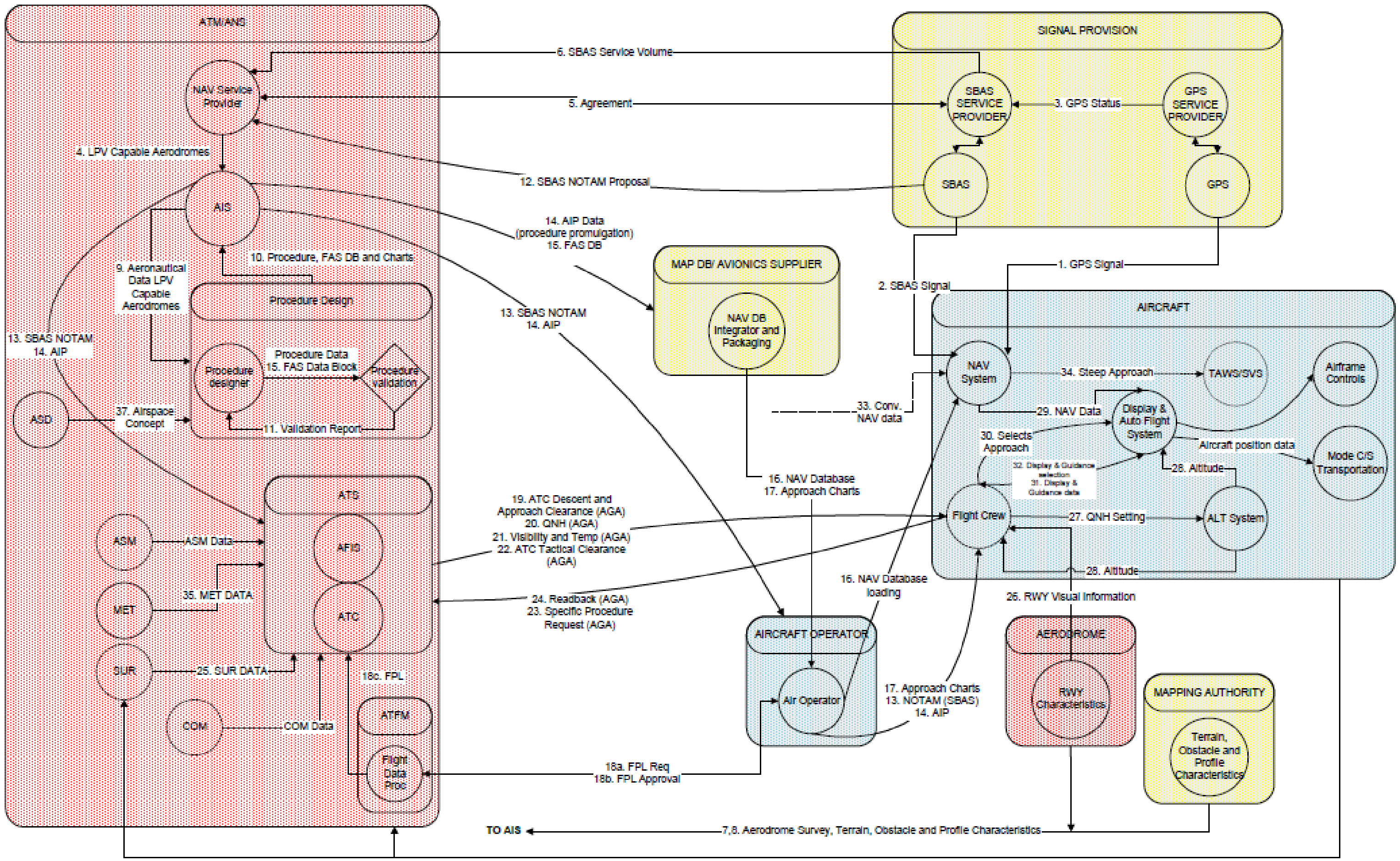
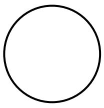
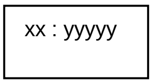


Figure 4-3: 02.0.2.04 OFA SPR-level Model

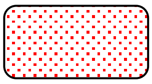
The symbols used in the logical model are as follows:

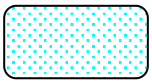

Operational node: could be a machine-based element, a human element or a combination of the two.

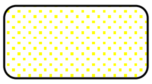

Needline: indicate a required data flow between nodes

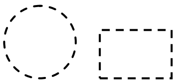


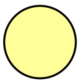
Needline information: indicate the type of required flow between nodes

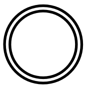

Set of operational nodes associated to Air Navigation Services Area


Set of operational nodes associated to the airspace users


Set of external operational nodes


Optional node and/or data flow


External node


Human actor

A Description of the ADV-APV approach SPR-level Model is made in subsections below by identifying and describing all information exchanges that make up all information need lines between operational nodes. The tables identify who exchanges what information, with whom, why the information is necessary, and with what quality (requirements) the information exchange must occur.

A.1.1.3.3.1.1 Aircraft Elements

The aircraft elements in the SPR-level model are the following:

Information item #	Description/Content	Usage	Sending node	Receiving node	Requirements
27	QNH setting / altimeter setting for approach	To provide to the altimeter system the QNH setting	Flight crew	Alt Sys	-EASA AIR OPS -EASA AMC 20-28
28	Altitude / indication of the aircraft baro altitude	To indicate the baro-altitude during the approach. To materialize the DA/H for the decision to land	Alt Sys	Flight crew	-EASA AMC 20-28
29	Nav data / Transmission of the ADV LPV, LPV path to be flown, lat/vert deviations and indication of the status of the LPV approach capability	To provide to the Display & guidance system the LPV path to be flown (extracted from the airborne navigation database) along with lateral & vertical deviations with regards to this path and the status of the LPV approach capability	NAV System	Display & guidance	EASA AMC 20-28
30	Selected ADV LPV procedure	To provide to the airborne navigation system the arrival/approach to be flown (corresponding to the selected runway end)	Flight crew	NAV System	EASA AMC 20-28
31	Display & guidance data / indication of all data relevant for ADV LPV operations in manual or automatic guidance	To indicate the ADV LPV data provided by the NAV system (e.g. ADV LPV path, lateral & vertical deviations ARPT ID, Path ID, distance to the runway threshold and LPV approach capability status)	Display & guidance	Flight crew	EASA AMC 20-28 RTCA DO229D
32	Display/guidance selection	To provide to the Display & Guidance system the necessary information (e.g. selection of the autopilot or flight director mode)	Flight crew	Display & guidance	EASA AMC 20-28

Information item #	Description/Content	Usage	Sending node	Receiving node	Requirements
33	Conv nav data (optional) / Indication of the conventional navigation information	To provide to the Display & guidance system the necessary information from the “conventional” navigation system including speed / altitude / heading / vertical speed and whenever required from the radio navigation system (e.g if missed approach is based on it)	Conv Nav data	NAV System (Display & guidance)	EASA AMC 20-28
34	Steep approach information (optional)	To provide an appropriate output to an installed TAWS enabling the use of the excessive downward deviation from a glideslope function. Note: only applicable where operational regulations require the use of a Class A TAWS or a Class A TAWS is installed.	Nav System	TAWS	EASA AMC 20-28

A.1.1.3.3.1.2 Ground Elements

The ground elements in the SPR model are the following:

Information item #	Description/Content	Usage	Sending node	Receiving node	Requirements
7	Survey aerodrome & terrain data / set of aerodrome, terrain and obstacle data having fulfilling the required accuracy and integrity for ADV LPV operations	Collect all necessary data for the ADV LPV approach procedure design with the sufficient accuracy and integrity. Data include terrain data, obstacle data and aerodrome data (runway, lighting, magnetic variation and rate of change, weather statistics, Altimetry source,…).	Aerodrome	AIS provider	-ICAO Annex 14 -ICAO Annex 15 -ICAO Doc 9906

Information item #	Description/Content	Usage	Sending node	Receiving node	Requirements
8	Survey terrain, Obstacle and profile data fulfilling the required accuracy and integrity for ADV LPV operations	Collect all necessary data for the ADV LPV approach procedure design with the sufficient accuracy and integrity. Data include terrain data, obstacle data and aerodrome data (runway, lighting, magnetic variation and rate of change, weather statistics, altimetry source,…).	Mapping Authority	AIS Provider	-ICAO Doc 9906
9	Aeronautical data / Definition of the runway/terrain/obstacle data for the location where ADV LPV operations will be implemented	To provide all the validated aeronautical aerodrome data (runway/terrain/obstacle) in order to design the ADV LPV procedure	AIS provider	Procedure design	-ICAO Annex 4 -ICAO Annex 15 -ICAO Doc 9906
26	Rw visual information / Visual observation of the runway and its lights	To provide sufficient runway visual information and lighting for a landing at the DA and with the minimum RVR. If the runway or its lights are not visible by decision altitude, landing will not be performed. If the runway or its lights are visible at DA (or before), landing will be performed using this information.	Runway characteristics (Runway Lights)	Flight Crew	ICAO Annex 14

A.1.1.3.3.1.3 External Entities

The external entities in the SPR-level model are the following:

Information item #	Description/Content	Usage	Sending node	Receiving node	Requirements
1	GPS Signal/ GPS signals in space	aircraft positioning	GPS service provider	NAV system	-ICAO Annex 10 vol I chapter 3.7.3.1

2	SBAS signal / SBAS signals in space	aircraft positioning	SBAS service provider	NAV system	-ICAO Annex 10 vol I chapter 3.7.3.4[3]
3	GPS Status / Status of the GPS constellation	To inform on the status of the GPS navigation infrastructure (GPS satellite)	GPS service provider	SBAS Service provider	No requirements
4	ADV LPV capable aerodrome list where ADV LPV approach could be implemented	To inform where ADV LPV approach could be implemented	ANSP- NAV service provider	AIS provider	ICAO Doc 8061Vol II, PBN Implementation Plan
			AIS provider	Procedure designer	
5	Agreement between SBAS service provider and the navigation service provider	Agreement on using SBAS for navigation service in the applicable area	SBAS service provider	ANSP NAV service provider	-EGNOS Service Definition Document ref EGN-SDD SoL V1.0
6	SBAS service volume / Definition of the geographical area where SBAS delivers performances for ADV LPV operations	To inform where ADV LPV operations procedures can be implemented	SBAS service provider	ANSP NAV service provider	-EGNOS Service Definition Document ref EGN-SDD SoL V1.0
10	Procedure & Chart / Design of the ADV LPV approach procedure, definition of the FAS data block and development of the approach chart	-To design the ADV LPV approach procedure and develop the FAS data Block supporting this approach. -To define the layout and content of the ADV LPV approach chart(s)	Procedure design	AIS provider	-ICAO Doc 8168 volume II APV-SBAS criteria -ICAO Doc 9906
11	Val report / ADV LPV approach procedure validation report	To show that the designed procedure is compliant with PANS OPS and fly-able for a set of aircraft classes	Procedure validation	Procedure designer	-ICAO Doc 9906 -ICAO Doc 8071 Vol II -ICAO Doc 8168 volume II APV-SBAS criteria
12	SBAS NOTAM proposal / Propose a NOTAM indicating a service degradation of the SBAS system	To inform on a foreseen degradation of the SBAS system performance by providing a proposed NOTAM	SBAS service provider	ANSP- NAV service provider	-EGNOS Service Definition Document ref EGN-SDD SoL V1.0
13	SBAS NOTAM / Inform airspace users about a service degradation of the SBAS system	To inform on a foreseen degradation of the SBAS system performance impacting ADV LPV	AIS provider	Air Operator	-ICAO Annex 15
			AIS service provider	ATS (ATCO or AFISO)	

[3] EGNOS SIS continuity does not satisfy the ICAO ANNEX 10 SIS continuity requirement

			approach	Air operator	Flight crew	
14		AIP / Aeronautical Information Publication	To distribute the Aeronautical Information Publication (AIP) relative to the ADV LPV procedure	AIS provider	Air Operator	-ICAO Annex 15 -Commission Regulation (EU) No 73/2010
				AIS provider	NAV Database integrator & packer	
				AIS provider	ATS(ATCO or AFISO)	
				Air Operator	Flight crew	
15		FAS DB / Final Approach Segment Data Block	To provide the FAS Data block description (including the CRC) for navigation data base coding and procedure validation	AIS provider	NAV Database integrator & packer	-ICAO Annex 10 -ICAO Doc 8168 volume II
				Procedure designer	Procedure validation	
16		NAV database / Navigation data base including the FAS Data block and the necessary waypoints to fly the ADV LPV procedure	To provide the navigation data base supporting the ADV LPV procedure in a correct format for the loading on the airborne system	NAV Database integrator & packer	Air Operator	- EASA AMC 20-28 - EU-OPS - EASA LOA type 1 and 2
				Air Operator	NAV system	
17		Approach Charts / maps and charts of the ADV LPV approach procedure	To distribute maps and charts before conducting the ADV LPV approach operation- maps and chart are adapted from the AIP (11) to the needs and procedures of the flight crew	Map DB/Avionics Supplier	Aircraft Operator	EASA LoA
				Air Operator	Flight crew	-EU-OPS -ICAO Annex6
18	a	FPL req / Flight Plan request	To provide the necessary information for the flight in particular flight planning item 10 (eqt & capabilities) and 18 (other information)	Air Operator	Flight data processing system	- ICAO PANS ATM -ICAO DOC 7030 EUR
	b	FPL approval / Flight Plan approval	Indicate if the flight plan is approved or rejected	Flight data processing system	Air Operator	- ICAO PANS ATM -ICAO DOC 7030 EUR

	c	Flight Plan / flight plan content	Contain the information of the accepted flight plan	Flight data proc (Flight Data processing)	ATS (ATCO)	- ICAO Annex 11 - ICAO PANS ATM -ICAO DOC 7030 EUR
19	ATC Descent and Approach clearance		To provide the approach clearance before or at the Initial Approach Fix	ATS (approach controller for controlled aerodrome)	Flight Crew	-ICAO Annex 11 -PANS ATM
				ATS (ACC controller for uncontrolled aerodrome)	Flight Crew	
20	QNH / Altimeter setting for the approach		To provide the altimeter setting when below the transition altitude Note: QNH is a data transmitted by the ATS but stemming from the MET service provider	ATS (AFIS)	Flight Crew	-ICAO Annex 11 -PANS ATM
21	Visibility / Visibility and temperature at the aerodrome		To provide the visibility and when applicable the RVR for arriving aircraft, and for operator requirements regarding temperature	ATS (AFIS)	Flight Crew	-ICAO Annex 11 -PANS ATM
22	ATC Tactical clearance / ATC tactical clearance and information for the approach		To provide tactical clearance and instructions during the approach like vectoring (heading), altitude or speed constraints. For certain instruction like vectoring, radar is required.	ATS (ATCO)	Flight Crew	-ICAO Annex 11 -PANS ATM
23	Specific procedure request		To indicate a preferred approach procedure when such approach is not the default one at the aerodrome	Flight Crew	ATS (ATCO)	-ICAO Annex 11 -PANS ATM

24	Readback/ Read-back of the safety-related parts of ATC clearances and instructions to ensure integrity of the information exchanges	To confirm that flight crew has correctly understood the ATC clearances and instructions (18, 19, 20 and 21) - It should include at least route clearances, clearances and instructions to land on any runway, runway in use, altimeter setting (QNH), heading and or any speed instructions.	Flight Crew	ATS (ATCO)	-ICAO Annex 11 -PANS-ATM
25	Surveillance information (optional) / indicate the location of the aircraft during an approach	To monitor the trajectory of the aircraft conducting the arrival/approach and/or to provide surveillance vectoring for the approach interception if needed tactically	Surveillance Monitoring	ATS (ATCO)	-ICAO Annex 11 -PANS-ATM
35	Met data / Meteorological Data	To provide appropriate meteorological data for the approach	MET service provider	ATS	ICAO Annex 3
36	ASM Data (optional)	To provide a function with the primary objective of maximizing the utilization of available airspace by dynamic time-sharing and, at times, the segregation of airspace among various categories of airspace users on the basis of short-term needs	Airspace management	ATS	ICAO Doc 4444
37	ASD	To provide an Airspace Concept to use as the basis for the design of airspace and the regulating system of the air traffic, so as to achieve the goals and needs of the stakeholders.	Authorities, Navigation strategy goals, ANSP targets,	Procedure Design	ICAO PBN Manual

A.1.1.3.3.2 Task Analysis

See chapter 5.1.3 in [28]

A.1.1.3.3.3 Derivation of Safety Requirements (Functionality and Performance – success approach)

The table below lists the Safety Objectives (Functionality and Performance) derived in section 2, and shows how they map to both Safety Requirements (Functionality and Performance) which have been derived from the SPR-level model, and the SPR-level model nodes.

Safety Objectives (Functionality and Performance from success approach)	Requirement (forward reference)	Maps on to
SO 001	**SR 001, SR 002, SR 003, SR 004, SR 005**	4, 7, 8, 9, 10, 37
SO 002	**SR 002, SR 003, SR 006, SR 007, SR 008, SR 009, SR 010, SR 011, SR 012, SR 013, SR 014, SR 015, SR 016**	7,8,14,15,16,17,25,**29**, 30,31,32,33
SO 003	**SR 002, SR 003, SR 006, SR 007, SR 008, SR 009, SR 010, SR 011, SR 012, SR 013, SR 014, SR 015, SR 016**	7,8,14,15,16,17,25,**29**, 30,31,32,33
SO 004	**SR 006, SR 017, SR 018, SR 019, SR 020, SR 021, SR 022, SR 012, SR 013, SR 014, SR 015**	14,19,20,21,22,27,28,29,30, 31,32
SO 005	**SR 006, SR 023, SR 017, SR 018, SR 019, SR 020, SR 024, SR 011**	14,18c,19,20,21,22,24,25
SO 006	**SR 025, SR 026, SR 021, SR 022, SR 012, SR 013, SR 014, SR 015, SR 016**	1,2,27,28,29,30,31,32,33
SO 007	**SR 004, SR 005, SR 027, SR 007, SR 008, SR 009, SR 017, SR 020, SR 022, SR 012, SR 013, SR 014, SR 015**	9,10,11,15,16,17,19,22,28, 29,30,31,32
SO 008	**SR 025, SR 026, SR 002, SR 003, SR 004, SR 005, SR 006, SR 008, SR 009, SR 020, SR 011, SR 021, SR 012, SR 014, SR 015, SR 016**	1,2,3,7,8,9,10,14,16,17,22, 25,27,29,31,32,33
SO 009	**SR 028, SR 029, SR 023, SR 017, SR 020, SR 024, SR 011, SR 021**	18,19,22,24,25,27,26,
SO 010	**SR 028, SR 029, SR 023, SR 017, SR 020, SR 024, SR 011, SR 021**	18,19,22,24,25,27,26,
SO 011	**SR 030, SR 031, SR 032, SR 009, SR 017, SR 020, SR 033,**	3,13,17,19,22,23,24,32,33

Safety Objectives (Functionality and Performance from success approach)	Requirement (forward reference)	Maps on to
	SR 024, SR 015, SR 016	
SO 012	SR 021, SR 022, SR 012, SR 013, SR 014, SR 015, SR 016	27,28,29,30,31,32,33
SO 013	SR 008, SR 009, SR 024, SR 021, SR 022, SR 013, SR 014, SR 015, SR 016	16,17,27,
SO 014	SR 023, SR 017, SR 018, SR 019, SR 020, SR 024, SR 011	18,19,20,21,22,23,24,25

Table 4-13: Mapping of Safety Objectives to SPR-level Model Elements

The table below lists the Safety Requirements (Functionality and Performance) which have been derived from the SPR-level model.

Note that some of the requirements listed here do not introduce novel aspects compared to the existing operations upon which they depend. None-the-less they are included here as they are a necessary part of the concept, more than assumptions, conformance to the given standard is required as part of the concept.

Safety Requirement (functionality & performance)	Requirement
SR 001	The NAV Service provider shall provide to AIS Provider a list of aerodromes capable for ADV-APV approach operations, based upon information provided by the SBAS service provider as to which aerodromes will be supported by the required SBAS performance.
SR 002	Terrain, obstacle and survey aerodrome data used in the design of the flight procedure for the required accuracy and integrity of ADV-APV operations shall be provided by the Aerodrome to the AIS Provider in compliance with the data quality requirements of ICAO Annex 14, ICAO Annex 15, ICAO Doc 9906 and EU Reg 73/2010.
SR 003	Survey terrain, aerodrome, obstacle and profile data used in the design of the flight procedure for the required accuracy and integrity of ADV-APV operations shall be provided by the Mapping Authority to the AIS Provider in compliance with the aeronautical data/information quality requirements of EU Reg 73/2010 and ICAO Doc 9906.
SR 004	Runway, terrain and obstacle for the location where ADV LPV operations will be operated shall be provided by the AIS Provider to procedure designer in compliance with the aeronautical data/information quality requirements of EU Reg 73/2010, ICAO Annex 15 and ICAO Doc 9906.
SR 005	The ADV-APV approach procedure and chart design and definition of the FAS data block shall be provided by the procedure designer to the AIS provider in compliance with the data quality requirements of ICAO Doc 8168 volume II and ICAO Doc 9906.

