Final Project Report

Document information	
Project Title	Approach Procedure with Vertical Guidance
Project Number	05.06.03
Project Manager	NATS
Deliverable Name	Final Project Report
Deliverable ID	D000
Edition	00.01.03
Template Version	03.00.00
Task contributors	
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Abstract

This project assessed both existing LPV approach procedures and advanced RNP based approach procedures with RF turns connecting directly to a vertically guided final approach segment based on SBAS. The project performed validation activities to assess the expected benefits and both ground and airborne operational feasibility of the advanced procedures using both fast-time and real-time simulation methods. V3 validation was successfully achieved through live flights using an ATR-42-600 regional aircraft. The results were reported in Release 4 within SESAR Solution #51 'Enhanced terminal operations with LPV procedures'.

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Rational for rejection
None.

Document History

Edition	Date	Status	Author	Justification
00.00.01	20/07/2015	Final	[redacted]	Submitted version
00.01.01	20/09/2015	Final		Updated version
00.01.02	22/10/2015	Final		Updated version
00.01.03	05/11/2015	Final		Updated version

Acronyms

A comprehensive list of applicable acronyms can be found in the SESAR ATM Lexicon. To aide readability of this document the prominent acronyms used herewith are provided in the below table.

Acronym	Definition
APV	Approach Procedure with Vertical Guidance
ATM	Air Traffic Management
ENB	Enabler
GNSS	Global Navigation Surveillance System
ICAO	International Civil Aviation Organisation
LPV	Localiser Performance with Vertical Guidance
OI	Operational Improvement
PCP	Pilot Common Project
RNAV	Area Navigation
RNP	Required Navigation Performance
SBAS	Satellite Based Augmentation System

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

1 Project Overview

This project assessed existing (Phase 1 – LPV) and advanced (Phase 2 – ADV APV) RNP based approach procedures with a vertically guided final approach segment based on SBAS and performed assessment activities culminating in V3 validation through live flight trials.

1.1 Project progress and contribution to the Master Plan

Two phases of work were addressed within the project, details of which are provided below.

Phase 1 – LPV

The project was tasked with performing initial validation on baseline Operational Improvements relating to existing LPV approach procedures. Whilst such procedures were already in operation around the world, this work was included to further encourage implementation of LPV procedures in Europe in response to the ICAO resolution of the 36th Assembly.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AOM-0604	Enhanced terminal operations with LPV using SBAS	Project validation activities addressed ATC training and ATC procedures for the implementation of LPV approach procedures; safety assessment work was performed resulting in the production of Common Safety Criteria for the implementation of LPV procedures.	V2/V3	V3
PRO-AC-06	Cockpit Procedures for LPV based approach procedures	n/a (Baseline ENB)	V3	V3

Associated system enablers, such as A/C-01 and A/C-06, are covered by the corresponding system project (P09.10) and are therefore not shown in the table above.

Phase 2 – ADV APV

This phase of work built on the work performed in Phase 1 and addressed the 'Advanced APV' concept which consists of an RNP approach procedure (aircraft follows a pre-defined flight path which is not constrained by the location of ground-based navigation aids) with vertical guidance that consolidates several existing operations and techniques into a single procedure. It should be noted that the project *partially* addresses the targeted OI, AOM-0605, and the scope of the validation is limited to LPV aspects only.

The project produced 4x advanced procedures which were used to assess for project validation activities, which included an assessment of expected benefits through V2 fast-time simulation and ATC operational feasibility through V2 real-time simulation. This validation led to subsequent airborne operational feasibility and fly-ability validation through both V2 real-time simulations and V3 live flight trials of an advanced procedure produced within the project. The V3 validation was performed in association with the corresponding systems project, P09.10. Project documentation was iteratively updated to produce final, consolidated V3 documentation in support of the targeted SESAR Solution. An additional exercise was added at the end of the project to address the applicability of RNP based approach procedures in high density, high complexity TMAs, as detailed in PCP AF-1. The results of this work were incorporated into the final, consolidated documentation.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AOM-0605	Enhanced terminal operations with RNP automatic transition to ILS/GLS/LPV	Project validation activities addressed both ground and airborne aspects of this OI through fast-time simulations, real-time simulations and live flight trials. Consolidated documentation was produced in support of this validation and submitted in the Final Data Pack for SESAR Solution #51 'Enhanced terminal operations with LPV procedures and reported in Release 4. *Note: the scope of the project validation was limited to LPV aspects of this OI.*	V1	V3

Associated system enablers, such as A/C-07 and CTE-N06, are covered by the corresponding system project (P09.10) and are therefore not shown in the table above.