Safety Requirement (functionality & performance)	Requirement
SR 006	The ADV-APV procedure shall be published in the Aeronautical Information Publication (AIP) and distributed between the AIS Provider and Air Operator/NAV Database supplier (integrator and packer)/ATS and between Air Operator and Aircraft/Flight Crew in compliance with the aeronautical data quality requirements of ICAO Annex 15, EU Reg 73/2010, and ED-76
SR 007	The Final Approach Segment Data Block description (including the CRC) shall be provided by the procedure designer for procedure validation in compliance with the aeronautical data quality requirements of ICAO Annex 10, ICAO Doc 8168 volume II and EU Reg 73/2010
SR 008	The NAV Database supplier (integrator and packer) shall provide the navigation data (including the FAS Data Block and necessary waypoints) supporting the ADV-APV procedure in a correct format for the loading on the airborne system via the Air Operator in conformance as a minimum with the requirements of EASA AMC 20-27, AIR-OPS and EASA LOA type 1 and 2
SR 009	The NAV Database supplier (integrator and packer) shall adapt the validated ADV-APV procedure from the AIP into approach charts and maps to the needs and procedures of the flight crew and distribute to the Air Operator via EASA LOA
SR 010	The Air Operator shall provide the ADV-APV procedure approach charts and maps to the flight crew in compliance with AIR-OPS and ICAO Annex 6
SR 011	In accordance with ICAO Annex 11 and PANS-ATM, the trajectory of the aircraft conducting arrival/approach surveillance monitoring (optional, but required for tactical intervention/vectoring) shall indicate aircraft position and compliance with the procedure (including RF leg and CDO) and allow ATC to perform tactical vectoring for approach interception as necessary
SR 012	The NAV data of the ADV-APV path to be flown (including any lat/vert deviations from the published path and status of LPV approach capability) shall be derived from the NAV database system and transmitted to the aircraft's Display and Auto flight system based on compliance and certification with EASA AMC 20-27
SR 013	Flight crew shall select the ADV-APV arrival/approach procedure to be flown, corresponding to the selected runway end, from the aircraft's Flight Management System (the procedure being extracted from the NAV database system) based on compliance and certification with EASA AMC 20-27 and 20-28.
SR 014	The ADV-APV operations data from the NAV database system shall be displayed to the flight crew (they are RNAV flight path and associated data –e.g. constraints…-, and LPV approach data –e.g. ident, channel…) based on compliance and certification with EASA AMC 20-27 and AMC 20-28.
SR 015	The flight crew shall be able to select the AFS mode, i.e. either the Autopilot and/or the Flight Director) based on compliance with EASA AMC 20-27 and AMC 20-28.
SR 016	It shall be possible to provide necessary information from the conventional navigation system (including speed, altitude, heading, vertical speed)s, as well as from SBAS, to the aircraft's NAV database system and therefore Display and Auto flight

Safety Requirement (functionality & performance)	Requirement
	system based on compliance with EASA AMC 20-27
SR 017	ATS (APP controller for controlled aerodrome or ACC controller for uncontrolled aerodrome) shall provide the Flight Crew with the ATC Descent and Approach clearance before or at the Initial Approach fix in accordance with ICAO Annex 11 and PANS-ATM
SR 018	Flight crew shall receive QNH/Altimeter setting from the ATIS or ATC for the ADV-APV approach in accordance with ICAO Annex 11 and PANS-ATM and acknowledge to ATS when transitioning below transition altitude
SR 019	Flight crew shall receive aerodrome visibility and temperature information from the ATIS or ATC for the ADV-APV approach in accordance with ICAO Annex 11 and PANS-ATM
SR 020	In accordance with ICAO Annex 11 and PANS-ATM, information, tactical clearance and instructions (vectoring/heading, altitude, speed constraints) shall be provided by ATS and monitored for compliance as necessary
SR 021	On receipt from ATIS or ATC, Flight Crew shall input QNH/Altimeter setting into the aircraft's ALT system, in compliance with EU OPS and EASA AMC 20-27
SR 022	The ALT system shall indicate to the Flight Crew (to assist DA/H action) the barometric altitude during the ADV-APV approach based on compliance with EASA AMC 20-27
SR 023	The Flight Plan content, including ADV-APV details of the accepted flight plan, shall be provided to ATS by Flight Data Processing in compliance with ICAO Annex 11, ICAO PANS-ATM and ICAO Doc 7030 EUR
SR 024	Flight crew shall read back all ATC clearances and instructions (heading and/or speed), QNH/altimeter settings, in compliance with ICAO Annex 11 and PANS-ATM
SR 025	Aircraft's NAV system shall receive aircraft positioning GPS signals in space from the GPS Service Provider in compliance with ICAO Annex 10 vol I chapter 3.7.3.1
SR 026	Aircraft's NAV system shall receive aircraft positioning SBAS signals in space from the SBAS Service Provider in compliance with ICAO Annex 10 vol I chapter 3.7.3.1
SR 027	ADV-APV approach validation report shall demonstrate that the designed procedure is fly-able for the aircraft classes that will utilize the procedure in compliance with ICAO PANS-OPS Doc 8168 volume II APV-SBAS criteria, ICAO Doc 9906 ad ICAO Doc 8071 Vol II
SR 028	Air Operator shall provide necessary flight information to ATS flight data processing, confirming ADV-APV ability (equipment and training) through compliance with EASA AMC 20-27 , ICAO PANS ATM and ICAO Doc 7030 EUR
SR 029	Flight data processing shall indicate to the Air Operator if the flight plan is approved or rejected in compliance with ICAO PANS-ATM and ICAO Doc 7030 EUR
SR 030	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 and EU Reg 73/2010

Safety Requirement (functionality & performance)	Requirement
SR 031	AIS Service Provider shall inform the Air Operator and ATS on a foreseen degradation of the SBAS system performance impacting ADV-APV approach by providing a NOTAM in accordance with ICAO Annex 15 and EU Reg 73/2010
SR 032	Air Operator shall inform Flight Crew on a foreseen degradation of the SBAS system performance impacting ADV-APV approach by forwarding NOTAM in accordance with ICAO Annex 15 and EU Reg 73/2010
SR 033	Flight crew shall indicate to ATS the preferred approach procedure when this is different to the default procedure at the aerodrome, in compliance with ICAO Annex 11 and PANS-ATM

Table 4-14: Derivation of Safety Requirements (functionality and performance) from Safety Objectives

As the airborne elements are considered to be in scope for this project, requirements have been specified for them. There are therefore **no assumptions** derived from the assessment of the SPR-level model.

It is noted that some of the above could be considered as assumptions, for example SR 30 which relates to the SBAS provider (an external entity). They have not been recorded as such here as they are so integral to the concept that they constitute an entirely necessary part of any system which would implement the concept. They must be validated for the safety assessment itself to be valid. The SESAR SPR template does not provide for the inclusion of assumptions, and it was felt in particular that the above should be included in the SPR document.

A.1.1.3.3.4 Traceability

As discussed in section 3.3, **no Functional Model was judged to be required** in the assessment of this concept, as it is already mature enough for an SPR-level model to be developed directly. As a result there is no need for a mapping between a Functional Model and the SPR-level model.
The only OI step applicable to this concept is AOM-0605 Enhanced terminal operations with automatic RNP transition to ILS/GLS/LPV. This OI step therefore is mapped to all model elements of the SPR-level model.

A.1.1.3.4 Analysis of the SPR-level Model – Normal Operational Conditions

A.1.1.3.4.1 Scenarios for Normal Operations

The following scenarios have been selected for analysis of ADV-APV nominal operations. They have been developed to be consistent with the scenarios used in Phase 1 of the project.

ID	Scenario	Rationale for the Choice
1	ADV-APV procedure execution	This scenario represents a normal flight utilising the ADV-APV concept
2	Establish SBAS service	Pre-requisite for scenario 1 in the situation where SBAS is used (rather than simply GNSS)

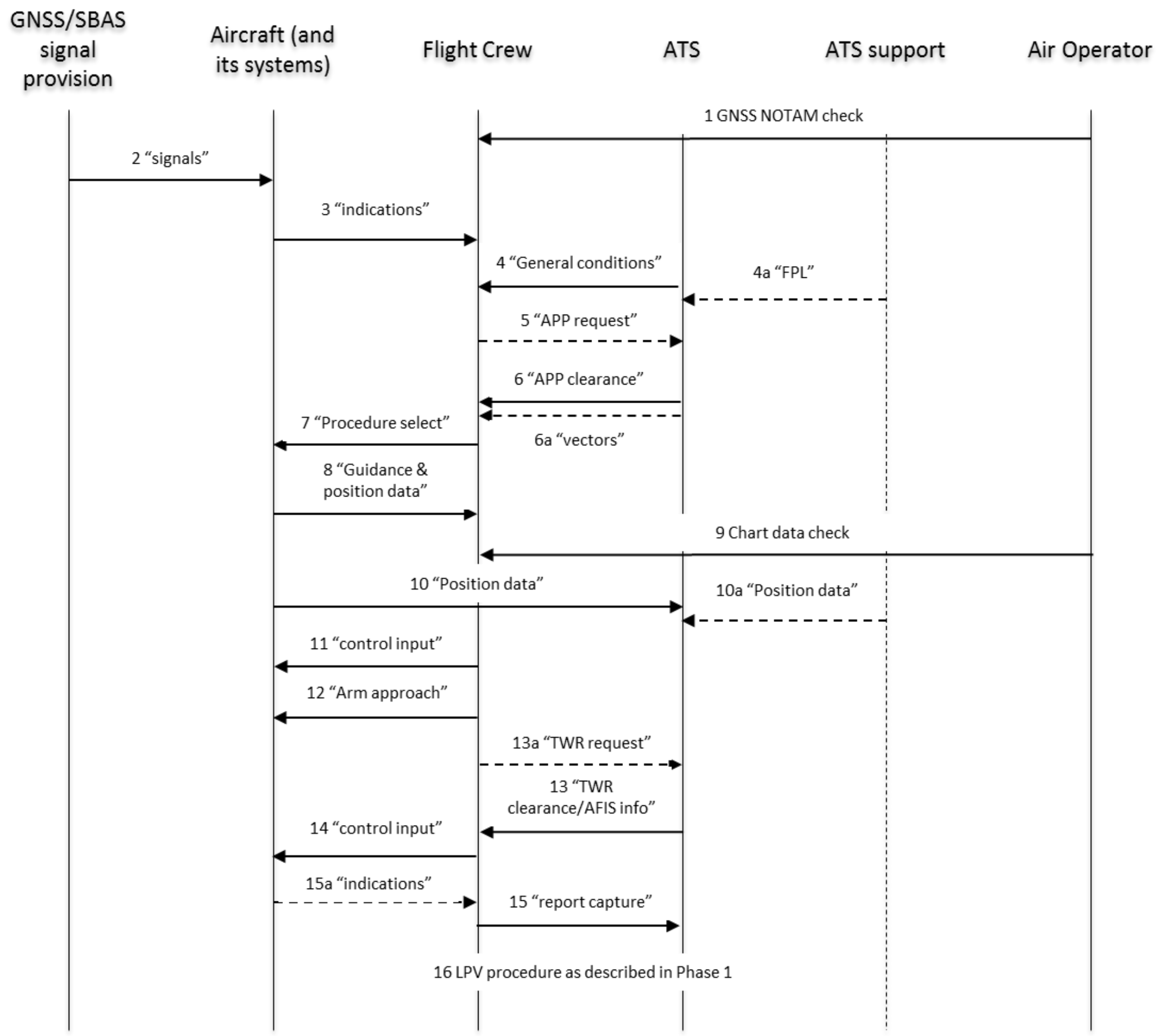
3	Procedure design, approval and diffusion	Pre-requisite for Scenario 1
4	Procedure approval	Examines in more detail the approval process of Scenario 3

Table 4-15: Operational Scenarios – Normal Conditions

Scenarios 2-4 are functionally identical to those in Phase 1, but equally required for the provision of an ADV-APV procedure as for LPV.

A.1.1.3.4.2 Thread Analysis of the SPR-level Model – Normal Operations

A.1.1.3.4.2.1 Scenario # 1 ADV-APV Procedure Execution



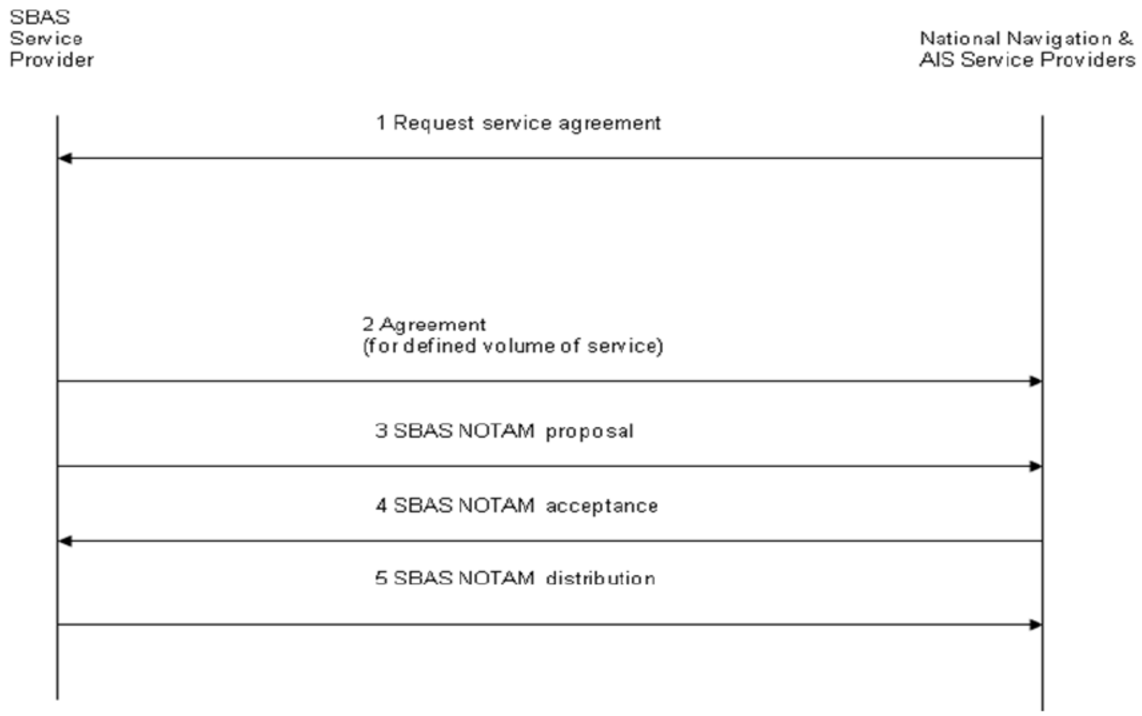
Observations (valid for all thread diagrams in this document):

- Dotted line ("Xa" actions) are optional

- The "ATS support" element is mainly referring to the "Radar Monitoring" and "ATFM" logical model elements.

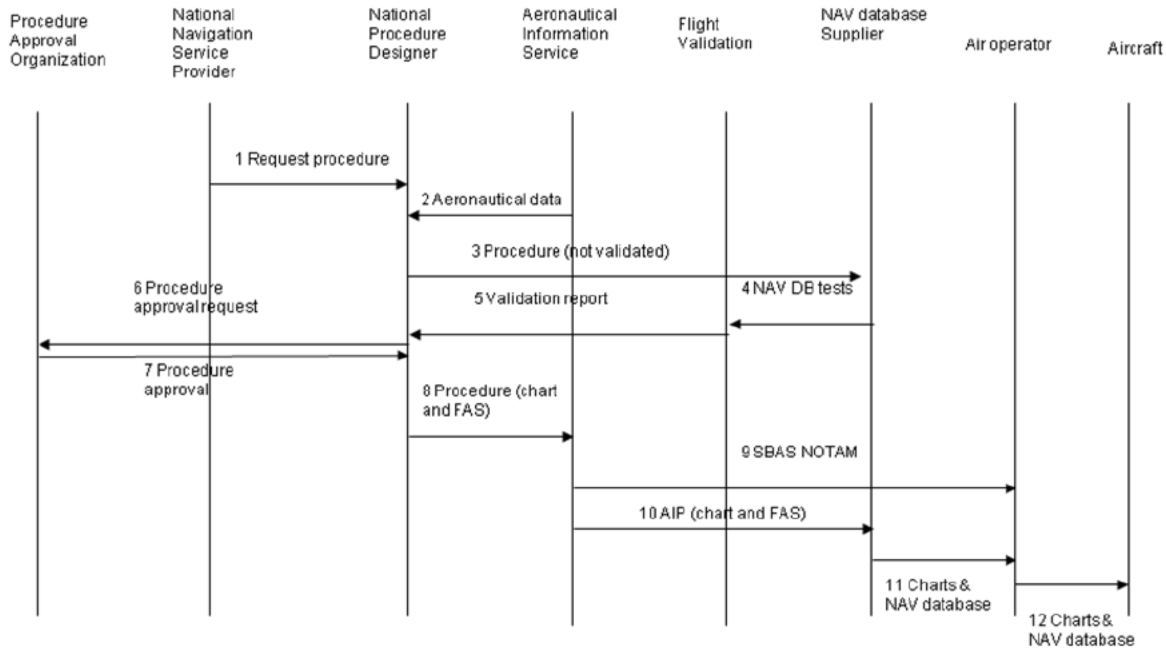
ACTIONS
1. Flight Crew check GNSS NOTAM information in pre-flight phase.
2. *Aircraft and systems* receive GPS and EGNOS signals (continuously)
3. Pilot observe that indications on *aircraft and systems* indicate that ADV-APV approach can be executed (and continue to monitor until the landing is performed using visual guidance).
4. ATS provides MET and aeronautical information to the flight crew [4a ATS support systems provide ATS with FPL data]
5. Flight crew issue approach request.
6. ATS issue arrival route and approach clearance (6a: Alternatively, ATS vectors the aircraft to approach intercept)
7. Flight crew select the arrival route and approach on aircraft and systems
8. Aircraft provides guidance and position information and to the Flight crew (continuously). Additionally the flight crew observe that CDO is being implemented correctly (if in use)
9. Flight Crew compare aircraft navigation data with approach charts
10. Aircraft provides position data to ATS, either through sighting or Transponder (continuously) [10a: If radar surveillance is available, it is forwarded to ATS as well]
11. Flight crew control the aircraft to follow arrival route (or ATS vectors). In case of autopilot usage, it just consists in AP selection orders
12. Before IAF, Pilot arm approach mode (to automatically capture LPV)
13. (13a: If ATC present, approach ATCO transfers aircraft to control tower frequency) 13: Flight crew changes frequency from approach to tower control.
14. At FAF/FAP, the pilot (or autopilot) control the aircraft to capture the LPV trajectory and stabilize.
15. (15a: If using autopilot the aircraft provides information relating to the transition from RNP APCH or A-RNP with RF leg onto LPV FAS at FAP) 15: Flight crew confirm to ATC that the aircraft is established on the final track
16. LPV procedure conducted as per Phase 1

A.1.1.3.4.2.2 Scenario # 2 Establish SBAS Service



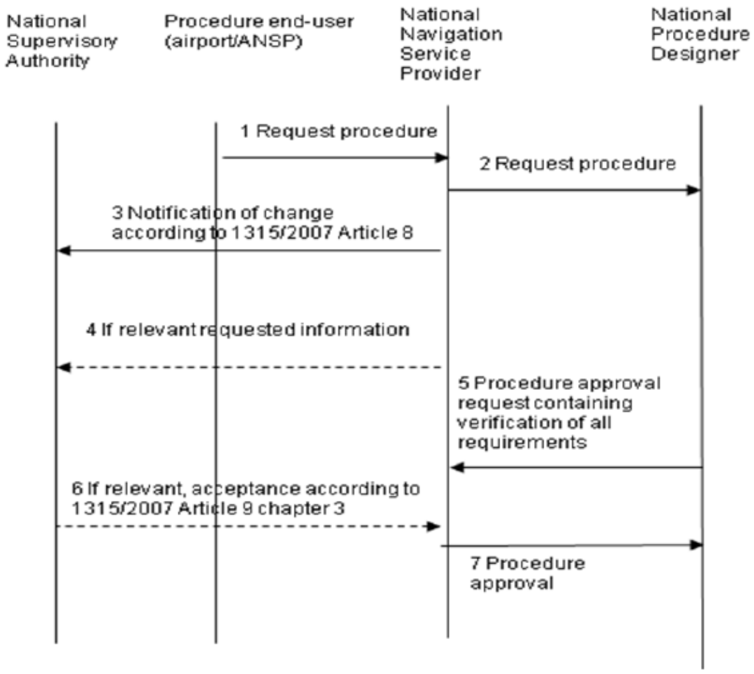
ACTIONS
1. The Navigation service provider that want to implement LPV procedures requests EGNOS service provider to enter into an agreement
2. An agreement is made for the provision of EGNOS in a defined area / for a defined set of airports.
3. The SBAS service provider sends SBAS NOTAM proposals to the AIS service provider (NOF) (continuously)
4. The AIS service provider reviews the NOTAM proposals and accepts them. (continuously)
5. The SBAS service provider distributes the definitive versions of SBAS NOTAMs (continuously)

A.1.1.3.4.2.3 Scenario # 3 Procedure design, approval and diffusion



ACTIONS
1. The national NSP (i.e. an ANSP which has established a service agreement with the SBAS service provider) requests a new ADV-APV procedure design to the national procedure designer.
2. AIS provides the national procedure designer with all necessary data (type and quality) for this task.
3. A draft version of the procedure is sent to the Nav DB supplier to generate a provisional NAV database.
4. The provisional NAV DB is tested and supplied to Flight Inspection
5. The procedure (chart & Nav DB) is tested both on ground and in flight. A validation report is produced and sent to the National NSP.
6. The National NSP requests procedure approval from the National NSA (= state)
7. The state approves procedure promulgation.
8. The national procedure designer supplies AIS with both charts and FAS data. AIS integrates this into the national AIP.
9. SBAS NOTAM are sent to aircraft operators' operations departments.
10. The NAV DB supplier takes AIP data to elaborate customized charts and NAV DBs.
11. The Aircraft operator obtains its charts & Nav DBs from the supplier
12. The operator's loads the NAV database in the aircraft on-board systems and places customized charts into the cockpit.

A.1.1.3.4.2.4 Scenario # 4 Procedure Approval



ACTIONS
1. The ADV-APV procedure end-user (airport or ANSP) requests a new procedure to the NSP.
2. The national NSP (i.e. an ANSP which has established a service agreement with the SBAS service provider) requests a new ADV-APV procedure design to the national procedure designer.
3. The NSP notifies the new change to the National Supervisory Authority (NSA)
4. (Optional) The NSP provides the NSA with additional information about the change.
5. The procedure designer requests procedure approval to the NSP. This request is supplemented with evidences of the verification of all applicable requirements.
6. (Optional) If the change needs explicit approval from the NSA, this is issued.
7. The NSP approves the procedure, which is subsequently sent to AIS and Aircraft Operators.

A.1.1.3.4.3 Effects on Safety Nets – Normal Operational Conditions

The effects of the concept on safety nets was assessed in Phase 1. This has been reviewed as part of this safety assessment, and is considered valid and applicable for this version. The relevant safety nets are repeated here:

A.1.1.3.4.3.1 Ground Based Safety Nets

STCA (Short Term Conflict Alert)

Depending to each location, the STCA is likely to be active initial and intermediate approach. In case it is active, no negative effect on its operation is anticipated in ADV-APV (note that the vertical profile of an aircraft flying an ADV-APV approach procedure is well defined).

A.1.1.3.4.3.2 Airborne Safety Nets

Radio Altimeter

Radio-altimeter might be used as a crosscheck mean to detect QNH setting errors or altimeters errors, only in case the terrain profile below the final approach is flat.

ADV-APV approach has no foreseen negative impact on Radio altimeter.

ACAS (Airborne Collision Avoidance System)

There is a theoretical potential for ACAS nuisance alerts to be affected by ADV-APV. However, that potential is not higher than for existing approaches.

A.1.1.3.4.4 Dynamic Analysis of the SPR-level Model – Normal Operational Conditions

Dynamic Analysis of the SPR level model is validated through the use of live flight trials conducted in May 2014 in accordance with the validation plan. Diversions from the plan were documented at the time of the trials.

The aim of the analysis is to test the ADV-APV concept under a range of normal and abnormal operational scenarios in an appropriate environment. The live flight trials exercise was based on the Advanced APV procedure for Torino, Italy.

The scenarios to be tested were generated using:

- Use cases from the 5.6.3 OSED
- Validation Plan.

The results of this analysis are used to provide evidence on the validity of ADV-APV operations for normal operational conditions and also the dynamic aspects of the system.

A.1.1.3.4.5 Additional Safety Requirements (functionality and performance) – Normal Operational Conditions

No additional Safety Requirements (over and above those identified from the SPR level model) have been identified as a result of analysis of normal operations threads.

A.1.1.3.5 Analysis of the SPR-level Model – Abnormal Operational Conditions

A.1.1.3.5.1 Scenarios for Abnormal Conditions

ID	Scenario	Rationale for the Choice
1	Flight cannot execute procedure	Main scenario whereby procedure cannot execute (for example due to bad weather)
2	GNSS signal failure leads to missed approach	Credible abnormal condition (since GNSS signals are outside scope of the project). Note that GNSS

		signal loss may be over a very short, or extended time period.
3	Cold temperature below designated ICAO chart minimum	This would cause the procedure to be cancelled during this situation.