The project contributed to SESAR Solution #51 'Enhanced terminal operations with LPV procedures' which was assessed in Release 4 System Engineering Review #3.

1.2 Project achievements

Phase 1 validation was performed to encourage implementation of LPV procedures at European airports. Accordingly, the validation performed at Bristol airport was performed in association with an implementation project. The procedure design and validation results from project activities have led to the operational implementation of an RNAV(GNSS) approach procedure to LPV minima at Bristol Airport (EGGD). Additionally, work on PBN based approach procedures is being taken forward in SESAR Large Scale Demonstration projects.

Phase 2 validation was performed in support of SESAR Solution #51 'Enhanced terminal operations with LPV procedures' with V3 validation successfully achieved through live flight trials at Turin, Italy with an ATR-42-600 regional aircraft. Initial work on the applicability of RNP based approach procedures in high density, high complexity Terminal Manoeuvring Areas, as defined in PCP AF-1, was performed within the project. This work is expected to form the basis of further implementation work within the assessed environment.

1.3 Project Deliverables

The project performed its validation as part of OFA02.01.01 'Optimised 2D/3D Routes' and reported Phase 1 results within Release 1. The following table presents the *relevant* deliverables that have been produced by the project in support of Phase 1 activities. *Note: a full list of project deliverables can be found on the SESAR Extranet.*

Reference	Title	Description
D07	Benefits Assessment for LPV Procedures	This document is mainly addressed to the decision makers in the implementation of LPV operations and more generally to those States who wish to implement LPV operations. It presents real cases of the application of the common methodology to support ANSPs, Regulators or Airport Providers to decide the airports where to first implement LPV operations. The methodology is here applied to a set of airports in Italy, Norway, United Kingdom and Spain. These examples show that the application of the methodology supports the identification of the dominant criteria adopted by the involved stakeholders (e.g. benefits, hurdles, external threats and opportunities, traffic volumes of the runways, etc.) and also enables the analysis of the identification of the major blocking points (namely: hurdles and external threats), among the involved stakeholders, for the implementation of LPV.
D09	European Regulatory Processes for LPV Implementation	This document is addressed to those who wish to understand how the implementation of RNP APCH procedures to LPV minima is regulated in the European environment. The applicable standards are identified, the European regulatory framework is introduced and the common regulations that are applicable under the Single European Sky legislation are identified. It follows by describing how the EGNOS service provider has been certified as a provider of European air navigation services. The process for aircraft certification and operational approval is descr bed along with examples of how the operational approval process is performed nationally in the four States participating in this project (Norway, Italy, Spain and UK). The document concludes by proposing a way forward for harmonising the ANSP approvals process within Europe.
D10	Common Criteria for Procedure Design, Coding and Flight Verification Report	This document reports the overall criteria for the design, coding and validation of RNP APCH operations to LPV minima using GPS augmented by EGNOS. It proposes a set of common criteria, based on the procedures and recommendations of the involved stakeholders: Eurocontrol Agency, four ANSPs (AENA, ENAV, NATS and NORACON) and Industry (Airbus and Thales).
D11	LPV Procedures	This document provides the main outcomes of the LPV Design Activities performed at the four runway-ends selected in 05.06.03 because of their suitability for LPV procedures implementation bringing benefits. The report includes local Design and Validation reports and Development plans. It provides some feedback, wherever poss ble, to the common design criteria contained in D10 and some recommendations about design aspects that were not fully clear in that report.
D13	ATC Procedures and Training Report	This document draws together results from the ATC real-time simulation exercise of an implementation of an LPV procedure at Glasgow and inputs from the contributing SESAR partners to assess the LPV procedures implementation impact on ATC and to propose and validate new LPV ATC procedures and training for controllers to implement LPV operations. It also summarises the results of the Glasgow simulation.
D14	NOTAM Implementation Report	This document is mainly addressed to the decision makers in the implementation of LPV operations and more generally to those States who wish to implement LPV operations. It presents recommendations for implementation and provision of EGNOS NOTAM for LPV procedures. Currently there is a system in place to issue NOTAMs for the airports where LPV procedures are approved. This document is focused on