Table 4-16: Operational Scenarios – Abnormal Conditions

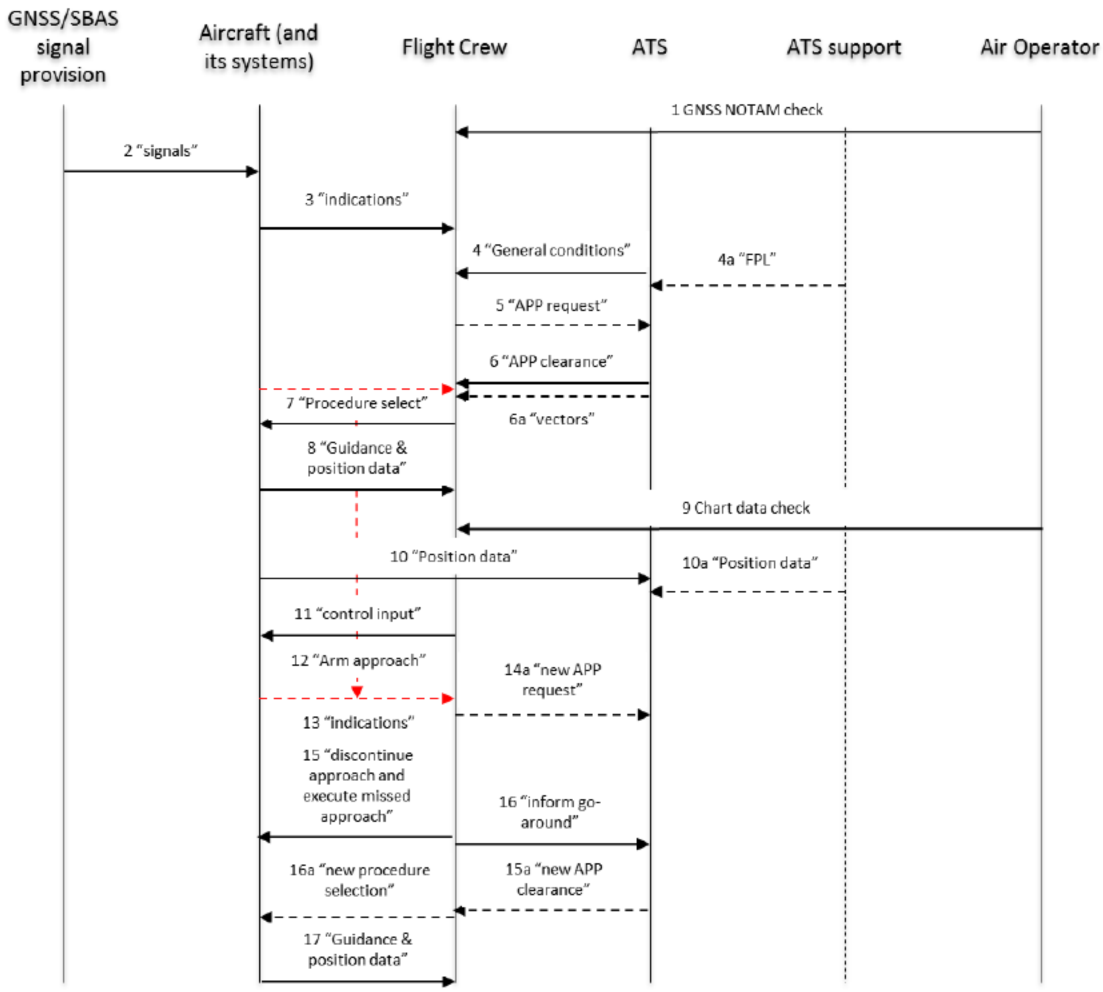
A.1.1.3.5.2 Derivation of Safety Requirements (Functionality and Performance) for Abnormal Conditions

Ref	**Abnormal Conditions / SO *(Functionality and Performance)***	**Mitigations (SR 0xx and/or A 0xx)**
1	SO 015	**SR 017, SR 018, SR 019, SR 029, SR 034**

Table 4-17: Safety Requirements or Assumptions to mitigate abnormal conditions

A.1.1.3.5.3 Thread Analysis of the SPR-level Model - Abnormal Conditions

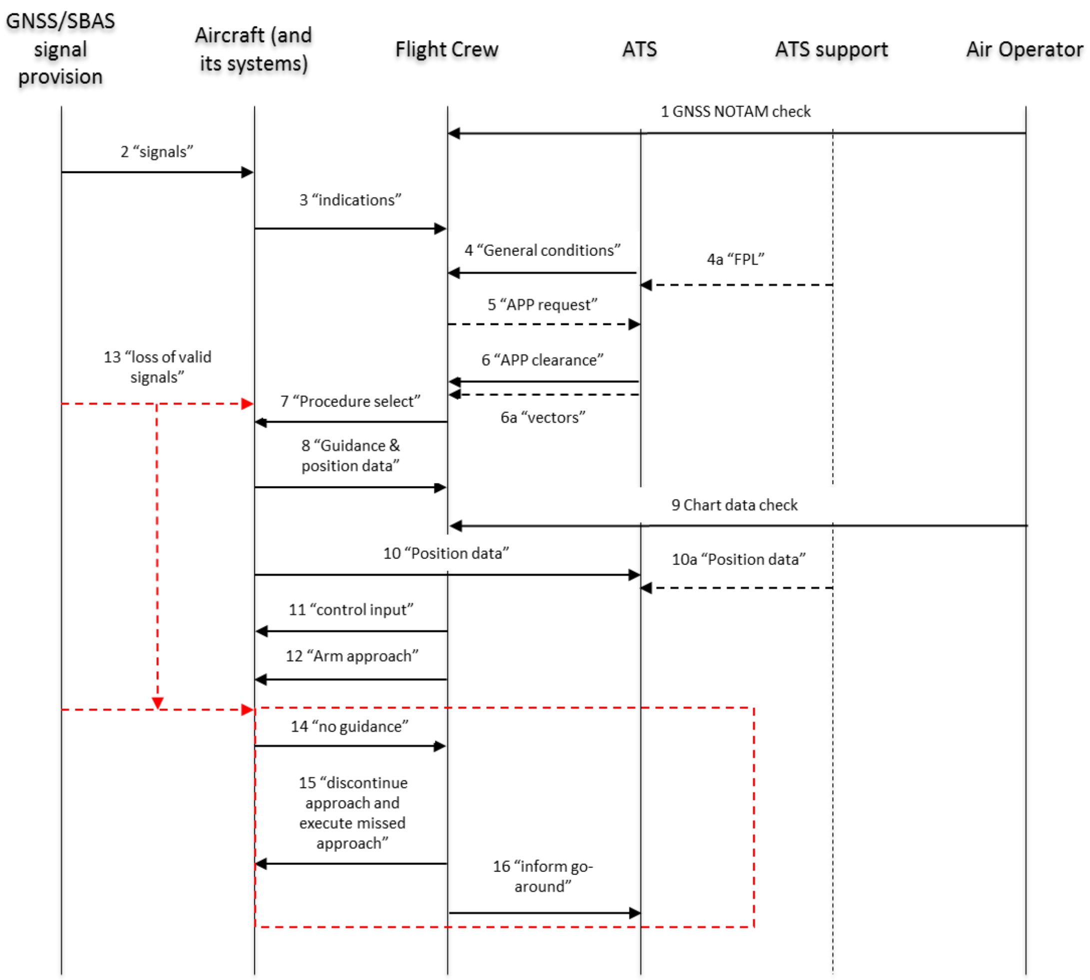
A.1.1.3.5.3.1 Scenario # 1 Flight cannot execute procedure



ACTIONS
1. Flight Crew check GNSS NOTAM information in pre-flight phase
2. *Aircraft and systems* receive GPS and EGNOS signals (continuously)
3. Pilot observe that indications on *aircraft and systems* indicate that ADV-APV approach can be executed (and continue to monitor until the landing is performed using visual guidance)
4. ATS provides MET and aeronautical information to the flight crew [4a: ATS support systems provide ATS with FPL data]
5. Flight crew issue approach request.
6. ATS issue arrival route and approach clearance (6a: Alternatively, ATS vectors the aircraft to approach intercept)
7. Flight crew select the arrival route and approach on aircraft and systems
8. Aircraft provides guidance and position information and to the Flight crew (continuously)
9. Flight Crew compare aircraft navigation data with approach charts

10. Aircraft provides position data to ATS, either through sighting or Transponder (continuously) [10a: If radar surveillance is available, it is forwarded to ATS as well]
11. Flight crew control the aircraft to follow arrival route (or ATS vectors). In case of autopilot usage, it just consists in AP selection orders
12. Before IAF Pilot arm approach mode
13. Pilots observe that indications on *aircraft and systems* indicate that the approach cannot be executed. This could be caused, for example, by weather. This event can occur at any point from action 6 to action 12.
14. (14a Pilot request an alternative approach from ATS)
15. (15a ATS issue instructions (or direct to) for an alternative procedure) 15 Pilots discontinue approach and execute go-around
16. (16a Flight crew select new procedure on aircraft and systems) Flight crew select new procedure on aircraft and systems
17. Aircraft provides guidance and position information and to the Flight crew (continuously) to execute missed approach (for example in the case of missed approach procedure with RF leg)

A.1.1.3.5.3.2 Scenario # 2 GNSS signal failure leads to missed approach



ACTIONS
1. Flight Crew check GNSS NOTAM information in pre-flight phase.
2. *Aircraft and systems* receive GPS and EGNOS signals (continuously)
3. Pilot observe that indications on *aircraft and systems* indicate that ADV-APV approach can be executed (and continue to monitor until the landing is performed using visual guidance).
4. ATS provides MET and aeronautical information to the flight crew [4a ATS support systems provide ATS with FPL data]
5. Flight crew issue approach request.
6. ATS issue arrival route and approach clearance (6a: Alternatively, ATS vectors the aircraft to approach intercept)
7. Flight crew select the arrival route and approach on aircraft and systems
8. Aircraft provides guidance and position information and to the Flight crew (continuously)
9. Flight Crew compare aircraft navigation data with approach charts.
10. Aircraft provides position data to ATS, either through sighting or Transponder (continuously) [10a: If radar surveillance is available, it is forwarded to ATS as well]
11. Flight crew control the aircraft to follow arrival route (or ATS vectors). In case of autopilot usage, it just consists in AP selection orders.
12. Before IAF Pilot arm approach mode
13. Aircraft and systems indicate a loss of service such that the approach cannot be continued.
14. The aircraft displays no valid navigation & guidance data.
15. Pilot make appropriate go-around input
16. Pilot instruct ATS on missed approach

A.1.1.3.5.3.3 Scenario # 3 Cold temperature below designated ICAO chart minimum

ACTIONS
1. MET identify cold temperature below designated ICAO chart minimum
2. ANS notify operators (e.g. via NOTAM)
3. Flight Crew check NOTAM information in pre-flight phase.
4. Procedure cannot be executed

A.1.1.3.5.4 Effects on Safety Nets – Abnormal Operational Conditions

There are no additional foreseen effects on safety nets arising from abnormal operational conditions compared to normal operational conditions.

A.1.1.3.5.5 Dynamic Analysis of the SPR-level Model – Abnormal Operational Conditions

Please refer to Section 3.4.4

A.1.1.3.5.6 Additional Safety Requirements – Abnormal Operational Conditions

ID	Description	Thread Action Number [Scenario # xx]
SR 034	In compliance with ICAO Annex	Phase 1

ID	Description	Thread Action Number [Scenario # xx]
	14, Flight Crew shall be provided with sufficient runway visual information and lighting for a landing at the DA/H and with the minimum RVR	
SR 035	In the event of loss of GNSS signals the navigation system shall not attempt to execute a missed approach procedure incorporating RF legs If the procedure specifically implements an RF turn to meet requirements for terrain separation, then any aircraft flying the procedure shall be equipped with additional navigation capabilities (for example inertial) to complete the missed approach in absence of GNSS signals	Scenario #2 14
SR 036	In the event of loss of GNSS signals known prior to the procedure, the procedure shall not be attempted	
SR 037	In the event the temperature is below the designated ICAO chart minimum (it is assumed that the chart minimum incorporates a suitable buffer zone), the operator shall be informed that the procedure may not be undertaken (e.g. via NOTAM) and the ADV-APV procedure shall not be executed	Scenario #3 3, 4

Table 4-18: Additional Safety Requirements from Thread Analysis – Abnormal Operational Conditions

A.1.1.3.6 Design Analysis – Case of Internal System Failures

A.1.1.3.6.1 Causal Analysis

For each system-generated hazard (see A.1.1.2.8.1) a top-down identification of internal system failures that could cause the hazard has been conducted. This analysis has been recorded within fault trees presented below.

The quantification of the fault trees has been performed bottom up, based on expert opinion, and industry standards where available (assumptions are made for human performance, known values are used for performance of aircraft equipment/avionics which must conform to standards etc.). This has allowed three assessments to take place:

- achievability of safety objectives;
- critical paths within the fault trees (and thus causal factors) where further mitigations are required in order to meet safety objectives with a wide safety margin; and,
- quantification of integrity requirements where quantification is possible, and existing standards do not apply.

The analysis has been mostly concerned with order-of-magnitude performance based on assumptions and quantification of probabilities. The quantification is primarily for the purpose of identifying critical factors which need mitigating, and that the safety objectives are achievable.

Where the causes for hazards are modelled to be the same (for example Hz06,07,08,09) the fault tree has only been presented once. In particular where sub-trees are identical they are not repeated.

Note that within the sub-sections below only the most pertinent features of each fault tree are described in detail. Sub-section A.1.1.3.6.1.10 provides a table summarising all the causal factors and their rationale.

A.1.1.3.6.1.1 OH-001a, Failure to laterally follow the defined route segment as provided by the procedure in non-mountainous environment resulting into controlled flight toward terrain

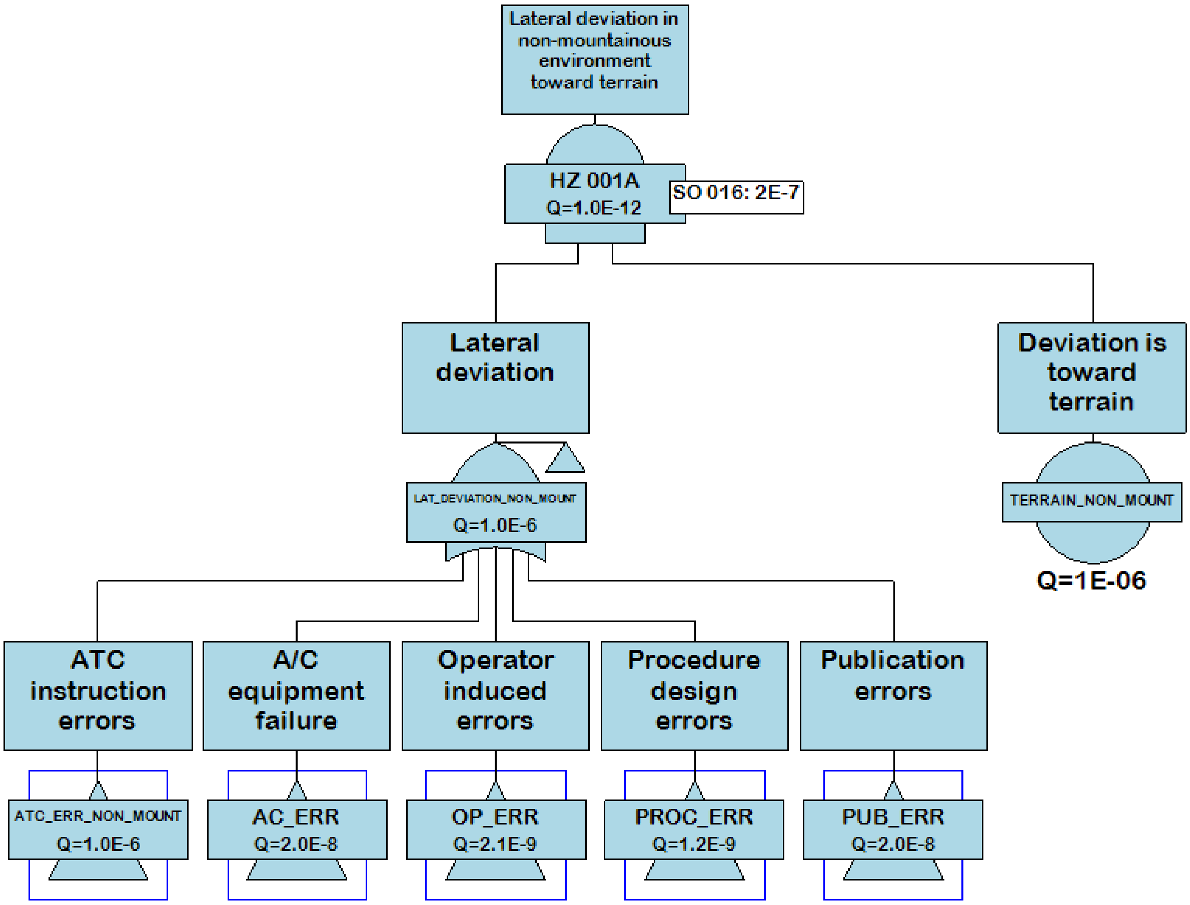


Figure 4-4: OH 001a fault tree

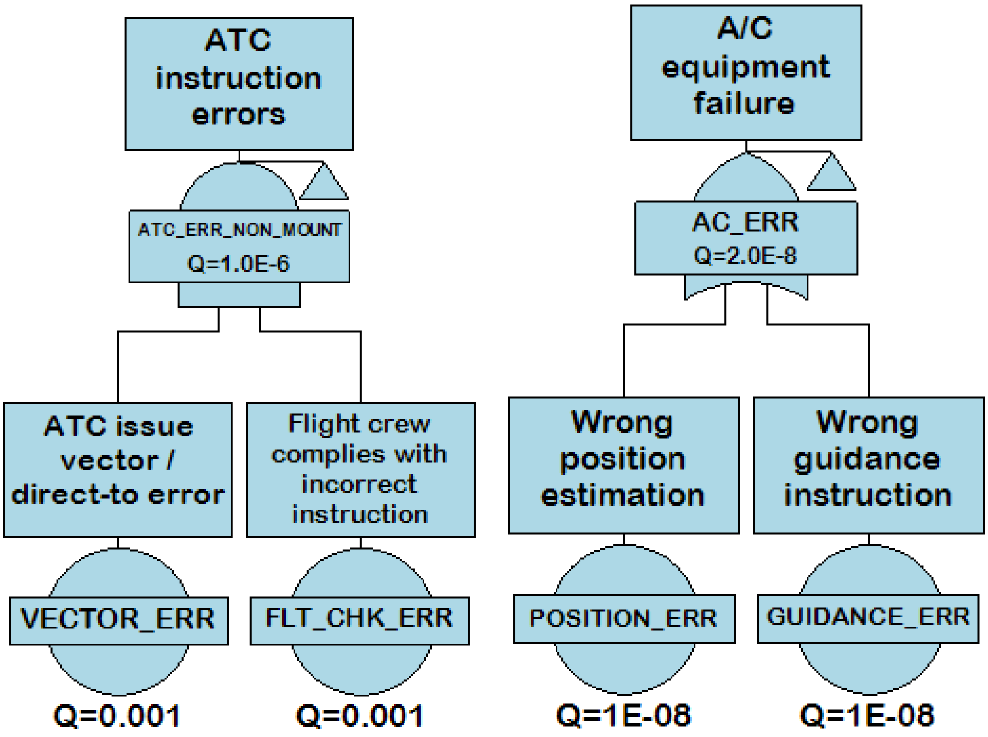


Figure 4-5: ATC instruction errors and A/C equipment failure sub-trees

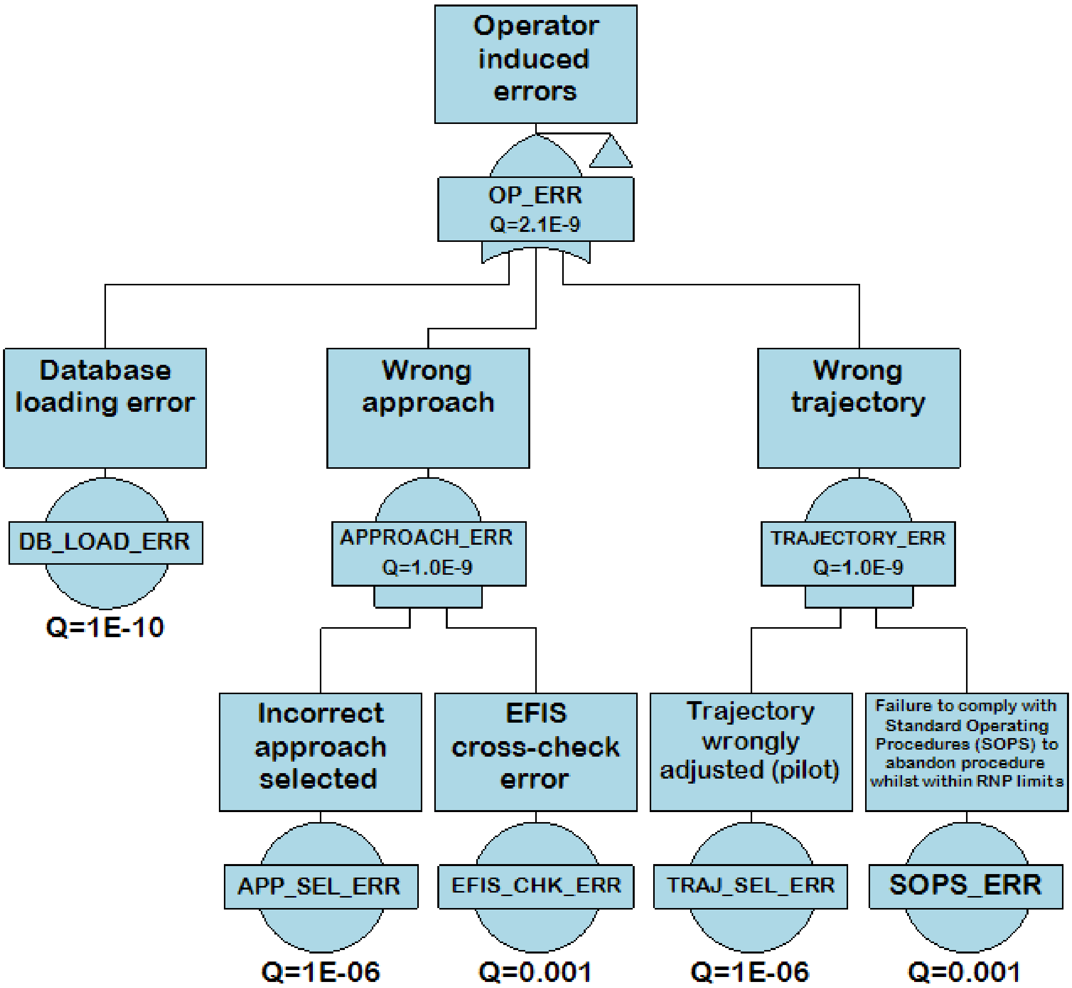


Figure 4-6: Operator induced errors sub-tree

Note: APP_SEL_ERR is set to 1E-06, as it is assumed that both of the flight crew are involved in selecting/checking the approach before it is undertaken, and therefore both would have to fail such that the wrong approach had been selected.