		highlighting some recommendations that have not been taken into account yet in the current implementation that are relevant for the needs of SESAR.
D15	Common Safety Criteria Report	This document is comprised of the LPV approach Safety Acceptance Criteria (SAC), Safety Objectives (SO) and high-level Safety Requirements (SR). The high-level safety requirements to be met by the ANSP are essential for a safe implementation of an LPV approach. The common safety requirements have been determined in accordance with the SESAR Safety Reference manual (SRM) developed by SESAR WP 16.06.01. The Common Criteria are applicable to certain operational environments (non-precision approach instrument runway end and precision approach instrument runway end). The scope of these common criteria is limited to straight-in LPV approach with an optimum glide path angle of 3° thus it excludes: LP approaches, steep glide path angle approaches, offset final approach track alignment and simultaneous approaches to parallel or near parallel instrument runways. *Note: this document has been reviewed by EASA and National Authorities. Whilst the majority of comments have been accepted, comments #25 and #42 may be addressed in any future activities building on the work performed within this document [5].*
D16	LPV Safety Cases	This document contains the safety cases for each APV SBAS Instrument Flight procedure designed within the project. The participating ANSP have verified safety requirements related to the procedure design activity. Some participating ANSP have also performed more implementation activities than Task 11, and have also verified safety requirements related to these additional activities. Each Local Safety assessment report is enclosed this deliverable in separate appendices. The experience of each ANSP in using the results of the Common Safety Criteria report (D15) is described, and this experience have also resulted in recommendation for ANSPs in using the Common Safety Criteria report, and also recommendation for the potential improvements of that report subsequent SESAR.
D19	Aircraft Assessment Report (INTEROP)	This document is the INTEROP of the advance LPV concept. It is based on the description of the advanced LPV concept in D08 that includes an analysis of the safety objectives. This document includes interface requirements, and allocates OSED requirements to the aircraft segment. There are no requirements allocated to the ground segment.

The project performed its validation as part of OFA02.01.01 'Optimised 2D/3D Routes' and reported Phase 2 results within Release 4.

The following table presents the *relevant* deliverables that have been produced by the project in support of SESAR Solution #51 'Enhanced terminal operations with LPV procedures'. *Note: a full list of project deliverables, including validation reports and earlier versions of the documents listed below, can be found on the SESAR Extranet.*

Reference	Title	Description
D12	Advanced Procedures (GEN)	This document contains the SESAR Project 5.6.3 Advanced LPV approach procedure designs, linking CDA technique, RF turns and LPV FAS, as developed by AENA, ENAV, NATS and NORACON for selected airports in Italy, Spain, UK and Norway. The document describes the airport selection criteria, the environment in which these procedures would be implemented and provides an overview of the anticipated benefits. Available design standards used are listed and assessed for weakness and incompleteness. Problems identified during the design process are discussed.
D38	V3 SPR	This 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 (D15) 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.
D40	V3 OSED	This document provides the links with relevant DOD, a detailed description of the concept and its operating method and the functional and qualitative requirements applicable to it. The researched concept is called Advanced APV and consists of a RNP approach procedure down to LPV minima with the initial and intermediate segments flown applying CDA technique, where poss ble, including an RF legs in the Intermediate Approach Segment connecting directly to the LPV Final Approach Segment.
D41	V3 INTEROP	This document is the INTEROP of the advanced APV concept. This V3 INTEROP refines the first version of the INTEROP (D19) and is based on the OSED V3 (D40) and considers the results of the advanced LPV validation exercises. This document includes interface requirements and INTEROP requirements for the aircraft segment. There are no INTEROP requirements for the ground segment.

1.4 Contribution to Standardisation

The operational concept assessed within this project is based on approach procedures using existing Navigation Specifications, namely RNP APCH as detailed in AMC20-27 with, additionally, LPV using Satellite Based Augmentation System (SBAS) as detailed in AMC20-28.