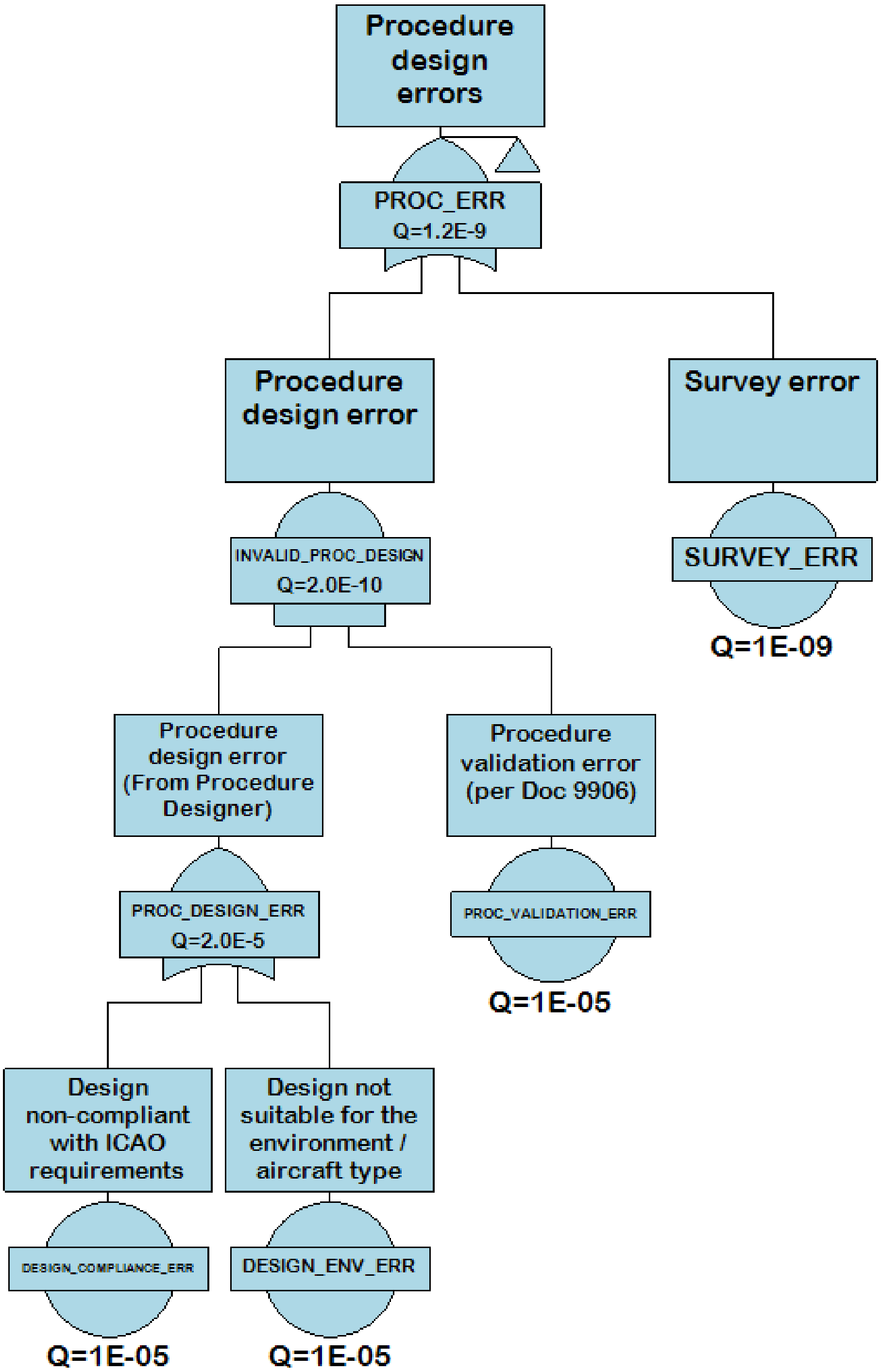


Figure 4-7: Procedure design errors sub-tree

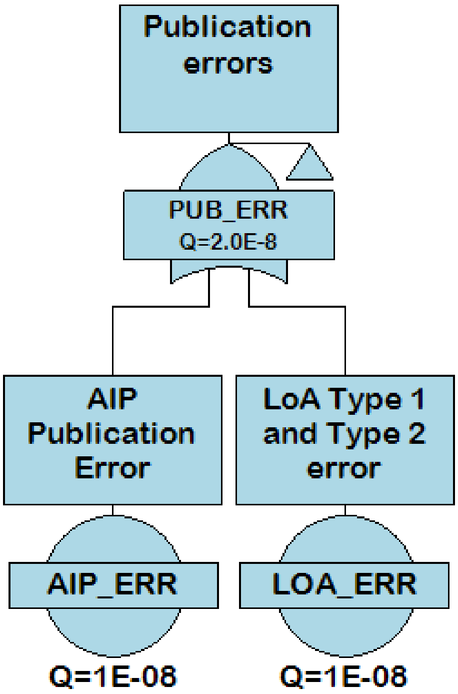


Figure 4-8: Publication errors sub-tree

A lateral deviation is only hazardous if it is toward terrain (in the context of CFIT). In non-mountainous or obstacle-free environment this is extremely unlikely to be the case, for safety cases developed for specific implementations the TERRAIN_NON_MOUNT event may very well be set to 0. For the purpose of this safety assessment it has been set to a very low probability (1E-6). The safety objective is achieved in any case where the probability of any given lateral deviation being towards terrain is 0.1 or less.

The situation can be caused by several elements; Aircraft systems (AC_ERR), Operator error including air crew (OP_ERR), Navigation service (ATC_ERR_NON_MOUNT), Aeronautical Information Service (PROC_ERR), and other handling of navigation data (PUB_ERR). If the route segment has a purpose to separate the aircraft from other traffic, (including restricted airspace), the lateral deviation may cause loss of traffic separation – however, this does not result in any new situation compared to existing operations.

The following causes leading to OH1, which are also relevant to other hazards, have been captured:

- The causes are initiated by ANS:
  - The trajectory is erroneous:
    - An error occurs during the design or the promulgation of the procedure in the AIP
- The causes are initiated by the Data Base integrator-packer, GNSS/SBAS provision, Aircraft or Flight crew:
  - The trajectory is erroneous:
    - An error occurs during the data integration and/or data packing in the navigation database; or

- An error occurs during the loading of the RNAV database in the aircraft.

- The lateral position estimate is erroneous and not detected during flight:
  - The position error exceeds the lateral protection level without being alerted in time due to unacceptably *degraded* received GNSS signal[4] or,
  - The lateral deviation is wrong on the aircraft display and not detected due to a wrong horizontal position estimation (assuming the SiS is correct)
  - The system has not transitioned to the missed approach mode
- The aircraft control is erroneous and not detected:
  - Guidance instructions on aircraft display are wrong and not detected; or
  - The trajectory is not correctly adjusted along the procedure.

Given that equipment, procedure design and publication performance rates as required by applicable standards exceed what is required to meet the SO, the key causes of the hazard are operator induced (OP_ERR) or ATC induced errors (ATC_ERR_NON_MOUNT).

Operator induced errors are mitigated with the following events:

- EFIS cross-check error (EFIS_CHK_ERR). When selecting an approach procedure it is assumed that both the flying and non-flying air crew check the selected procedure given a typical human performance for routine tasks this gives and error rate of 1E-6 (APP_SEL_ERR) based on the assumption of 1E-3 for systematic human tasks. Following the selection of the approach, the EFIS would then give the flight crew immediate feedback which provides a further chance to detect an error *before* the procedure is undertaken (i.e. before on-board monitoring is in effect).

- Failure to comply with Standard Operating Procedures to abandon procedure whilst within RNP limits (SOPS_ERR). Again it is assumed that any adjustment to trajectory is subject to cross-check by the non-flying air crew (TRAJ_SEL_ERR). If the wrong trajectory is still implemented, then SOPS will dictate that the procedure be abandoned well before the RNP limits (and thus any potential conflict with terrain) are breached, only if this is failed will the aircraft be on a trajectory which is in conflict with terrain. Again 1E-3 is assumed for this systematic human task.

Within the context of this hazard, the ATC instruction errors (ATC_ERR_NON_MOUNT) are still within the bounds of performance required by the SO, however this is not the case for OH 001b, which is addressed below.

[4] Note that loss of GNSS signal is considered an abnormal condition.

A.1.1.3.6.1.2 OH-001b Failure to laterally follow the defined route segment as provided by the procedure in mountainous or obstacle environment resulting into controlled flight toward terrain

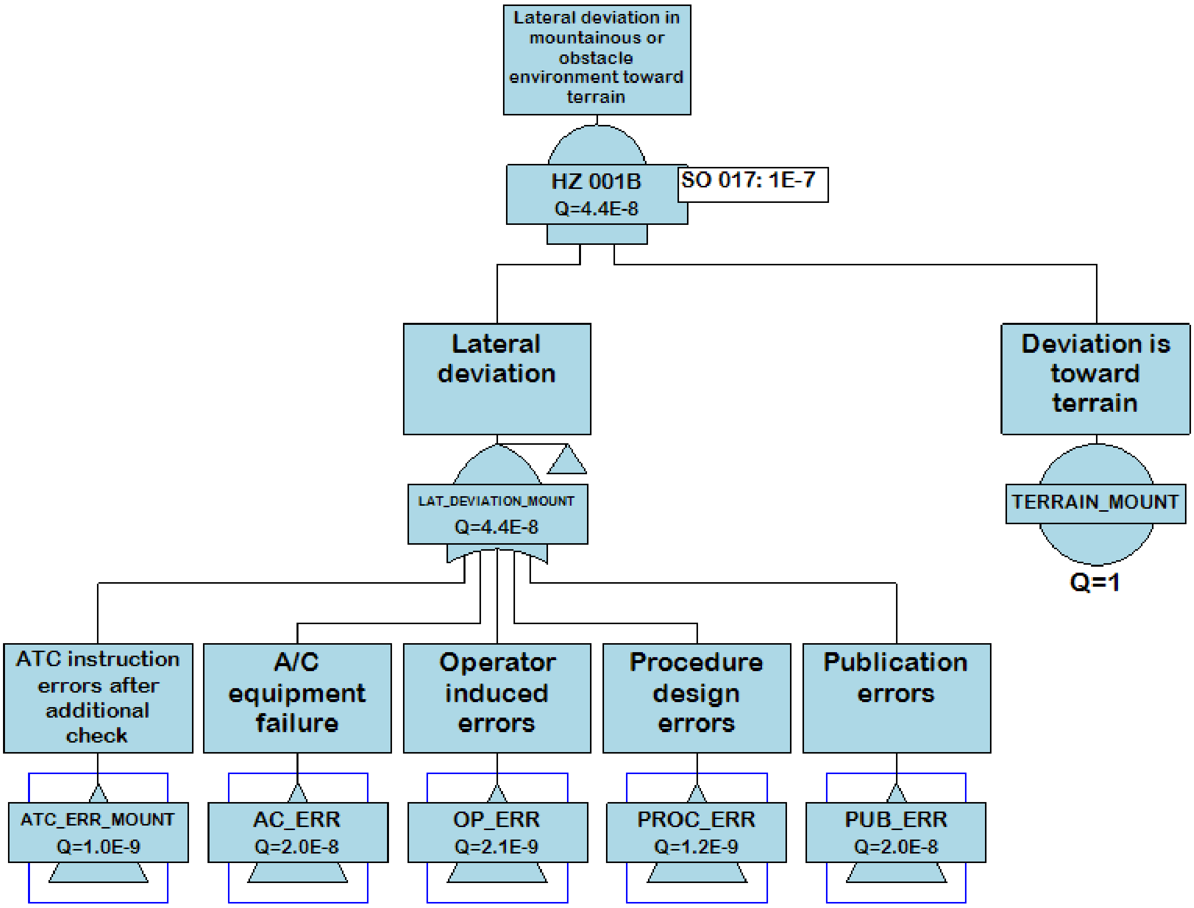


Figure 4-9: OH-001b Fault tree

Within the context of OH 001b, the probability of a deviation being toward terrain is much greater than OH 001a due to the presence of mountainous terrain. It is assumed that in the worst case the procedure is designed with terrain/obstacles such that a lateral deviation beyond RNP parameters to either side will result in a trajectory in conflict with terrain. It is felt that a more realistic approximation would be Q=0.5 or even Q=0.1, as not every segment of the approach route would have terrain immediately outside RNP protection surfaces on both sides at the same altitude. Clearly this would be affected by the specifics of an actual implementation of an RNP procedure for a particular terrain in accordance with ICAO PANS OPS. It has been left as Q=1 here, to demonstrate conformance with the Safety Objective, and to highlight the issue for further, more detailed assessments to take into consideration.

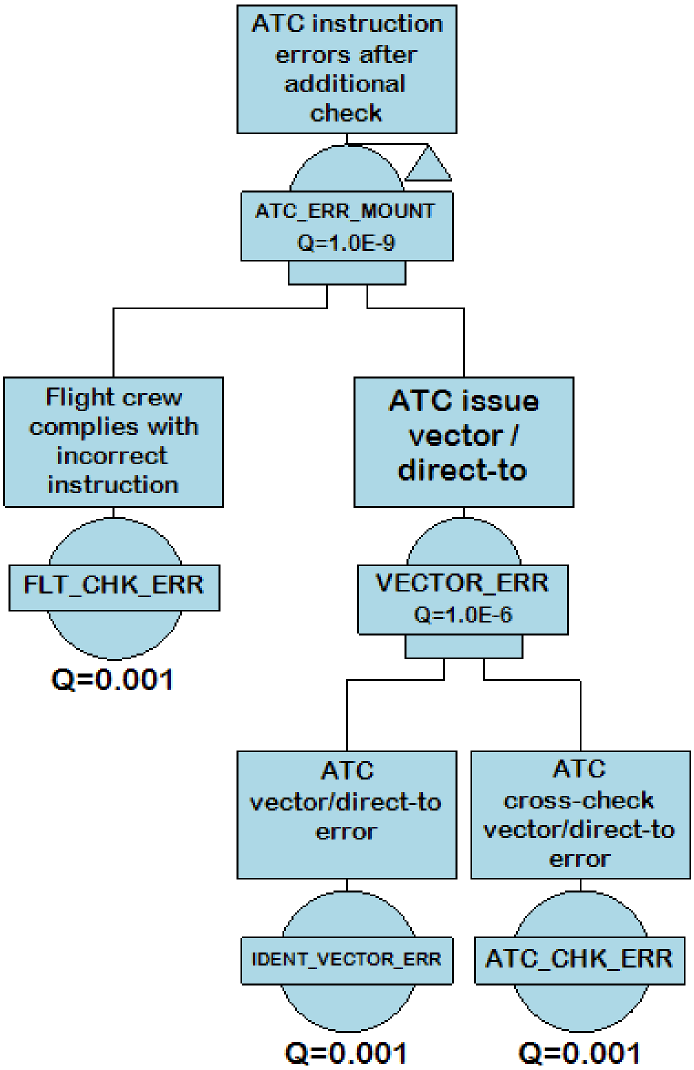


Figure 4-10: ATC instruction errors after additional check sub-tree

Without an additional mitigation (compared to OH 001a), the estimated order of magnitude performance of the ATC instruction errors gate is insufficient to achieve the SO. Therefore an additional mitigation is required to ensure safety in such a scenario. The mitigation proposed is an additional cross check be performed (ATC_CHK_ERR) prior to the issue of any vector or direct-to instruction to ensure that the resulting trajectory is not in conflict with terrain. The nature of this cross-check is not dictated here, but has been set to a typical value for human performance of a routine task. It could therefore be met by a cross-check by an ATCO, or given the future environment, a suitable controller tool.

A.1.1.3.6.1.3 OH-002 Failure to vertically follow the defined route minimum altitudes as provided by the procedure resulting into controlled flight toward terrain

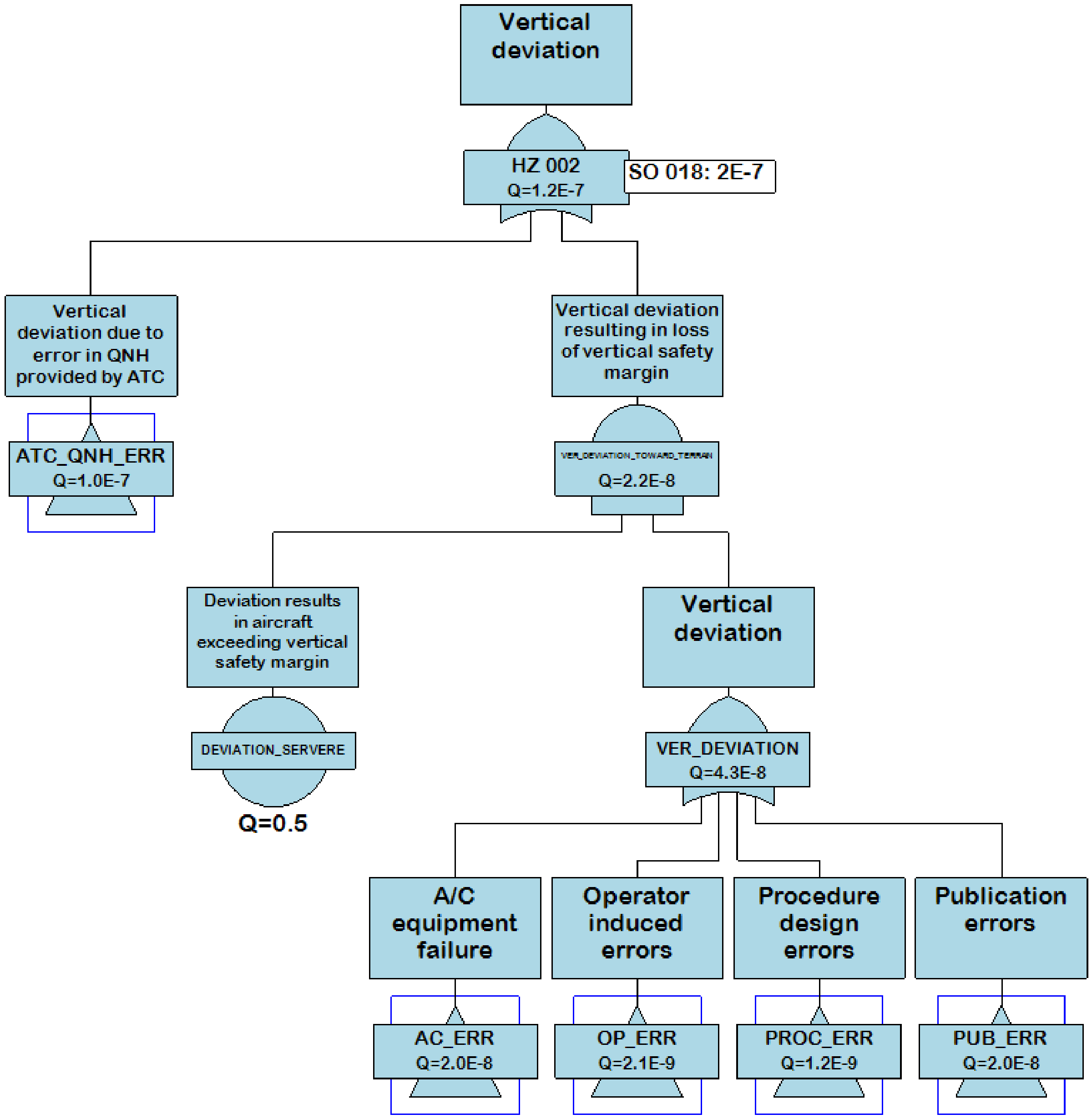


Figure 4-11: OH 002 fault tree

The following causes have been identified, which are specific to vertical deviation, and therefore not included in the description of OH 001:

- Pressure setting is erroneous and the aircraft is flying too low:
  - The QNH is erroneously transmitted to the aircraft prior to commencing the approach due to either an ATC/ATIS error or a system error in the production of meteorological data.

- The vertical position is erroneous and not detected during flight:
  - The pilot misunderstands QNH or miss-sets the altimeter

The principle difference between OH 001 and OH 002 is shown in the diagram above. In particular:

- a vertical deviation caused by ATC would be driven by QNH rather than a vector or direct-to (this is described below)
- a vertical deviation could theoretically result in trajectory toward terrain. Since the deviation could either lower, or raise trajectory, a probability of 0.5 has been used (DEVIATION_SERVERE).

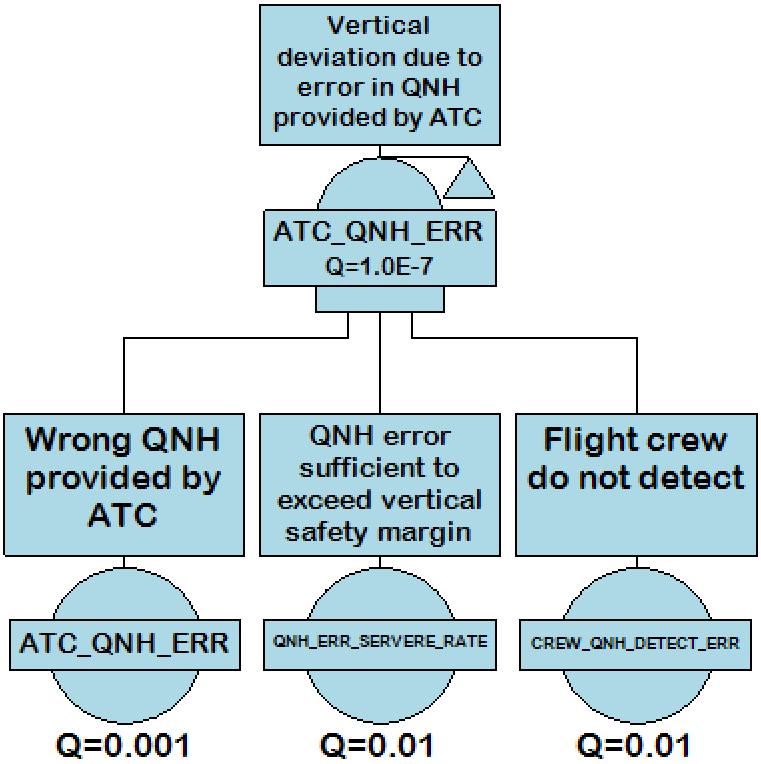


Figure 4-12: QNH error to pilot sub-tree

A standard human performance rate for a routine task of 1E-3 has been taken for the probability that the ATCO provides an erroneous QNH (ATC_QNH_ERR). However, for such an error to result in a hazardous vertical deviation, it must be both significant enough to cause navigation system error exceeding the vertical safety margin (QNH_ERR_SERVERE_RATE) *and* not be believed by the flight crew (CREW_QNH_DETECT_ERR). These two factors are clearly related; as the QNH error increases, it becomes more likely to exceed the vertical safety margin, but less plausible, and therefore less likely to be believed by flight crew. Therefore a representatively 'middle ground' has been assumed with both factors being assigned a value of 1E-2 for human error. This is mitigated through the read back process as required by SR 024.

It is noted that while the navigation system will use SBAS geometrical vertical guidance, the flight crew will most likely still consult their altimeter, and a wrong QNH could still therefore lead to flight crew error.

A.1.1.3.6.1.4 OH 003 Failure to perform a stabilized approach

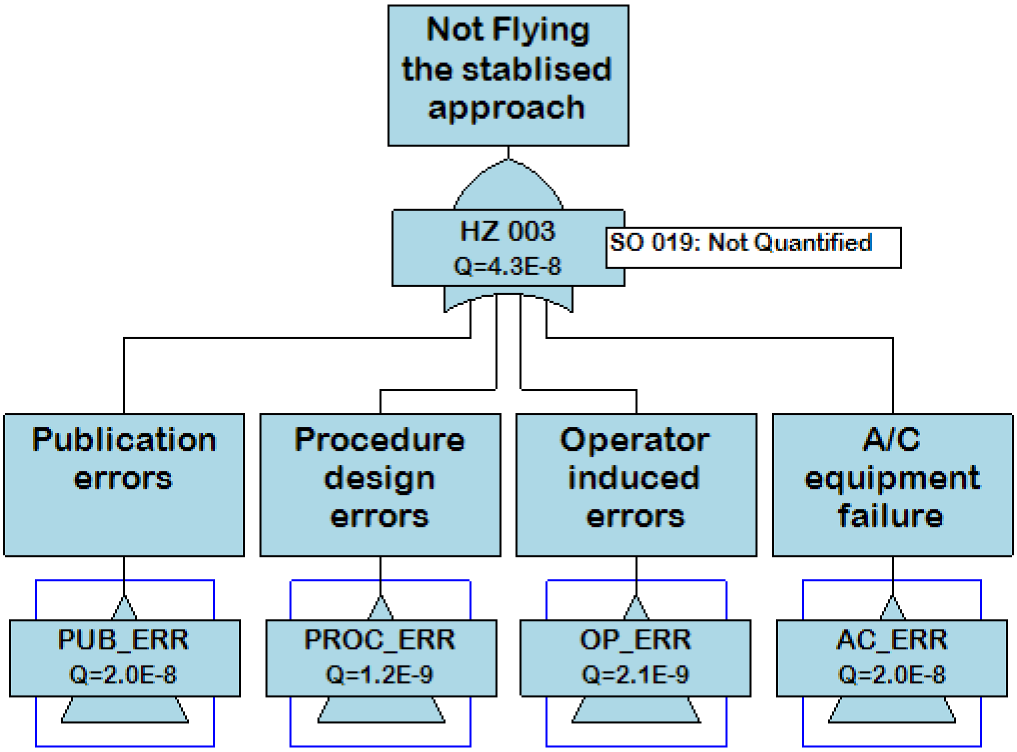


Figure 4-13: OH 003 fault tree

The classification of this hazard is not quantified, as the lowest severity class CFIT-SC3(b) seems too severe for this situation. However the objective should be that this hazard occurrence should be no more frequent for ADV-APV compared to other approaches.

The following causes leading to OH3 have been captured as:

- System components in the aircraft/NAV system
- The causes are initiated by the Pilot
- The causes are initiated by the Route/Procedure design/Publication

If the pilot does not follow established procedures, including speed, or follow ATC clearances, it could lead to a non-stabilized approach. If the procedure is very demanding to fly and the pilot is not accordingly trained for the procedure, it could be a factor for a non-stabilized approach.

These other causes are the same as covered for OH 001, and the related branches of the fault tree are shown above (section A.1.1.3.6.1.1)

The procedure design could be so challenging that the pilot and/or the aircraft system would not be able to configure the aircraft as to ensure a stable approach.

A.1.1.3.6.1.5 OH 004 Failure to change mode from LNAV to LPV

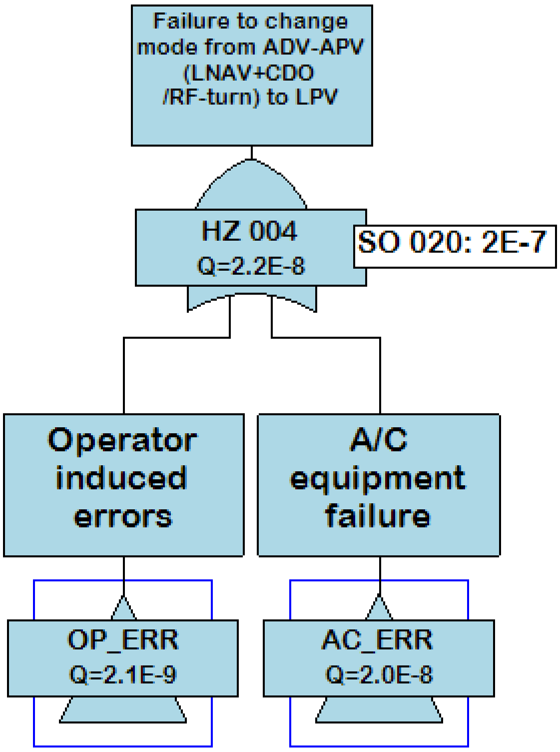


Figure 4-14: OH 004 fault tree

This particular issue was reported in validation VP483, in that case the aircraft system reverted to ALT hold instead of changing from LNAV to LPV. In those cases either an unacceptably high workload was experienced to correct the issue, or the procedure had to be abandoned.

There are only two potential causes of this hazard, operator (flight crew) errors, or aircraft equipment failure. These branches of the fault tree are the same as for OH 001 and are shown above (section A.1.1.3.6.1.1).

A.1.1.3.6.1.6 OH 005a Failure to laterally follow the defined missed approach route segment as provided by the procedure in non-mountainous environment resulting into controlled flight toward terrain

The fault tree for OH 005a is the same as for OH 001a, as the causes are considered to be identical. The difference between the hazards is only in the phase of flight that is affected. The operational consequences to the hazards are different (i.e. the event side of the hazard analysis), which is covered by the severity classification in section A.1.1.2.8.

A.1.1.3.6.1.7 OH 005b Failure to laterally follow the defined missed approach route segment as provided by the procedure in mountainous or obstacle environment resulting into controlled flight toward terrain

The fault tree for OH 005b is the same as for OH 001b, as the causes are considered to be identical. The difference between the hazards is only in the phase of flight that is affected. The operational consequences to the hazards are different (i.e. the event side of the hazard analysis), which is covered by the severity classification in section A.1.1.2.8.

A.1.1.3.6.1.8 OH 006 – 009 Failure to properly sequence traffic/space aircraft

There are four difference hazards which are covered by the following fault tree, all of which are determined to have the same causal factors. Again the difference with each hazard is the phase of flight that is affected. The operational consequences to the hazards are different (i.e. the event side of the hazard analysis), which is covered by the severity classification in section A.1.1.2.8.

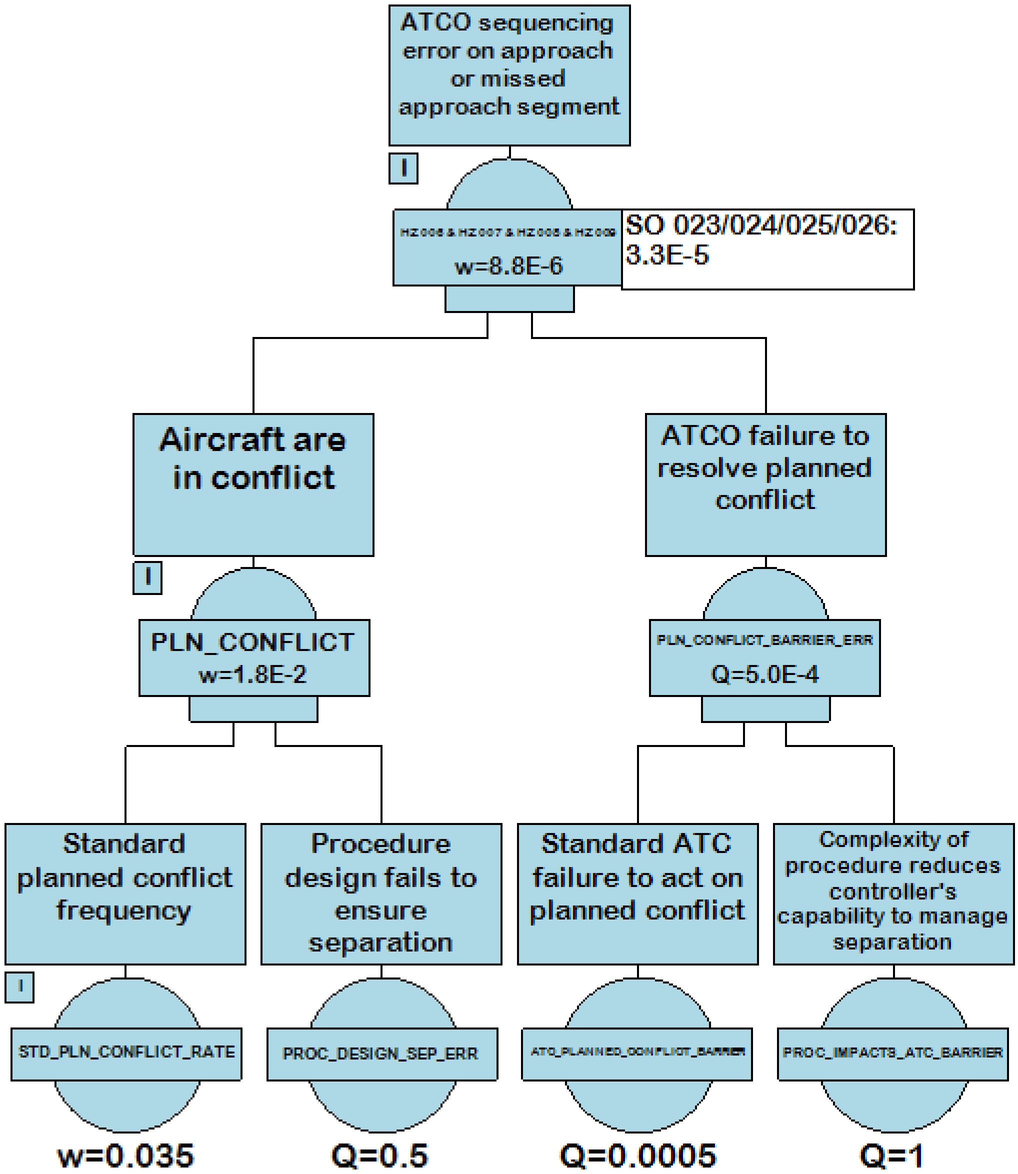


Figure 4-15: OH 006/007/008/009 common fault tree

It is noted that although the hazards all share causes, they are not common causes, as the hazards are considered to be mutually exclusive: the hazards apply to a different phase of flight, and cannot occur at the same time. Although some combinations of hazards 006/007/008/009 could technically occur at the same time, it is not considered credible. This is covered in section A.1.1.3.6.2 below.

There are two sides to the fault tree (in common with the approach taken within the Mid Air Collision AIM model). 1) that a conflict exists, and 2) that the ATCO barrier (in this case the planning barrier) must fail.

1) In order for the conflict to exist, there must arise a situation whereby two (or more) aircraft are on a conflicting trajectory. This is factored by STD_PLN_CONFLICT_RATE, the quantification of which is taken from the Mid Air Collision AIM model. This is taken to be the average probability that a planned conflict may exist. This is then modified by the fact that the situation is not 'average', but rather involving an aircraft on part of the procedure (which may be either the approach, or a missed approach). Since part of the objective of the procedure design is to ensure aircraft are separated there must be an improvement in the base probability of a planned conflict existing. For this analysis a conservative estimate of 0.5 has been taken (PROC_DESIGN_SEP_ERR).

2) Given that a planned conflict is a standard situation for a controller to resolve, the standard effectiveness for the barrier has been taken (ATCO_PLANNED_CONFLICT_BARRIER), again from the Mid Air Collision AIM model. However the particular situation may be affected by complexities introduced by the procedure. This is therefore added as a modification factor (PROC_IMPACTS_ATC_BARRIER). Given that validation results indicated ATCOs considered the proposed concept, rules and change of practices operationally acceptable and feasible, and in the absence of other data, this analysis has assigned a value of 1 (no modification). Nonetheless it is recorded here, as if the procedure did impair the ATCO's ability to resolve any such conflict, in which case it may affect achievability of the SO. It is therefore recommended for further investigation in following assessments.

A.1.1.3.6.1.9 OH 010 Failure to manage separation of an aircraft executing a company contingency procedure with other traffic

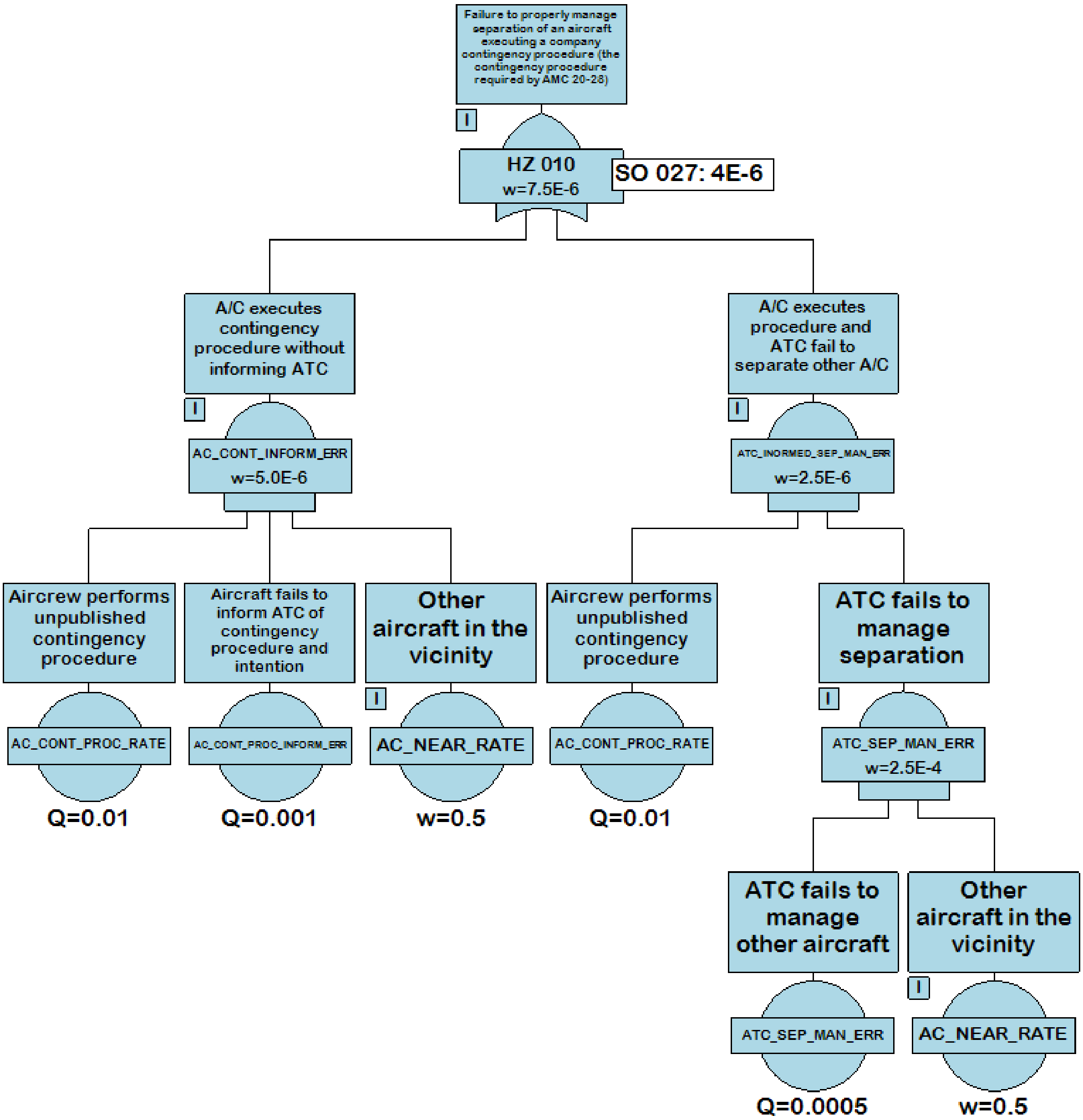


Figure 4-16: OH 010 fault tree

There are two possible causes for OH 010 to occur:

1) The aircraft executes a contingency procedure without informing ATC.

2) The aircraft executes a contingency procedure, informs ATC, and ATC fail to manage separation.

In either case it is necessary for another aircraft to be on a conflicting trajectory for the hazard to occur. As with other hazards, a conservative quantification of 0.5 has been used in the assessment, the reality will depend upon airspace design.

Within 1), it is expected that the aircrew would perform the published missed approach in most cases, and so a value of 1E-2 has been taken for unpublished contingency procedure on the basis of human performance. Since the task of informing ATC that an unpublished contingency procedure has been undertaken is a systematic task a value of 1E-03 has been taken for failure probability.

Within 2), since the resolution of a planned conflict is a standard situation for the ATCO, the standard effectiveness for the barrier has been taken (ATCO_PLANNED_CONFLICT_BARRIER), again from the Mid Air Collision AIM model.

Note that this SO is within the same order of magnitude, but not 'met'. Subject to the considerations as discussed in section A.1.1.3.6.1, it is therefore recommended that further work adopts additional focus upon this hazard.

A.1.1.3.6.1.10 Summary of causal factors

Event	Description	Rate	Rationale
AC_CONT_PROC_INFORM_ERR	Aircrew fails to inform ATC of contingency procedure and intention	1.00E-03	Standard human performance for routine task
AC_CONT_PROC_RATE	Aircrew performs unpublished contingency procedure	1.00E-02	Assumption. Aircrew would normally use published missed approach
AC_NEAR_RATE	Other aircraft in the vicinity	5.00E-01	Conservative assumption
AIP_ERR	AIP Publication Error	1.00E-08	ED125 probability associated with Critical severity
APP_SEL_ERR	Incorrect approach selected	1.00E-06	On basis of two flight crew and routine crew cross check
ATC_CHK_ERR	ATC cross-check vector/direct-to error	1.00E-03	Standard human performance for routine task
ATC_PLANNED_CONFLICT_BARRIER	Standard ATC failure to act on planned conflict	5.00E-04	Based on Mid Air Collision AIM for ineffective management of planned conflict
ATC_QNH_ERR	Wrong QNH provided by ATC	1.00E-03	Assumption based on human performance for routine task
ATC_SEP_MAN_ERR	ATC fails to manage other aircraft	5.00E-04	Based on Mid Air Collision AIM for ineffective management of planned conflict
CREW_QNH_DETECT_ERR	Flight crew do not detect	1.00E-02	Assumption, balanced with QNH_ERR_SERVERE_RATE
DB_LOAD_ERR	Database loading error	1.00E-10	Requires failure of 2 ED125 Major (i.e. 1E-05) events.
DESIGN_COMPLIANCE_ERR	Design non-compliant with ICAO requirements	1.00E-05	ED125 probability associated with Major severity
DESIGN_ENV_ERR	Design not suitable for the environment / aircraft type	1.00E-05	ED125 probability associated with Major severity
DEVIATION_SERVERE	Deviation results in aircraft exceeding vertical safety margin	5.00E-01	Deviation can either be away from terrain (up) or toward terrain (down). It may in fact be less.
EFIS_CHK_ERR	EFIS cross-check error	1.00E-03	Standard human performance for routine task
FLT_CHK_ERR	Flight crew complies with incorrect instruction	1.00E-03	Standard human performance for routine task
GUIDANCE_ERR	Wrong guidance instruction	1.00E-08	ED125 probability associated with Critical severity
IDENT_VECTOR_ERR	ATC vector/direct-to error	1.00E-03	Standard human performance for routine task
LOA_ERR	LoA Type 1 and Type 2 error	1.00E-08	ED125 probability associated with Critical severity
POSITION_ERR	Wrong position estimation	1.00E-08	ED125 probability associated with Critical severity

Event	Description	Rate	Rationale
PROC_DESIGN_SEP_ERR	Procedure design fails to ensure separation	5.00E-01	Conservative assumption
PROC_IMPACTS_ATC_BARRIER	Complexity of procedure reduces controller's capability to manage separation	1.00E+00	No impact, but included to show criticality of this aspect of the procedure design
PROC_VALIDATION_ERR	Procedure validation error (per Doc 9906)	1.00E-05	ED125 probability associated with Major severity
QNH_ERR_SEVERE_RATE	QNH error sufficient to exceed vertical safety margin	1.00E-02	Assumption, balanced with CREW_QNH_DETECT_ERR
SOPS_ERR	Failure to comply with Standard Operating Procedures (SOPS) to abandon procedure whilst within RNP limits	1.00E-03	Standard human performance for routine task
STD_PLN_CONFLICT_RATE	Standard planned conflict frequency	3.50E-02	Based on Mid Air Collision AIM planned conflict model
SURVEY_ERR	Survey error	1.00E-09	Assumed to involve at least two check/validation steps and the initial action, all at standard human performance for routine task
TERRAIN_MOUNT	Deviation is toward terrain	1.00E+00	In mountainous/obstacle terrain the worst case is that any deviation from the route is toward terrain (note: as discussed above this will vary per specific procedure and more typical value is expected to be 1.00E-01)
TERRAIN_NON_MOUNT	Deviation is toward terrain	1.00E-06	In non-mountainous terrain the probability of a deviation being toward terrain or obstacle is extremely remote.
TRAJ_SEL_ERR	Trajectory wrongly adjusted (pilot)	1.00E-06	On basis that this is a two pilot approach and both crew routinely check the trajectory
VECTOR_ERR	ATC issue vector / direct-to error	1.00E-03	Assumed lower than 1E-3 since ATC must have justification to issue vector.

A.1.1.3.6.2 Common Cause Analysis

The common cause analysis has been completed as a part of the causal analysis. The table below summaries the causal factors which are common to more than one hazard, and which hazards they are common to. The rows which are in grey indicate causal factors which either relate to only one hazard, hazards which are mutually exclusive (for example OH 001a and OH 001b are for different operating environments), or are merely modification factors/probabilities and therefore cannot affect multiple hazards.

It is expert opinion that although many of the casual factors contribute to multiple hazards, this does not lead to an increase in the required integrity requirements associated. The rationale for this is recorded in the table below. The principle rationale, is that although multiple hazards could be triggered by a single causal factor, the hazards that are effected lead to the same outcome. For example an AIP publication error could lead to lateral and vertical deviation simultaneously, however the severity of this would be no worse than the severity of either alone, as the outcome is still the same: controlled flight towards terrain. The mitigations to resolve the hazard also remain unchanged.

ID	Causal factor	Affected Hazards	Rationale
AIP_ERR	AIP Publication Error	OH001A, OH005B, OH001B, OH002, OH003, OH005A	OH 001A, 001B 0005A and 005B are mutually exclusive, as they are either different phase of flight, or environments. Although OH 002 and another could be affected simultaneously the severity of the outcome would remain the same as for a single hazard.
AC_CONT_PROC_INFORM_ERR	Aircraft fails to inform ATC of contingency procedure and intention	OH010	Single hazard
AC CONT PROC_RATE	Aircrew performs unpublished contingency procedure	OH010	Single hazard
ATC_CHK_ERR	ATC cross-check vector/direct-to error	OH001B, OH005B	Different phases of flight, so cannot be simultaneously affected.
ATC_SEP_MAN_ERR	ATC fails to manage other aircraft	OH010	Single hazard
VECTOR_ERR	ATC issue vector / direct-to error	OH001A, OH002	Although OH 001A and 002 could be affected simultaneously the severity of the outcome would remain the same as for a single hazard.
IDENT_VECTOR_ERR	ATC vector/direct-to error	OH001B, OH005B	Different phases of flight, so cannot be simultaneously affected.
PROC_IMPACTS_ATC_BARRIER	Complexity of procedure reduces controller's capability to manage separation	OH006, OH007, OH008, OH009	The hazards represent different phases of flight or specific scenarios.
DB_LOAD_ERR	Database loading error	OH001A, OH001B, OH002, OH003, OH004, OH005A, OH005B	As AIP_ERR, except that OH004 is included here, but is a separate phase of flight
DESIGN_COMPLIANCE_ERR	Design non-compliant with ICAO requirements	OH001A, OH001B, OH002, OH003, OH005A, OH005B	As AIP_ERR
DESIGN_ENV_ERR	Design not suitable for the environment / aircraft type	OH001A, OH001B, OH002, OH003, OH005A, OH005B	As AIP_ERR
TERRAIN NON MOUNT	Deviation is toward terrain	OH001A	Single hazard
TERRAIN MOUNT	Deviation is toward terrain	OH001B, OH002	Probability only
DEVIATION SERVERE	Deviation results in aircraft exceeding vertical safety margin	OH002	Single hazard

ID	Causal factor	Affected Hazards	Rationale
EFIS_CHK_ERR	EFIS cross-check error	OH001A, OH001B, OH002, OH003, OH004, OH005A, OH005B	As DB_LOAD_ERR
SOPS_ERR	Failure to comply with Standard Operating Procedures (SOPS) to abandon procedure whilst within RNP limits	OH001A, OH001B, OH002, OH003, OH004, OH005A, OH005B	As DB_LOAD_ERR
FLT_CHK_ERR	Flight crew complies with incorrect instruction	OH001A, OH001B, OH004, OH005A, OH005B	As AIP_ERR
CREW_QNH_DETECT_ERR	Flight crew do not detect	OH002	Single hazard
APP_SEL_ERR	Incorrect approach selected	OH001A, OH001B, OH002, OH003, OH004, OH005A, OH005B	As DB_LOAD_ERR
LOA_ERR	LoA Type 1 and Type 2 error	OH001A, OH001B, OH002, OH003, OH005A, OH005B	As AIP_ERR
AC_NEAR_RATE	Other aircraft in the vicinity	OH010	Single hazard
PROC_DESIGN_SEP_ERR	Procedure design fails to ensure separation	OH006, OH007, OH008, OH009	As PROC_IMPACTS_ATC_BARRIER
PROC_VALIDATION_ERR	Procedure validation error (per Doc 9906)	OH001A, OH001B, OH002, OH003, OH005A, OH005B	As AIP_ERR
QNH_ERR_SERVERE_RATE	QNH error sufficient to exceed vertical safety margin	OH002	Single hazard
ATC_PLANNED_CONFLICT_BARRIER	Standard ATC failure to act on planned conflict	OH006, OH007, OH008, OH009	As PROC_IMPACTS_ATC_BARRIER
STD_PLN_CONFLICT_RATE	Standard planned conflict frequency	OH006, OH007, OH008, OH009	Probability only
SURVEY_ERR	Survey error	OH001A, OH001B, OH002, OH003, OH005A, OH005B	As AIP_ERR
TRAJ_SEL_ERR	Trajectory wrongly adjusted (pilot)	OH001A, OH001B, OH002, OH003, OH004, OH005A, OH005B	As DB_LOAD_ERR
GUIDANCE_ERR	Wrong guidance instruction	OH001A, OH001B, OH002, OH003, OH004, OH005A,	As DB_LOAD_ERR

ID	Causal factor	Affected Hazards	Rationale
		OH005B	
POSITION_ERR	Wrong position estimation	OH001A, OH001B, OH002, OH003, OH004, OH005A, OH005B	As DB_LOAD_ERR
ATC_QNH_ERR	Wrong QNH provided by ATC	OH002	Single hazard

Table 4-19: Causal factors and related hazards

A.1.1.3.6.3 Formalization of Mitigations

Mitigations identified in the causal analysis are recorded in the table below. Their introduction is recorded in the fault tree, and is described within the relevant sub section of section A.1.1.3.6.1.

Safety Requirement	Requirement (functionality & performance)	Safety Objective
SR 038	The flight crew shall check that their trajectory remains free of conflict with terrain before undertaking a vector or direct-to during an ADV-APV procedure	SO16, SO17, SO21, SO22
SR 039	Both members of the flight crew shall ensure that the trajectory has been correctly configured before attempting an ADV-APV procedure	SO16, SO17, SO18, SO19, SO20, SO21, SO22
SR 040	Both members of the flight crew shall ensure that the correct approach has been selected before undertaking the ADV-APV procedure.	SO16, SO17, SO18, SO19, SO20, SO21, SO22
SR 041	Both members of the flight crew shall check that the ADV LPV procedure data in the FPLN match those of the published chart.	SO16, SO17, SO18, SO19, SO20, SO21, SO22
SR 042	An ATC cross check shall be performed prior to issuing a vector or direct-to for an aircraft undertaking an ADV-APV procedure	SO17, SO22
SR 043	As per EASA AMC 20-27, ATCOs shall receive training specifically on the nature of the procedure and relationship with traffic.	SO23/24/25/26

Table 4-20: Additional safety requirements from analysis of design

A.1.1.3.6.4 Safety Requirements (integrity/reliability)

The following integrity/reliability requirements have been identified through causal analysis:

Safety Requirement	Requirement (functionality & performance)	Related SRs	Related Hazard
SR 044	The probability of aircraft nav system providing a wrong position estimation shall be no greater than $1x10^{-8}$ per	SR 018, SR 022,	HZ 001AH

Safety Requirement	Requirement (functionality & performance)	Related SRs	Related Hazard
	flight.	SR 025, SR 026, SR 030, SR 031, SR 032	Z 001B H Z 002 HZ 003 HZ 004 H Z 005A HZ 005B
SR 045	The probability of aircraft nav system providing a wrong guidance instruction shall be no greater than $1x10^{-8}$ per flight.	SR 012, SR 014	HZ 001A H Z 001B H Z 002 HZ 003 HZ 004 H Z 005A HZ 005B
SR 046	The probability of a database loading error on the aircraft nav systems shall be no greater than $1x10^{-10}$ per flight.	SR 007, SR 008, SR 009, SR 010	HZ 001A H Z 001B H Z 002 HZ 003 HZ 004 H Z 005A HZ 005B
SR 047	The probability of a survey error in the procedure design shall be no greater than $1x10^{-9}$ per flight.	SR 002, SR 003, SR 004	HZ 001A H Z 001B HZ 002 HZ 003 H Z 005A HZ 005B
SR 048	The probability of a procedure validation error shall be no greater than $1x10^{-5}$ per flight.	SR 002, SR 003, SR 004	HZ 001A H Z 001B HZ 002 HZ 003 H Z 005A HZ 005B
SR 049	The probability of the procedure design being unsuitable for environment or aircraft type shall be no greater than $1x10^{-5}$ per flight.	SR 002, SR 003, SR 004	HZ 001A H Z 001B HZ 002

Safety Requirement	Requirement (functionality & performance)	Related SRs	Related Hazard
			HZ 003 HZ 005A HZ 005B
SR 050	The probability of a procedure design not being compliant with ICAO requirements shall be no greater than $1x10^{-5}$ per flight.	SR 002, SR 003, SR 004	HZ 001A HZ 001B HZ 002 HZ 003 HZ 005A HZ 005B
SR 051	The probability of an AIP publication error shall be no greater than $1x10^{-5}$ per flight.	SR 006	HZ 001A HZ 001B HZ 002 HZ 003 HZ 005A HZ 005B
SR 052	The probability of an LoA Type 1 or Type 2 error shall be no greater than $1x10^{-5}$ per flight.	SR 006	HZ 001A HZ 001B HZ 002 HZ 003 HZ 005A HZ 005B

A.1.1.3.7 Achievability of the Safety Criteria

The applicable Safety Acceptance criteria for Baseline#1(ILS Cat I approach) require that there shall be, during ADV-APV final approach, no increase of controlled flight towards terrain compared to LPV (SAC#4), no increase of Controlled Flight Toward Terrain (CFTT – CF4) during initial and intermediate approach with ADV-APV compared to current initial and intermediate approach navigation (SAC#5), no increase of Controlled Flight Toward Terrain (CFTT – CF5) during Missed approach with ADV-APV compared to current missed approach navigation (SAC#6), no increase of imminent infringement (MF5-9) during initial and intermediate approach with ADV-APV compared to RNP APCH (or current NAV) initial and intermediate approach (SAC#7) and that the likelihood of Runway over-run and/or hard landing (non-stabilized) due to ADV-APV shall not increase compared to LPV (SAC#9).

The SAC from Phase 1 are judged by expert opinion to still apply in Phase 2.

The general approach to showing that SACs have been satisfied through the derivation of success-case and failure-case Safety Requirements is done in several stages, as follows:

- A SPR-level model (see A.1.1.3.3) of the different “element” composing the ADV-APV approach “System” has been defined but not validated. Such model encompasses all the elements from the procedure design to the aircraft operation including the necessary GNSS/SBAS Signal In Space and the data base integrator & packer activities.

- Success-case safety requirements have been derived using the SPR-level model and a mapping of these requirements towards the Safety objectives

- Additional success-case safety requirements have been derived considering normal and abnormal operations. The operational scenarios have not fully been identified and the associated thread analysis that should have been carried out for each scenario is then not complete.

- For each Operational Hazard (OH), a causal analysis has been made and an initial fault tree developed. A fault tree quantification permits to verify if SO defined have been satisfied. Mitigation to reduce the likelihood of specific failures will then be captured as additional success-case safety requirements and failure-case safety requirements will be determined to limit the frequency with which identified failures can be allowed to occur considering the SO.

Safety Requirements which are not under the control of ANSP like those associated to database supplier, aircraft operator, and aircraft navigation system and flight crew will be defined as Safety Assumptions.

A.1.1.3.8 Realism of the SPR-level Design

A.1.1.3.8.1 Achievability of Safety Requirements / Assumptions

The requirements and assumptions developed in this phase of the safety assessment 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 is stated in line with existing standards.

First it is recalled that safety requirements have been determined/derived only for elements under the managerial control of ANSP. Assumptions have been identified for the others elements (data base supplier, aircraft, flight crew…)

The vast majority of ANSP Functional and performance safety requirements are capable of being satisfied in a typical implementation because they are relying on either existing standards (e.g ICAO SARPS or Documents) or because similar requirements have been already implemented locally by certain States (e.g US).

The achievability of the ANSP Integrity safety requirements are less obvious. Some integrity safety requirements should be easily satisfied because they are not different from those applicable to the baseline situation (e.g. QNH transmission, ATC vectoring towards the final approach path) or because they are derived from existing standards which are well known by the ANSP community (e.g. GNSS/SBAS SIS integrity).

Others integrity safety requirements like those applicable to the procedure design or the procedure publication require a high level of integrity (e.g. The probability of designing an incorrect ADV-APV approach procedure shall be no more than 1.0 E-7 per approach). Achievability of these requirements might be a challenge for ANSP but such requirements are necessary to guarantee the level of safety associated to LPV approach operations. The ANSP shall demonstrate the compliance against those safety requirements by relying on an appropriate assurance process to be applied internally.

Furthermore the analysis of the internal failure modes has been derived bottom up utilising either existing industry figures for typical performance, performance which is required by existing standards or conservative assumptions.

Assumptions (elements outside of the managerial control of ANSP) are capable of being satisfied in a typical implementation because they are relying mainly on the EASA AMC 20-28 which is the airworthiness and ops approval guidance material for LPV approach. However some assumptions are not addressed directly by the EASA AMC 20-28 and therefore satisfaction of these safety assumptions cannot be shown at that stage. It is proposed to discuss these Safety assumptions with EASA in order to decide how to solve this concern.

A.1.1.3.8.2 “Testability” of Safety Requirements

In the previous phase of the project, the ANSP Functional and performance safety requirements are verifiable by direct means which could be flight procedure validation procedure/process, validation report, training certificate, copy of the agreement for the SBAS service provider, procedure designer sw tool approval, etc.. This approach has been maintained in this phase, which ensures that the requirements are testable.

As with the previous phase, most of ANSP Integrity safety requirements should rely on an appropriate assurance process to be implemented. This is particularly true for the procedure design and procedure publication. In such case the principle of the quality assurance process described in the ICAO Doc 9906 and the quality of aeronautical data of the Regulation (EU) N° 73/2010 should help the ANSP to demonstrate their compliance against these integrity safety requirements. Again the extended scope of this phase of the project does not change the above.

A.1.1.3.9 Validation & Verification of the Safe Design at SPR Level

The assurance of validation and verification of the SPR-level safety assessment requirements is an on-going activity. The safety assessment has been performed on the basis of the Use Cases, Scenarios and Operating Method described in the OSED [5]. These have been validated through the exercises described in the validation plan and recorded in the synthesis of validation results [33]. An on-going activity 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. An initial trace table which shows this mapping has been recorded in the main body of this document.

A.1.1.4 Detailed Safe Design at Physical Level

Project 05.06.03, as an operational project does not develop the concept to the Physical Level, and therefore no such design is available to be assessed. This stage of the safety assessment is therefore out of scope for the project. This is consistent with other SESAR operational projects. This level of assessment should be addressed in the related System project (09.2).

A.1.2 Security risk assessment

Discussions have been initiated with WP16.6.2 regarding a security risk assessment, but no assessment has been performed at this time.

The initial expectation is that the concept changes do not result in any new security risks, specifically as it is anticipated that no new primary or secondary assets would be identified. It is also felt unlikely that the impact resulting from the compromise of any assets would change. None-the-less an initial security risk assessment workshop is recommended during the industrialisation and deployment phase.

A.1.3 Environment impact assessment

An environmental impact assessment has not been performed for this project.

A.1.4 OPA

A.1.4.1 Introduction

A.1.4.1.1 Purpose of the document

The purpose of this document is to describe the result of the activities conducted according to the P05.06.03 Human Performance Assessment Plan (Ref. [36]), in order to derive the HP Assessment report for P05.06.03 including requirements and recommendations.

A.1.4.1.2 Intended readership

The SESAR intended readership includes the following OFA projects, because of the similarities of the Advanced LPV, RNP to GLS and RNP to ILS concepts :

- Project 09.09 members.
- Project 09.10 members.
- Project 05.06.03 members.
- Project 06.08.05 members.
- Project 05.03 members.

A.1.4.1.3 Human performance work schedule within the project

The Human Performance assessment activities for the P05.06.03 were performed during the flight test exercise VP-483, in May 2014.

A.1.4.1.4 Structure of the document

The structure of the document is as follows:

- Section 1: Introduction of the HP plan.
- Section 2: Overview of the HP assessment Process.
- Section 3: Results of the application of the HP assessment process to define the HP plan.
- Section 4: References.

A.1.4.1.5 Glossary of terms

Term	Definition
Human Factors (HF)	HF is used to denote aspects that influence a human's capability to accomplish tasks and meet job requirements. These can be external to the human (e.g. light & noise conditions at the work place) or internal (e.g. fatigue). In this way, "Human Factors" can be considered as *focussing on the variables that determine Human Performance*.
Human Performance (HP)	HP is used to denote the human capability to successfully accomplish tasks and meet job requirements. In this way, "Human Performance" can be considered *as focussing on the observable result of human activity in a work context*. Human Performance is a function of Human Factors (see above). It also depends on aspects related to Recruitment, Training, Competence, and Staffing (RTCS) as well as Social Factors and Change Management.
HP activities	HP activities are evidence-gathering activities that are carried out as part of Step 4 (Arguments & Evidence) of the HP assessment process. They can comprise, among others, activities such as task analyses, cognitive walkthroughs, and experimental studies.
HP assessment	An HP assessment is the documented result of applying the HP assessment process to the SESAR project-level (i.e. WP4-15 projects). HP assessments provide the input for the HP case.
HP assessment process	The HP assessment process is the process by which HP aspects related to the proposed changes in SESAR are identified and addressed. It covers the conduct of HP assessments on the project-level as well as the HP case building over larger clusters of projects. Further development of this process constitutes the scope of Project 16.04.01.
HP benefit	An HP benefit relates to those aspects of the proposed ATM concept that are likely to have a positive impact on human performance.
HP Case	An HP case is the documented result of combining HP assessments from projects into larger clusters (e.g. Operational Focus Areas, deployment packages) in SESAR.
HP issue	An HP issue relates to those aspects in the ATM concept that need to be resolved before the proposed change can deliver the intended positive effects on Human Performance.
HP impact	An HP impact relates to the effect of the proposed solution on the human operator. Impacts can be positive (i.e. leading to an increase in Human Performance) or negative (leading to a decrease in Human Performance).
HP recommendations	HP recommendations propose means for mitigating HP issues related to a specific operational or technical change. HF recommendations are proposals that require additional analysis (i.e. refinement and validation). Once this additional analysis is performed, HF recommendations may be transformed into HF requirements.
HP requirements	HP requirements are statements that specify required characteristics of a solution from an HF point of view. HP requirements should be integrated into the DOD, OSED, SPR, or specifications. HF requirements can be seen as the stable result of the HF contribution to the project, leading to a redefinition of the operational

Term	Definition
	concept or the specification of the technical solution.

A.1.4.1.6 Acronyms and Terminology

Term	Definition
APV	Approach Procedure with Vertical Guidance
ATCO	Air Traffic Controllers
ATM	Air Traffic Management
CDA / CDO	Continuous Descent Arrival/Operation
DA / DH	Decision Altitude / Decision Height
FAF/FAP	Final Approach Fix/Point
FMS	Flight Management System
GNSS	Global Navigation Satellite System
HMI	Human-Machine Interface
LNAV	Lateral NAVigation
LOC	LOCalizer
LPV	Localizer precision with Vertical Guidance
OSED	Operational Service and Environment Definition
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)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
VNAV	Vertical NAVigation
VS	Vertical Speed
xLS	x Landing System

A.1.4.2 The Human Performance Assessment Process

The purpose of the HP assessment process is to ensure that HP aspects related to SESAR technical and operational developments are systematically identified and managed.

Figure 17 provides an overview of the HP assessment process steps and the two main HP outputs: the HP Assessment Plan (Ref. [36]) and the HP Assessment Report (current document), feeding respectively into the Validation Plan and the Validation Report.

For detailed description of the process, refer to Ref. [19] and Ref. [34].

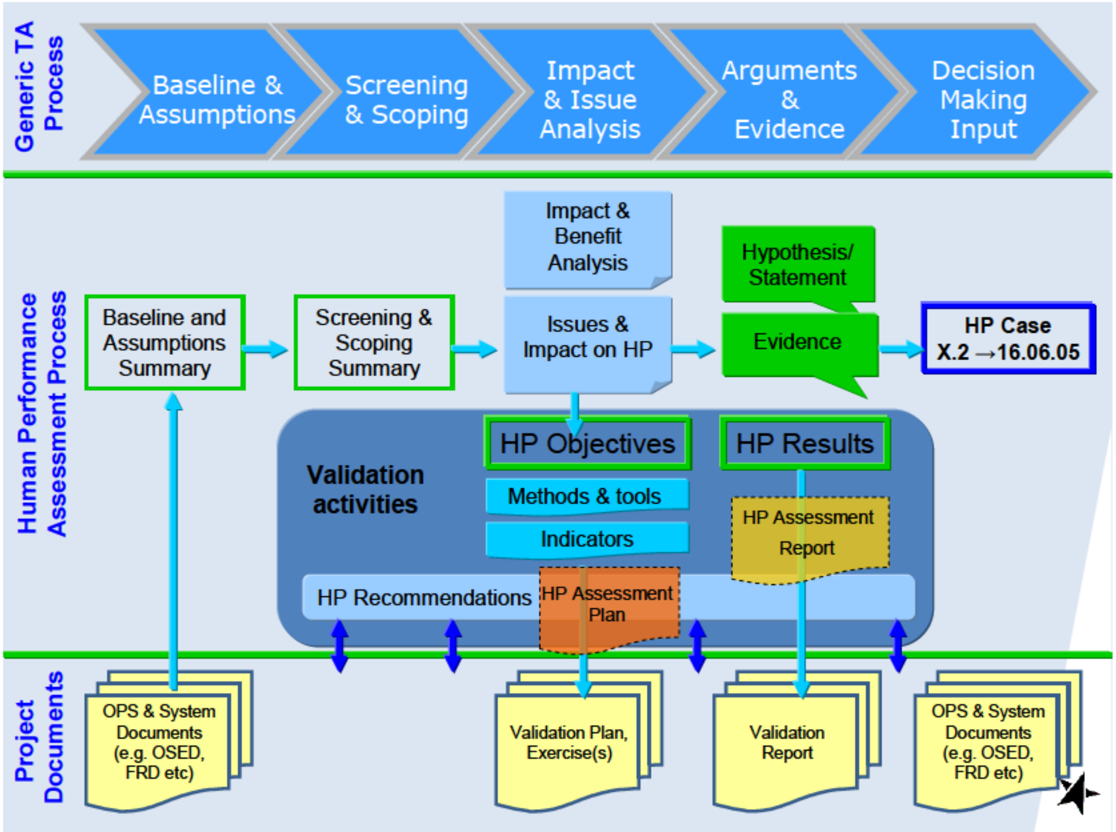


Figure 17: Steps of the HP assessment process

A.1.4.3 Human Performance Assessment

A.1.4.3.1 Description of Baseline and Assumptions - HP specifics

Refer to the VALP and HP Assessment Plan (Ref. [36]) and to the OSED (Ref. [35]) for descriptions of the advanced APV concept and the assumptions on which the project is based.

A.1.4.3.2 Screening and Scoping the Impact of the Change

This section describes the main HP-related impacts of the changes resulting from the proposed concept in terms of who will be impacted and how, and identifies the impacted HP work areas, focus of the HP assessments.

The table below is similar to the corresponding table of the HP Assessment Plan (Ref. [36]).

Table 21: Description of the change

HP WORK AREA/SUB-AREA	CHANGE & AFFECTED ACTORS
PROCEDURES , ROLES & RESPONSIBILITIES	
ROLES & RESPONSIBILITIES	FLIGHT CREW : THE FLIGHT CREW ROLES AND RESPONSIBILITIES WILL NOT CHANGE; ATCO : ROLES AND RESPONSIBILITIES WILL NOT CHANGE
PROCEDURES	FLIGHT CREW : DEPENDING ON THE AIRCRAFT DESIGN FOR THE ADVANCED LPV, THERE WILL BE SPECIFIC FLIGHT CREW PROCEDURES TO FLY AN ADVANCED LPV PROCEDURE; ATCO : OPERATING METHODS WILL NOT BE IMPACTED.
TASKS	FLIGHT CREW : THERE ARE NO TASK ADDED OR REMOVED. CURRENT TASKS MAYBE IMPACTED BY THE SPECIFIC PROCEDURES TO FLY THE ADVANCED LPV PROCEDURES; ATCO : THERE ARE NO TASK ADDED OR REMOVED.
HUMAN & SYSTEM	
ALLOCATION OF TASKS	AIRBORNE SIDE : AUTOMATION MAYBE PROVIDED BY THE AIRCRAFT DESIGN FOR THE ADVANCED LPV. THE OVERALL ALLOCATION OF TASKS BETWEEN HUMAN AND SYSTEM IS NOT CHANGED; GROUND SIDE : THE OVERALL ALLOCATION OF TASKS BETWEEN HUMAN AND SYSTEM IS NOT CHANGED.
PERFORMANCE OF TECHNICAL SYSTEM	AIRBORNE SIDE : THE AIRBORNE SIDE WILL BE REQUIRED TO BE COMPLIANT TO THE RNP WITH RF REQUIREMENT UP TO THE FAP; GROUND SIDE : PERFORMANCE OF TECHNICAL SYSTEM ARE NOT IMPACTED.
HUMAN – MACHINE INTERFACE	AIRBORNE SIDE : THE HUMAN – MACHINE INTERFACE MAYBE BE IMPACTED BY THE AIRCRAFT DESIGN FOR THE ADVANCED LPV; GROUND SIDE : HUMAN – MACHINE INTERFACE IS NOT IMPACTED.
TEAMS & COMMUNICATION	
TEAM COMPOSITION	FLIGHT CREW : THE TEAM COMPOSITION IS NOT CHANGED; GROUND SIDE : THE TEAM COMPOSITION IS NOT CHANGED
ALLOCATION OF TASKS	FLIGHT CREW : THE ALLOCATION OF TASKS IS NOT CHANGED; GROUND SIDE : THE ALLOCATION OF TASKS IS NOT CHANGED.
COMMUNICATION	FLIGHT CREW : THE COMMUNICATION (BETWEEN THE FLIGHT CREW) IS NOT CHANGED IN PARTICULAR. (IT MAY BE IMPACTED BY THE SPECIFIC PROCEDURES TO FLY THE ADVANCED LPV PROCEDURES.); GROUND SIDE : COMMUNICATION BETWEEN ATCO IS NOT CHANGED
WORKING ENVIRONMENT	

WORKPLACE LAYOUT	WORKSPACE LAYOUT IS NOT CHANGED.
PHYSICAL ENVIRONMENT	PHYSICAL ENVIRONMENT IS NOT CHANGED.
ORGANISATION & STAFFING	
COMPETENCE REQUIREMENTS	FLIGHT CREW : NO SPECIFIC COMPETENCE ARE REQUIRED; GROUND SIDE : NO SPECIFIC COMPETENCE ARE REQUIRED.
STAFFING REQUIREMENTS & STAFFING LEVELS	FLIGHT CREW : DEPENDING ON THE AIRCRAFT DESIGN FOR THE ADVANCED LPV, A SPECIFIC TRAINING MAYBE REQUIRED; GROUND SIDE : TRAINING MAYBE REQUIRED.
REGULATORY REQUIREMENTS	NO SPECIFIC REGULATORY REQUIREMENTS ARE FORESEEN.
TRAINING & DEVELOPMENT	
TRAINING REQUIREMENTS	FLIGHT CREW : DEPENDING ON THE AIRCRAFT DESIGN FOR THE ADVANCED LPV, A SPECIFIC TRAINING MAYBE REQUIRED; GROUND SIDE : TRAINING MAYBE REQUIRED.
TRAINING DESIGN	FLIGHT CREW : DEPENDING ON THE AIRCRAFT DESIGN FOR THE ADVANCED LPV, A SPECIFIC TRAINING MAYBE REQUIRED; GROUND SIDE : TRAINING MAYBE REQUIRED.

A.1.4.3.3 Summary of main HP Impacts - HP Assessment Objectives - HP Activities and Outcomes

This section presents:

- The main impacts identified through the issue analysis, which may result from the introduction of the advanced APV concept, in all the HP work areas that are identified as impacted in the previous section.
- The high level HP assessment objectives identified as a result of the issue analysis.
- The description of the HP activities required to address the HP objectives, identification of those activities that have been completed and summary of main findings resulting from the activities.

A.1.4.3.3.1 Issues and impacts, HP assessment objectives

The HP issues and benefits have been identified in the following table in the HP assessment plan [36]:

Table 22: HP Arguments, related HP issues and benefits, and proposed HP activity

Argument 1 : flight crew workload during the Advanced LPV procedure					
Issue ID	**HP issue / Benefit & impact**	**Priority**[5]	**HP validation objective**	**Potential mitigation**	**Recommmend activity/ies**
1.1	HP issue : if the flight crew workload is too high, the aircraft will not be in the proper configuration or position for the landing and a go-around will be performed.	**Medium**	See OBJ-05.06.03-VALP-0023-0180 : to assess the crew workload when performing advanced LPV operations.	No potential mitigation.	Yes : activity "aircraft crew workload assessment on regional platform"
Argument 2 : ATCO workload during the Advanced LPV procedure					
Issue ID	**HP issue / Benefit & impact**	**Priority**[6]	**HP validation objective**	**Potential mitigation**	**Recommended activity/ies**
1.2	HP issue : if the ATCO workload is too high, the controller is not able to manage the traffic flow.	**Medium**	See: • OBJ-05.06.03-VALP-0023.0250 - To assess the operational acceptability of the Advanced LPV Concept from ATCO perspectives in terms of, Rules, change of practices and Procedures; • OBJ-05.06.03-VALP-0023.0260 - To assess the operational feasibility of the Advanced LPV Concept from ATCO prospective in terms, Rules, change of practices and Procedures.	No potential mitigation.	ATCO workload assessment
Argument 3 : ATCO situational awareness during the Advanced LPV procedure					
Issue ID	**HP issue / Benefit & impact**	**Priority**[7]	**HP validation objective**	**Potential mitigation**	**Recommmend activity/ies**
1.3	HP issue : if the ATCO situational awareness is too low, the controller is not able to manage the traffic flow.	**Medium**	See: • OBJ-05.06.03-VALP-0023.0250 - To assess the operational acceptability of the Advanced LPV Concept from ATCO perspectives in terms of, Rules, change of practices and Procedures; • OBJ-05.06.03-VALP-0023.0260 - To assess the operational feasibility of the Advanced LPV Concept from ATCO prospective in terms, Rules, change of practices and Procedures.	No potential mitigation.	ATCO situational awareness assessment

1-Medium : the issue has a negative and significant impact on KPA other than safety, for instance, a degradation in efficiency or capacity, a negative impact on environment.

A.1.4.3.3.2 HP activities and outcomes

Table 23 presents a consolidated overview of the HP activities required to address the identified objectives :

Table 23: HP activities

HP ACTIVITY	PRIORITY[1]	STATUS[2]	JUSTIFICATION OF STATUS
1. FLIGHT CREW WORKLOAD ASSESSMENT ON REGIONAL PLATFORM	MEDIUM	COMPLETED	PERFORMED IN VP-483.
2. ATCO WORKLOAD ASSESSMENT	MEDIUM	COMPLETED	PERFORMED IN VP-483.
3. ATCO SITUATIONAL AWARENESS ASSESSMENT	MEDIUM	COMPLETED	PERFORMED IN VP-483.

1-Medium : the issue has a negative and significant impact on KPA other than safety, for instance, a degradation in efficiency or capacity, a negative impact on environment.

2- Completed, ongoing, pending

The following tables provide an overview of the content of each of the HP activities and of the main findings.

Table 24: Activity 1

ACTIVITY 1	FLIGHT CREW WORKLOAD ASSESSMENT ON REGIONAL PLATFORM
DESCRIPTION / OBJECTIVE	Flight crew workload assessment on regional platform: flight tests on regional platform will be performed to assess the flight crew workload.
ADDRESSED HP ASSESSMENT OBJECTIVES	Objective: the crew workload when performing advanced LPV operations is at an acceptable level.
ISSUES ADDRESSED / INVESTIGATED (FROM ISSUE ANALYSIS)	Issue 1.1.
TOOL/METHOD USED	NASA TLX questionnaire
ACTIVITY INFORMATION	The flight crew workload will be assessed during the flight tests on ATR-600 aircraft. Updated avionics for the advanced LPV will be installed.
SUMMARY OF MAIN FINDINGS	See in the VALR of VP-483 the results for OBJ-05.06.03-VALP-0023.0180. The workload to follow the FMS vertical profile, to get the full benefits of the CDA (no level off, even short), is acceptable but quite important, due to the need to continuously adjust the Vertical Speed target (as there is no coupled VNAV function). The behaviour described in paragraph 4.2.7 (the "unexpected behaviour" of the selected altitude management) increases the workload : - With the selected altitude at the altitude of the FAP, the workload to force the capture of the Glide-Slope is too high. - With the selected altitude at the altitude of the DA, there is no additional workload.

NEWLY IDENTIFIED ISSUES	No new issue has been identified.
RECOMMENDATIONS & REQUIREMENTS	No specific recommendation or requirement has been identified.

Table 25: Activity 2

ACTIVITY 2	ATCO WORKLOAD ASSESSMENT
DESCRIPTION / OBJECTIVE	Flight tests will be performed to assess ATCO workload.
ADDRESSED HP ASSESSMENT OBJECTIVES	OBJ-05.06.03-VALP-0023.0250 - To assess the operational acceptability of the Advanced LPV Concept from ATCO perspectives in terms of, Rules, change of practices and Procedures; OBJ-05.06.03-VALP-0023.0261 - To assess the operational feasibility of the Advanced LPV Concept in light traffic from ATCO prospective in terms, Rules, change of practices and Procedures.
ISSUES ADDRESSED / INVESTIGATED (FROM ISSUE ANALYSIS)	Issue 1.2.
TOOL/METHOD USED	NASA TLX questionnaire
ACTIVITY INFORMATION	ATCO workload will be assessed during flight tests on ATR-600 aircraft taking into account appropriate questionnaire. The questionnaire will be subjected to the ATCO after each run. ATCO will manage the aircraft providing clearances through the Controller Working Position (CWP).
SUMMARY OF MAIN FINDINGS	See in the VALR of VP-483 the results for OBJ-05.06.03-VALP-0023.250 and 261. ATCOs consider operationally acceptable and feas ble proposed Advanced LPV Concept, Rules, change of practices (in light traffic).
NEWLY IDENTIFIED ISSUES	No new issue has been identified.
RECOMMENDATIONS & REQUIREMENTS	No specific recommendation or requirement has been identified.

Table 26: Activity 3

ACTIVITY 3	ATCO SITUATIONAL AWARENESS ASSESSMENT
DESCRIPTION / OBJECTIVE	Flight tests will be performed to assess ATCO situational awareness.
ADDRESSED HP ASSESSMENT OBJECTIVES	OBJ-05.06.03-VALP-0023.0250 - To assess the operational acceptability of the Advanced LPV Concept from ATCO perspectives in terms of, Rules, change of practices and Procedures; OBJ-05.06.03-VALP-0023.0261 - To assess the operational feasibility of the Advanced LPV Concept in light traffic from ATCO prospective in terms, Rules, change of practices and Procedures.
ISSUES ADDRESSED / INVESTIGATED (FROM ISSUE ANALYSIS)	Issue 1.3.
TOOL/METHOD USED	SAHSA questionnaire

ACTIVITY INFORMATION	ATCO situational awareness will be assessed during flight tests on ATR-600 aircraft taking into account appropriate questionnaire. The questionnaire will be subjected to the ATCO after each run. ATCO will manage the aircraft providing clearances through the Controller Working Position (CWP).
SUMMARY OF MAIN FINDINGS	See in the VALR of VP-483 the results for OBJ-05.06.03-VALP-0023.250 and 261. ATCOs consider operationally acceptable and feas ble proposed Advanced LPV Concept, Rules, change of practices (in light traffic).
NEWLY IDENTIFIED ISSUES	No new issue has been identified.
RECOMMENDATIONS & REQUIREMENTS	No specific recommendation or requirement has been identified.

A.1.4.3.4 HP Assessment Findings and Conclusions

A.1.4.3.4.1 Main findings per HP assessment objective

<u>From the airborne side:</u>

The objective was the following:

- OBJ-05.06.03-VALP-0023-0180: to assess the crew workload when performing advanced LPV operations.

The results of the VP-483 flight test exercise are the following:

The workload to follow the FMS vertical profile, to get the full benefits of the CDA (no level off, even short), is acceptable but quite important, due to the need to continuously adjust the Vertical Speed target (as there is no coupled VNAV function).

<u>From the ATCO side:</u>

The objectives were the following:

- OBJ-05.06.03-VALP-0023.0250 - To assess the operational acceptability of the Advanced LPV Concept from ATCO perspectives in terms of, Rules, change of practices and Procedures;
- OBJ-05.06.03-VALP-0023.0261 - To assess the operational feasibility of the Advanced LPV Concept in light traffic from ATCO prospective in terms, Rules, change of practices and Procedures.

The results of the VP-483 flight test exercise are the following:

ATCOs consider operationally acceptable and feasible proposed Advanced LPV Concept, Rules, change of practices (in light traffic).

A.1.4.3.4.2 HP maturity of the concept addressed by the project and conclusion

Given the results of the paragraph above, the advanced APV is assessed as mature at the V3 level from a HP point of view (in light traffic).

Appendix B OSED

The project was asked to include material from other project documentation, notably the final version of the OSED [5], to support this final SPR document. The annexed material from the OSED document is limited to two sections; the section on expected benefits, which consolidates the results of project validation exercises in the context of the performance requirements included in Section 3.1.2, and the section on Scenarios and Use Cases which is included to support understanding of the operating environment assessed within the scope of project validation activities.

B.1 Expected Benefits

Initially expected benefits

In the frame of the production of D06 *"Benefit assessment for advanced procedures report"* and this OSED, the following potential benefits had been identified by the members of the P05.06.03 project team and the operational airspace user expert group supporting them.

Novelty 1: Combined use of RNP, RF turns and CDA:

- **Reduces track miles**, **resulting in less fuel consumption and less CO2 emission**, through the combined use RF and TF legs with RNP values from 1 down to 0.3. This composition can allow the construction of shorter trajectories, e.g. when noise sensitive and obstacle-rich areas are to be considered. This favours shorter paths, especially for traffic arriving from opposite directions than the runway orientation compared to standard LPV that require a straight and aligned segment up to FAP.
- Because of the increased adherence to horizontal nominal paths through the use of RF and TF legs with RNP values from 1 down to 0.3:
    - **increases ground track predictability and repeatability** for Air Traffic Controllers and pilots;
    - **concentrates noise distribution to specific non-sensitive areas** when applicable. In case the airport is not noise-sensitive, full focus on optimised routing (fuel/CO2) should be prioritised, because a RF turn defines a fixed turn trajectory, whereas TF/TF fly-by and fly-over transitions do not, and;
    - **fly optimised CDA descent profiles** for each aircraft **and aiming to avoid level flight segments** because distance to runway is known very accurately.
- **Increases the airport accessibility**, because a procedure with RF and TF legs with (RNP values from 1 down to 0.3) before the turn to FAP can make it possible to construct LPV FAS to a runway where a standard LPV cannot be constructed due to surrounding terrain.
- Keeps or **decreases the Flight Crew and ATC operational workload** compared to current operations, at aerodromes where all aircraft have to be radar vectored to final approach intercept, because ATCO does not need to vector, and pilot does not need to follow vectors. However at busy aerodromes where radar vectors are frequently used to sequence traffic, the Advanced APV may increase ATC operational workload within a mixed equipage environment involving Advanced APV and (e.g.) ILS aircraft. For such environments, a higher level of RNAV equipage is required to successfully implement such procedures in dense and complex terminal airspace.
- Provides the benefits of curved approaches with RNP down to 0,3 **without the cost and burden** of the specific aircraft and operational qualification and crew training required for **RNP AR operations.**
- Continuous CDA (idle or near idle engine):

- **Increases flight efficiency** through the **reduction of fuel consumption and CO2 emissions** together with **increased noise mitigation** utilised with an aircraft trajectory at higher altitudes including avoiding excessive low-altitude level-offs. Therefore, the procedure design should not include any altitude constraints.

Novelty 2: RF turn directly linked to final approach point:

- **Reduces track miles**, where possible, resulting in less fuel consumption and less CO2 emission, through the use of a RF turn directly to FAP. This favours shorter paths, especially for traffic arriving from opposite directions than the runway orientation compared to standard LPV that require a straight and aligned segment up to FAP.
- Increases the **airport accessibility**, because a procedure with RF turn to FAP (especially a RF turn with RNP 0.3) can make it possible to construct LPV to a runway where a standard LPV cannot be constructed due to surrounding terrain.
- Provides the benefits of curved approaches onto a short precision-type final approach segment, **without the cost and burden of** the specific aircraft and operational qualification and crew training required for **RNP AR operations**.

Novelty 3: Shortest possible final approach segment:

- **Reduces track miles**, where possible, **resulting in less fuel consumption and less CO2 emission**, especially in combination with a RF turn directly to FAP. This favours shorter paths, especially for traffic arriving from opposite directions than the runway orientation compared to standard LPV that require a straight and aligned segment up to FAP.

Novelty 4: RF turns in the final phase of the missed approach:

- Increase the **airport accessibility**, because with the use of RF turns (especially with low RNP value) can make it possible to reduce the LPV minima where the missed approach must confront terrain obstacles.
- Through the better adherence to horizontal nominal paths with the use of RF and TF legs:
    - **Increase ground track predictability and repeatability for air traffic controllers and pilot.**
    - **Concentrate noise distribution to specific non-sensitive areas** when applicable. In case the airport is not noise-sensitive, full focus on optimised routing (fuel/CO_2) should be prioritised.

Note 1: To maximise the benefit of this Advanced APV concept the FAS should be available not only as an APV-SBAS procedure but also as an APV-Baro procedure, making this concept available to more aviation users and reducing the burden of a mixed traffic regarding the capability or not to fly this advanced approach.

Note 2: Though the proposed Advanced APV concept clearly favours the above benefits, it is to be highlighted that some issues relative to SBAS are as well important to keep in mind: interoperability between the different SBAS constellations, interest of commercial aircraft operators in investing in SBAS-based avionics modifications, future of SBAS with GALILEO deployment, etc. However, those issues are out of the scope of 5.6.3 project.

Confirmed benefits

Outcomes of exercises EXE-05.06.03-VP-225, -353, -623, VP-482 and VP-483 have confirmed some of these benefits and provided results on other areas. They are summarized in the table below.

- In case result is different in Low or Medium traffic density/complexity, this is highlighted (L/L or M/M annotated).

- In blue when benefits where identified above as expected.

KPA/TA	Benefit	EXE-05.06.03-VP-225 (Flight simulation)	EXE-05.06.03-VP-353 (ATM FTS)	EXE-05.06.03-VP-623 (ATC RTS) M/M (DOD 1c)	EXE-05.06.03-VP-482 (Flight simulation)	EXE-05.06.03-VP-483 (Flight tests)	EXE-05.06.03-VP-792 (ATC RTS) H/H (DOD 2c)
EFF	Reduces track miles/distance flown per flight.		**Confirms**	**Confirms**			
	Reduces arrival time flown per flight.		**Confirms**	**Confirms**			
	Reduction of delay length		(L/L) = **(M/M) Contradicts**				
ENV	Reduces fuel consumption per flight.		**Confirms**	**Confirms**			Indicative assessment **Confirms**
	Reduces CO2 emission.			**Confirms**			
	Concentrates noise distribution to specific non-sensitive areas.	**Confirms** (flight follows desired ground track accurately)	Confirms (if Advanced APV is not interrupted)	**Confirms**	**Confirms** (flight follows desired ground track accurately)	**Confirms** (flight follows desired ground track accurately)	
	Increased noise mitigation.		**Confirms** (without evaluation of overshoots or trajectory deviations due to need for ATC Tactical intervention)				
	Favours very optimised CDA descent profiles.						
	Favours avoiding level flying (before the FAS).			**Confirms**			
HP	Decreases Flight Crew operational workload.	Confirms (Minor decrease of workload for both aircraft category C and D)			Confirms (Flight Crew workload at an acceptable level.)	Confirms (Flight Crew workload at an acceptable level.)	

KPA/TA	Benefit	EXE-05.06.03-VP-225 (Flight simulation)	EXE-05.06.03-VP-353 (ATM FTS)	EXE-05.06.03-VP-623 (ATC RTS) M/M (DOD 1c)	EXE-05.06.03-VP-482 (Flight simulation)	EXE-05.06.03-VP-483 (Flight tests)	EXE-05.06.03-VP-792 (ATC RTS) H/H (DOD 2c)
	Decreases ATCOs operational workload or ATC tasks.		**Contradicts** (indicates to be feasible mainly for light density traffic)	**Contradicts**		(L/L) Confirms (ATCO workload at an acceptable level.)	No adverse effects on ATCO workload or tasks
	DOD: Controller (-) Less flexibility due to fewer options.						**Confirms** Need for flexibility for approach sequencing and separation tasks (DOD 2c)
	Eliminates the cost and **burden of** RNP AR operations (a/c and flight crew **training**).						
CAP	Decreases ATCOs operational workload. [DOD: (+) Less interventions (+) Predictability, situation awareness]		**Contradicts** (ATC Tactical Interventions in APP is increased)	**= (L/L)** **Contradicts** (M/M)		(L/L) Confirms (ATCO workload at an acceptable level.)	No adverse effects on ATCO workload or tasks
	TMA/APP increased throughput		**Not concluding** (ATC Workload was not possible to be evaluated)	**= (L/L)** **Contradicts** (M/M)			No adverse effects on throughput
	Airport increased throughput		**Confirms** (Runway throughput is maintained similar to ILS and it might be feasibly increased to levels of runway capacity limit)				Airport throughput maintained

KPA/TA	Benefit	EXE-05.06.03-VP-225 (Flight simulation)	EXE-05.06.03-VP-353 (ATM FTS)	EXE-05.06.03-VP-623 (ATC RTS) M/M (DOD 1c)	EXE-05.06.03-VP-482 (Flight simulation)	EXE-05.06.03-VP-483 (Flight tests)	EXE-05.06.03-VP-792 (ATC RTS) H/H (DOD 2c)
	Reduction in 'not accommodated' flights in RBT		**Contradicts** (mainly for moderate to heavy traffic demands)				
PRE	Improved punctuality and less variance of flight durations [DOD: Increased predictability (less time variations)]		**Contradicts**	**=**			
FLX	DOD: ATM: (-) Reduced flexibility, reduced throughput.						**Confirms** Need for flexibility for approach sequencing and separation tasks (DOD 2c)
SAF	Easier integration and separation of a/c (mixed or all APV)			**Contradicts** **Unconfirmed** (if all are APV)			**Confirms** (if all are RNAV equipped)
	Increase ground track adherence and repeatability (for AUs and ATCOs). [DOD: (+) Predictability, situation awareness]	**Confirms** (AUs)		**Confirms** (lateral) **=** (global)	**Confirms** (flight follows desired ground track accurately)	**Confirms** (flight follows desired ground track accurately)	
	Decreases ATCOs operational workload (concern for safety if workload above inadmissible limits)			**Contradicts** (for moderate and heavy traffic)		(L/L) Confirms (ATCO workload at an acceptable level.)	No adverse effects on ATCO workload or tasks
A&E	Increases airport accessibility (where standard LPV cannot be constructed). [DOD: (+) Airport accessibility]	**Confirms**			**Confirms**	**Confirms**	

Table 27: Expected benefits

B.2 Reference Scenario

While previous operational environment description shows that the Advanced APV is expected to be implemented in most of the possible scenarios, including H/H with full RNAV equipage (see Alternate scenario), the following bullets provides a **reference scenario** for which the validation of the concept will be **maximised**, in the envisaged mixed-equipage environment:

- Low density/Low complexity TMA/APCH
- ATC available, providing speed control and/or radar vectoring instructions but not vertical instructions.
- Radar surveillance along all the procedure (controlled airspace) allowing radar vectoring till the FAP.
- Communications coverage available along all the procedure.
- Instrument Runway.
- IMC conditions as worst case.
- One conventional approach procedure in the destination or alternative airport.
- Several IAFs.
- One ADV APV procedure per runway end.
- Mixed traffic (capable and not capable of ADV APV; slow and fast aircraft).
- No initial separation problem ("at the IAF the traffic will be sequenced and spaced").
- RF connected to short final LPV segment with ADV APV missed approach (with RF in the final segment of the MA).
- Availability of AMAN, DMAN, Conflict Detection or automated conformance monitoring tool is NOT assumed
- Range of temperatures.
- Range of wind.
- Non mountainous terrain.

The selection of this reference scenario results from the following rationale:

- This scenario is the one tested in executed exercises (EXE -623 and -353) with positive results. That is why only low density/low complexity would be included in this reference.
- The SAR has to be developed with the tools provided by projects 16.6.1 (SRM) and 16.1.1 (AIM), these tools (models) only exist currently for ATC environment.
- This is a most common scenario in EATM.
- It is a "success oriented" scenario for the safety analysis, that is, there are many possibilities that the safety analysis will conclude that the ADV APV can be implemented in this scenario.

- Consistent with the Use Case (1) included in this OSED (Chapter 5).

B.3 Alternate Scenario

While the reference scenario describes the proposed implementation environment where maximum benefit will be obtained, the following bullets provide an **alternate scenario** for which the validation of the concept is **feasible** in higher density/complexity environment, as assessed in VP-792.

- High density/High complexity TMA/APCH
- ATC available, applying path-stretching and/or path-shortening techniques through ‘Direct to’ instructions, speed control and vertical instructions. Use of radar vectoring instructions is permitted as required.
- Radar surveillance along all the procedure (controlled airspace) allowing radar vectoring till the FAP. Any ‘Direct to’ instructions must be completed by the waypoint preceding the Intermediate Fix (IF).
- Communications coverage available along all the procedure.
- Instrument Runway.
- IMC conditions as worst case.
- One conventional approach procedure in the destination or alternative airport.
- Single IAF.
- One ADV APV procedure per runway end.
- Mandatory RNAV equipage and ability to perform RNP transition to ILS, GLS, LPV final approach segment. All final approaches accommodated assuming co-located FAP/GS.
- Arriving aircraft will ideally be sequenced and spaced at the IAF, however this will be achieved Standing Agreements (e.g. ‘miles in trail’) with adjacent TMA sectors, therefore some spacing issues may be present.
- RF connected to short as possible final LPV segment with ADV APV missed approach (with RF in the final segment of the MA).
- Availability of AMAN, DMAN, Conflict Detection or automated conformance monitoring tool is NOT assumed
- Range of temperatures.
- Range of wind.
- Non mountainous terrain.

The selection of this reference scenario results from the following rationale:

- This scenario is the one tested in executed exercises (EXE -792) with positive results.
- The SAR has to be developed with the tools provided by projects 16.6.1 (SRM) and 16.1.1 (AIM), these tools (models) only exist currently for ATC environment.

- Consistent with the Use Case (2) included in this OSED (Chapter 5).

B.4 Use Case 1 (Reference)

Sub-scenarios 1c (Use Case 1) and 2c (Use Case 2) of the 5.2 Step 1 Detailed Operational Description (DOD) are applicable.

A model of the sub-process "Perform Advanced APV Procedure" is available in the EATMA Portal and is included in the 5.2 Step 1 DOD. This model has been produced by SWP5.2 and B4.01 with the inputs (e.g. the Use Case 1 here included) and support of P05.06.03 and OFA02.01.01. Therefore, it is not included here but it is advised to consult this material when reading the provided Use Cases for a more comprehensive understanding.

This Use Case is applicable to the **Reference scenario**, for low/low density/complexity TMAs.

General Conditions:

- Aircraft is certified and equipped for Advanced APV concept. Flight Crew is trained for the actual Advanced APV concept scenario(s).
- Radar vectoring is considered as a backup/fallback means for ATCOs to establish and/or maintain the required aircraft separation.

Pre-Conditions:

- A/C on-board systems are prepared for RNAV/RNP approach.
- Approach briefing completed.
- The Flight Crew has planned for and is also expecting to receive a clearance before Initial. Approach Fix (IAF).
- Aircraft is sequenced in traffic and applying CDA technique when passing IAF.

Post-Conditions:

- Aircraft is within operational limits (speed. altitude, lateral and vertical deviations…) when passing FAP and can fly the LPV final approach segment down to DA(DH), then either land or execute a missed approach if the visibility requirements are not fulfilled.

Exercises VP-623 and VP-353 (an ATC RTS simulation and airspace FTS simulation respectively) have shown that for the implementation of the Advanced APV in a medium or high density/complexity environment, where mixed-mode (equipage) traffic is accommodated, the following Use Case needs to be either further developed or used in conjunction with other Use Cases covering the use of additional separation and sequencing techniques and tools. This is because current ATC procedures do not adequately support the implementation of the Advanced APV with higher traffic levels within a mixed-equipage environment due to ATCO reservations regarding ensuring the required horizontal and/or vertical separation. In such instances, as assessed in VP-623 and VP-353, ATC need new specific guidelines/procedures to ensure separation is guaranteed, including Tactical Conflict Management guidelines.

Operating Methods:

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
1	**Clear the aircraft for the RNAV approach.**	**The crew selects the approach procedure.**		Before IAF	
2	**Monitor**	**Select the Managed FMS flight control mode to laterally follow a reference trajectory from FMS database.** Vertical mode: Ideally VNAV managed mode is used to fly the FMS predicted vertical path. However, even though not being the preferred solution (VNAV managing an optimized CDA is the most favourable FMS function), it is possible to use a vertical selected mode (V/S or FPA mode) to follow the FMS predicted vertical path.	FMS with RF capability, use of lateral managed guidance Follow up of FMS vertical profile thanks to managed VNAV guidance mode (preferred method)	Initial (IAF to IF)	
3	**Exceptionally ATCO could provide the Flight Crew with vectoring instructions (heading, speed and altitude changes).** Normally, radar vectoring should not be used when flying a procedure based on the Advanced APV concept. It is considered as mitigation means to be used by ATCOs to manage particular traffic	**Select the Heading mode (Selected) to follow a radar vector clearance**: fly the heading entered by pilot on ATC demand ("Direct To WPT" and "Hold/Descent to altitude" clearances may also be received from ATC) and **Select VTF function or equivalent if in radar vectoring:** CDI/VDI provides deviations			.

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
	conditions/configurations	according to Extended-FAS (needles are "not alive") on PFD.			
4	**Monitor**	**Select the appropriate Piloting mode for the Flight Guidance system and manoeuvre the aircraft on the initial approach route** Pilot will choose the piloting mode amongst: Autopilot, Flight Director or Manual. Depending on aircraft capability, there are three possibilities: - CDI/VDI only - CDI/VDI + FD - CDI/VDI + FD + AP	**FMS, feeding data to the different steering commands** Arming LPV guidance modes may be possible before the last RF turn depending on aircraft capabilities.	Initial (IAF to IF)	Mainly RF legs used. Allowed piloting mode(s) depends on the actual RNP specification for a particular Advanced APV approach procedure.
5	**Monitor**	**Arm approach flight control modes** This action aims at activating the LPV mode to automatically capture the lateral and vertical paths of the final approach. This action can be performed automatically or manually depending on the aircraft architecture.	**Switch navigation mode** SBAS LPV approach is armed and awaiting switch over to LPV as active mode. LPV approach mode is annunciated by a unique continuous indication.	Initial (IAF to IF)	Some systems may switch to active LPV mode when the aircraft is within the capture conditions, depending on guidance laws design. That is, the aircraft will be guided wrt the LPV FAS. Therefore, during the capture before the FAP, the aircraft must still respect the RNP corridor.
6	**Transfer from approach to tower control** Approach ATCO transfers aircraft to control tower frequency.	**Transfer from approach to tower control** Flight Crew changes frequency and contacts tower ATCO.		Intermediate (IF to FAP)	The transfer from APP to TWR could also happen once the aircraft is established in the final track; it depends on local conditions and different

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
					criteria apply. In this case due to the fact that the final segment could be reduced up to three NM and an RF leg linked to the FAP directly, it could be reasonable that the transfer happens before the aircraft is stable on the final track.
7	**Waiting for a confirmation from the crew that the aircraft is established on the final track.**	**Capture laterally the final approach path** - Capture the final approach trajectory laterally, being stabilized vertically, no later than the FAP, in order that the aircraft is correctly established on the final approach course whilst descending to the DA. Lateral control may be manual (FD or CDI) or automatic. - According to aircraft/operator Standard Operating Procedures, the Pilot Not-Flying could announce to Pilot Flying that he/she sees on PFD the lateral capture guidance mode is engaged.		Intermediate (IF to FAP)	If using autopilot the Flight Crew will monitor the transition from RNP APCH or A-RNP with use of RF leg onto LPV FAS at FAP and are ready to intervene if the transition is not successfully executed.
8	**Monitor**	**Procedure is discontinued prior to sequencing FAP in case of:**		Intermediate (IF to FAP)	

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		1/ Loss of Navigation indicated by a warning flag (absence of power, equipment malfunction or failure,) or, 2/ Loss of Integrity Monitoring (LOI) , : integrity monitoring capability is lost (navigation information is still available, without guarantee for integrity), or 3/ failure of one RNAV/GNSS system during a procedure where two redundant systems are necessary, or 4/ low altitude alert prior to sequencing FAP or , 5/Other conditions not related to navigation system. In case procedure is aborted, a missed approach shall be initiated.			
9	**Monitor**	**Intercept the final approach path and start final approach** Final approach path (virtual slope) is intercepted at or before FAP According to aircraft/operator Standard Operating Procedures, the Pilot Not-Flying could announce to Pilot Flying that he/she sees on PFD the vertical track guidance mode is engaged. AMC 20-28 v3.2 §7.1/ (7) and		Intermediate (IF to FAP)	

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		DO 229d §2.2.4.6.4 require the equipment to provide an altitude alert, prior to sequencing the FAP, if the estimated position is lower than the desired FAP height by more than 50m + VPL, unless the equipment provides a TAWS function. **Report whatever has been required by ATCO** e.g. path interception, final approach course acquired ("report established on approach course"), passing FAP			
10	**Provide landing clearance** Tower ATCO provides the landing clearance while ensuring runway is clear of traffic Other information provided with the landing clearance: last wind (course, speed).	**Landing clearance acknowledgement to TWR, Final checks and (re-) briefing for Missed Approach**		Final	
11	**Monitor**	**Monitoring the approach/adjusting the trajectory until DA** <u>Monitor</u> the approach until Decision Height. The following information are monitored: ○ Availability of guidance ○ Adherence to guidance (RNAV/GNSS computed		Final	Deviation from final approach path is visible in terms of: heading (on PFD and ND) and in terms of course diversion (on CDI and VDI on PFD) and aircraft representation diversion from established trajectory (on ND).

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		desired path and aircraft position relative to the path; flight progress monitored for plausibility – using XTE, CDU or MAP indications, as appropriate, for the track-keeping assessments) o Navigation performance/alerts (absence of integrity alert; the estimated position error indication to determine the navigational accuracy) Additionally, adjust the trajectory if in manual mode based on CDI for lateral, VDI for vertical, or based on FD If distance/altitude are provided on the chart, “Distance to Go” (to threshold) information can be used to perform distance/altitude checks. The purpose is to ensure that database content is valid. This can also enable verification of altimeter settings.			Baro altitude is used up to the FAF.
12	**Monitor**	**Procedure is aborted (and missed approach/ contingency procedure initiated) if:** 1/ Loss of Navigation indicated by warning flag (lateral, vertical or both).Examples could be: 1-a Both lateral and vertical		Final	

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		flags shall be displayed in case of: i)The absence of power or, ii)Equipment malfunction or failure or, ii)detection by Fault Detection of a position failure that cannot be excluded 1-b Vertical flag shall be displayed when : i) no valid SBAS message has been received for 4 seconds or more, ii) there are insufficient number of SBAS HEALTHY satellites, iii) the HPL exceeds the alert limit iv) the VPL_{SBAS} exceeds the VAL. 1-c Lateral flag shall be display when the vertical flag is displayed and the HPL_{SBAS} and HPL_{FD} exceeds 0.3 Nm or cannot be computed Note: Loss of Integrity Monitoring (LOI) after sequencing the FAWP is defined to be a loss of navigation. 2/ Other conditions not			

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		related to navigation system. The Flight Crew should notify ATC of any problem with the RNAV/GNSS system that results in the loss of the approach capability (according to AMC20-28)			
13	**Monitor**	**Decision for landing/missed approach at DA** The pilot shall decide at the latest at the DA (checked on baro altimeter) to continue approach or initiate a missed approach according to the visual cues. If not displayed on the primary navigation screen the pilot must read DA (DH) from chart based on Level Of Service indicated by System.		Final	
14	**Monitor**	**Continue approach visually and landing**		Final	
15	**Monitor**	**Start missed approach** The Flight Crew configures the aircraft for the missed approach and, on arrival to the missed approach point, engages TOGA thrust.		Missed Approach	In case the LPV missed approach can't be performed the fall-back is defined by contingency procedures specific to each approach/airport. Examples of contingency procedures

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
					would be either: - design LPV missed approach as an overlay of conventional MA and provide conventional NAVAIDS to support MA - dead reckoning (climb to ... on heading …), then radar vectors The loss of SBAS doesn't impact the Missed Approach, as LPV MA procedure can be supported by GPS only.
16	**Monitor**		**Engage managed lateral navigation mode to follow the lateral missed approach procedure** After initial climbing on holding heading, the FMS managed lateral navigation mode is engaged in order to allow missed approach guidance. Implementation Examples: 1) Flight Crew manually re engages FMS managed lateral navigation mode. In	Missed Approach	The point at which Flight Crew manually re-engages managed lateral navigation mode is highly aircraft dependent. It may be done after first missed approach turn point, or as soon as flying above 100ft.

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
			that mode aircraft follows the lateral missed approach procedure, climbing to the missed approach altitude, then turning to the MA turn waypoint, as defined in the procedure 2) FMS will switch to missed approach guidance at either (a) input from TOGA thrust or (b) single keystroke on CDU. FMS removes vertical guidance and continues lateral guidance to last final approach waypoint, then commences missed approach published procedure.		
17	**Monitor**		**Switch navigation mode: LPV approach to NPA approach or terminal.**	Missed Approach	
18	**Monitor**	**Inform ATCO of go-around**		Missed Approach	
19	**Acknowledges go-around.**			Missed Approach	
20	**Radar vectoring during Missed Approach** If the aircraft is on the missed approach procedure and above minimum vectoring altitude, it is possible			Missed Approach	

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
	that the controller issues a radar vector so that the missed approach procedure is abandoned at this point.				
21	**Monitor**	**Monitor the missed approach/ adjust the trajectory until above MSA**		Missed Approach	

Table 28: Advanced APV concept operating method - Use Case 1

B.5 Use Case 2 (Alternate)

Sub-scenarios 1c (Use Case 1) and 2c (Use Case 2) of the 5.2 Step 1 Detailed Operational Description (DOD) are applicable.

A model of the sub-process "Perform Advanced APV Procedure" is available in the EATMA Portal and is included in the 5.2 Step 1 DOD. This model has been produced by SWP5.2 and B4.01 with the inputs (e.g. the Use Case 1 here included) and support of P05.06.03 and OFA02.01.01. Therefore, it is not included here but it is advised to consult this material when reading the provided Use Cases for a more comprehensive understanding.

This Use Case is applicable to the **Alternate scenario**, for high/high density/complexity TMAs.

General Conditions:

- Aircraft is certified and equipped for Advanced APV concept. Flight Crew is trained for the actual Advanced APV concept scenario(s).
- Radar vectoring is considered as a backup/fallback means for ATCOs to establish and/or maintain the required aircraft separation.

Pre-Conditions:

- A/C on-board systems are prepared for RNAV/RNP approach.
- Approach briefing completed.
- The Flight Crew has planned for and is also expecting to receive a clearance before Initial. Approach Fix (IAF).
- Aircraft is sequenced in traffic when passing IAF.

Post-Conditions:

- Aircraft is within operational limits (speed. altitude, lateral and vertical deviations…) when passing FAP and can fly the LPV final approach segment down to DA(DH), then either land or execute a missed approach if the visibility requirements are not fulfilled.

This Use Case is applicable to the implementation of the Advanced APV in a medium or high density/complexity environment, where mixed-mode traffic in the initial and intermediate segment of the approach (i.e. transition) is *not* accommodated (mandatory RNAV equipage), as assessed in VP-792. Accommodation of mixed mode traffic in the final segment (ILS, GLS, LPV) is provided so long as the RNP intermediate segment connects to a co-located FAP/GS, as described in the Advanced APV concept.

Operating Methods:

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
1	**Clear the aircraft for the RNAV approach.**	**The crew selects the approach procedure.**		Before IAF	
2	**Monitor**	**Select the Managed FMS flight control mode to laterally follow a reference trajectory from FMS database.** Vertical mode: Ideally VNAV managed mode is used to fly the FMS predicted vertical path. However, even though not being the preferred solution (VNAV managing an optimized CDA is the most favourable FMS function), it is possible to use a vertical selected mode (V/S or FPA mode) to follow the FMS predicted vertical path.	FMS with RF capability, use of lateral managed guidance Follow up of FMS vertical profile thanks to managed VNAV guidance mode (preferred method)	Initial (IAF to IF)	
3	**ATCO provides the Flight Crew with 'Direct To WPT' instructions to establish and/or maintain the required approach spacing** **ATCO provides speed and/or altitude changes as required.** Normally, radar vectoring should not be used when flying a procedure based on the	**Select the assigned waypoint in the Managed FMS flight control mode to laterally follow the amended trajectory from FMS database.** **Select the assigned speed and/or altitude** as per ATC instructions. **Select the Heading mode (Selected) to follow a radar vector clearance**: fly the heading entered by pilot on ATC		Initial (IAF to IF)	.

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
	Advanced APV concept. It is considered as mitigation means to be used by ATCOs to manage particular traffic conditions/configurations	demand and **Select VTF function or equivalent if in radar vectoring:** CDI/VDI provides deviations according to Extended-FAS (needles are "not alive") on PFD.			
4	**Monitor**	**Select the appropriate Piloting mode for the Flight Guidance system and manoeuvre the aircraft on the initial approach route** Pilot will choose the piloting mode amongst: Autopilot, Flight Director or Manual. Depending on aircraft capability, there are three possibilities: - CDI/VDI only - CDI/VDI + FD - CDI/VDI + FD + AP	**FMS, feeding data to the different steering commands** Arming LPV guidance modes may be possible before the last RF turn depending on aircraft capabilities.	Initial (IAF to IF)	Mainly RF legs used. Allowed piloting mode(s) depends on the actual RNP specification for a particular Advanced APV approach procedure.
5	**Monitor**	**Arm approach flight control modes** This action aims at activating the LPV mode to automatically capture the lateral and vertical paths of the final approach. This action can be performed automatically or manually depending on the aircraft architecture.	**Switch navigation mode** SBAS LPV approach is armed and awaiting switch over to LPV as active mode. LPV approach mode is annunciated by a unique continuous indication.	Initial (IAF to IF)	Some systems may switch to active LPV mode when the aircraft is within the capture conditions, depending on guidance laws design. That is, the aircraft will be guided wrt the LPV FAS. Therefore, during the capture before the FAP, the aircraft must still respect the RNP corridor.

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
6	**Transfer from approach to tower control** Approach ATCO transfers aircraft to control tower frequency.	**Transfer from approach to tower control** Flight Crew changes frequency and contacts tower ATCO.		Intermediate (IF to FAP)	The transfer from APP to TWR could also happen once the aircraft is established in the final track; it depends on local conditions and different criteria apply. In this case due to the fact that the final segment could be reduced up to three NM and an RF leg linked to the FAP directly, it could be reasonable that the transfer happens before the aircraft is stable on the final track.
7	**Waiting for a confirmation from the crew that the aircraft is established on the final track.**	**Capture laterally the final approach path** - Capture the final approach trajectory laterally, being stabilized vertically, no later than the FAP, in order that the aircraft is correctly established on the final approach course whilst descending to the DA. Lateral control may be manual (FD or CDI) or automatic. - According to aircraft/operator Standard Operating Procedures, the Pilot Not-Flying could announce to Pilot Flying that he/she sees on		Intermediate (IF to FAP)	If using autopilot the Flight Crew will monitor the transition from RNP APCH or A-RNP with use of RF leg onto LPV FAS at FAP and are ready to intervene if the transition is not successfully executed.

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		PFD the lateral capture guidance mode is engaged.			
8	**Monitor**	**Procedure is discontinued prior to sequencing FAP in case of:** 1/ Loss of Navigation indicated by a warning flag (absence of power, equipment malfunction or failure,) or, 2/ Loss of Integrity Monitoring (LOI) , : integrity monitoring capability is lost (navigation information is still available, without guarantee for integrity), or 3/ failure of one RNAV/GNSS system during a procedure where two redundant systems are necessary, or 4/ low altitude alert prior to sequencing FAP or , 5/Other conditions not related to navigation system. In case procedure is aborted, a missed approach shall be initiated.		Intermediate (IF to FAP)	
9	**Monitor**	**Intercept the final approach path and start final approach** Final approach path (virtual slope) is intercepted at or before FAP According to aircraft/operator Standard Operating Procedures,		Intermediate (IF to FAP)	

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		the Pilot Not-Flying could announce to Pilot Flying that he/she sees on PFD the vertical track guidance mode is engaged. AMC 20-28 v3.2 §7.1/ (7) and DO 229d §2.2.4.6.4 require the equipment to provide an altitude alert, prior to sequencing the FAP, if the estimated position is lower than the desired FAP height by more than 50m + VPL, unless the equipment provides a TAWS function. **Report whatever has been required by ATCO** e.g. path interception, final approach course acquired ("report established on approach course"), passing FAP			
10	**Provide landing clearance** Tower ATCO provides the landing clearance while ensuring runway is clear of traffic Other information provided with the landing clearance: last wind (course, speed).	**Landing clearance acknowledgement to TWR, Final checks and (re-) briefing for Missed Approach**		Final	
11	**Monitor**	**Monitoring the approach/adjusting the trajectory until DA**		Final	Deviation from final approach path is visible in terms of: heading (on

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		Monitor the approach until Decision Height. The following information are monitored: ○ Availability of guidance ○ Adherence to guidance (RNAV/GNSS computed desired path and aircraft position relative to the path; flight progress monitored for plausibility – using XTE, CDU or MAP indications, as appropriate, for the track-keeping assessments) ○ Navigation performance/alerts (absence of integrity alert; the estimated position error indication to determine the navigational accuracy) Additionally, adjust the trajectory if in manual mode based on CDI for lateral, VDI for vertical, or based on FD If distance/altitude are provided on the chart, "Distance to Go" (to threshold) information can be used to perform distance/altitude checks. The purpose is to ensure that database content is valid. This can also enable verification of altimeter settings.			PFD and ND) and in terms of course diversion (on CDI and VDI on PFD) and aircraft representation diversion from established trajectory (on ND). Baro altitude is used up to the FAF.
12	**Monitor**	**Procedure is aborted (and missed approach/ contingency procedure initiated) if:**		Final	

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		1/ Loss of Navigation indicated by warning flag (lateral, vertical or both).Examples could be: 1-a Both lateral and vertical flags shall be displayed in case of: i)The absence of power or, ii)Equipment malfunction or failure or, ii)detection by Fault Detection of a position failure that cannot be excluded 1-b Vertical flag shall be displayed when : i) no valid SBAS message has been received for 4 seconds or more, ii) there are insufficient number of SBAS HEALTHY satellites, iii) the HPL exceeds the alert limit iv) the VPL_{SBAS} exceeds the VAL. 1-c Lateral flag shall be display when the vertical flag is displayed and the HPL_{SBAS} and HPL_{FD} exceeds 0.3 Nm or cannot be computed			

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		Note: Loss of Integrity Monitoring (LOI) after sequencing the FAWP is defined to be a loss of navigation. 2/ Other conditions not related to navigation system. The Flight Crew should notify ATC of any problem with the RNAV/GNSS system that results in the loss of the approach capability (according to AMC20-28)			
13	**Monitor**	**Decision for landing/missed approach at DA** The pilot shall decide at the latest at the DA (checked on baro altimeter) to continue approach or initiate a missed approach according to the visual cues. If not displayed on the primary navigation screen the pilot must read DA (DH) from chart based on Level Of Service indicated by System.		Final	
14	**Monitor**	**Continue approach visually and landing**		Final	
15	**Monitor**	**Start missed approach** The Flight Crew configures the		Missed Approach	In case the LPV missed approach can't be

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
		aircraft for the missed approach and, on arrival to the missed approach point, engages TOGA thrust.			performed the fall-back is defined by contingency procedures specific to each approach/airport. Examples of contingency procedures would be either: - design LPV missed approach as an overlay of conventional MA and provide conventional NAVAIDS to support MA - dead reckoning (climb to ... on heading …), then radar vectors The loss of SBAS doesn't impact the Missed Approach, as LPV MA procedure can be supported by GPS only.
16	**Monitor**		**Engage managed lateral navigation mode to follow the lateral missed approach procedure** After initial climbing on holding heading, the FMS managed lateral navigation mode is engaged in order	Missed Approach	The point at which Flight Crew manually re-engages managed lateral navigation mode is highly aircraft dependent. It may be done after first missed approach turn point, or

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
			to allow missed approach guidance. Implementation Examples: 1) Aircrew manually re engages FMS managed lateral navigation mode. In that mode aircraft follows the lateral missed approach procedure, climbing to the missed approach altitude, then turning to the MA turn waypoint, as defined in the procedure 2) FMS will switch to missed approach guidance at either (a) input from TOGA thrust or (b) single keystroke on CDU. FMS removes vertical guidance and continues lateral guidance to last final approach waypoint, then commences missed approach published procedure.		as soon as flying above 100ft.
17	**Monitor**		**Switch navigation mode: LPV approach to NPA approach or terminal.**	Missed Approach	
18	**Monitor**	**Inform ATCO of go-around**		Missed Approach	
19	**Acknowledges go-around.**			Missed Approach	

STEP	ATC	Flight Crew	A/C on-board System	Phase	Note
20	**Radar vectoring during Missed Approach** If the aircraft is on the missed approach procedure and above minimum vectoring altitude, it is possible that the controller issues a radar vector so that the missed approach procedure is abandoned at this point.			Missed Approach	
21	**Monitor**	**Monitor the missed approach/ adjust the trajectory until above MSA**		Missed Approach	

Table 29: Advanced APV concept operating method – Use Case 2

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