'The A-RNP specification in case of RNP values lower than 1 NM may be used in the Initial and/or Intermediate segments, however certification material (EASA AMC) is still to be developed for this specification. EASA AMC 20-28 can be considered as including SESAR A/C-06 enabler, "LPV approach based on SBAS".

It is assumed that the Navigation Database required for the Advanced APV concept meets ICAO Annex 15 requirements, complies with database requirements (detailed in EUROCAE ED 76A/RTCA Do 200A) and that the data is provided by an approved supplier. The Advanced APV procedures will be constructed using the appropriate design standards (ICAO DOC 8168 VOL II).

The current EASA and FAA certification standards partially cover the Advanced APV concept:

- For procedures with RNP values down to 1.0 NM without RF turns, it is covered by the EASA AMC 20-27; FAA AC 90-105 and FAA AC 20-138D.
- For procedures with RNP values down to 1.0 NM with RF turns, there is no EASA AMC but the FAA AC-90-105 and FAA AC 20-138D covers it.
- For procedures with RNP values down to 0.3 NM with RF turns, the A-RNP specification would apply, and there is neither EASA AMC nor FAA AC.
- No certification standard covering the transition from intermediate to final segment has been identified; in its absence the ICAO PBN Manual is a first reference.
- For the LPV FAS, EASA AMC 20-28 applies; FAA AC 90-107 also covers it.

The PBN Manual states that an aircraft certified for RNP-AR operations (following EASA AMC 20-26 or FAA 90-101A) is technically capable of flying the A-RNP procedure and meets the required performance. However, because the A-RNP functionalities are more numerous than RNP-AR (FRT, holding, parallel offset...), such aircraft will not be granted for an "implicit" A-RNP approval.' [4]

Through Coordination Plan 4.8 Issue 4.8.11 the project has maintained a dialogue with the FAA regarding the standardization initiatives for ADV-APV RNP approach that have been presented, mainly at ICAO IFPP and EUROCONTROL RAiSG meetings. *Note: within SESAR, P05.06.03 has coordinated with P06.08.05 regarding standardization initiatives due to both contributing to AOM-0605; P06.08.05 advanced approaches utilize a GBAS final segment in place of an SBAS final segment.*

Standardization activities are focused on supporting the amendment of PANS-OPS to provide criteria to design procedures connecting the RF turn onto the Final Approach for both SBAS LPV and GLS (GBAS) procedures. In the latest CP4.8 update (v13, 31 August 2015), Issue 4.8.11 has an Amber status because of concerns raised at the July 2015 PBNSG meeting concerning 1) extent to which PANS OPS criteria is supported by existing navigation specifications and 2) that RF legs should only be used where they were really needed. Further guidance should be developed for inclusion in the PBN manual on the judicious use of RF legs.

1.5 Project Conclusion and Recommendations

The main findings from the validation exercises can be summarised as follows:

- The Advanced APV procedure is deemed easily flyable;
  - Work is properly shared between Pilot and Co-pilot, and workload is acceptable;
  - Situational awareness reached good level.
  - The transition from RNP to LPV occurred correctly. RF leg directly to FAP, with a 3NM FAS length as a minimum, is deemed operationally acceptable.
  - Availability of VNAV is crucial to get full benefits of the CDA without excessive Flight Crew workload.
- From ATCOs' point of view:
  - The ATCOs understood the concept of Advanced APV and felt it was intuitive;
  - The concept is viable at airports in light traffic; The Advanced APV is more difficult to manage in moderate and heavy traffic.

- The main safety concern relates to the difficulty of integrating aircraft using the Advanced APV against non-APV equipped aircraft flying conventional approach procedures, even during light traffic periods.
- High (100% tested) RNAV equipage is required to make RNAV/RNP based approach procedures feasible in high density, high complexity terminal airspace.
- ATCO workload may be high due to the extensive monitoring and concentration required, particularly where specific guidelines/procedures to ensure that separation is guaranteed are not available. This was observed in all traffic levels.

The following potential benefits have been identified:

- Reduced track mileage, resulting in less fuel consumption and associated CO2 emissions,
- Increased ground track predictability and repeatability for air traffic controllers and pilots,
- Optimised CDA descent profiles for each aircraft and, where possible, avoiding level flight segments.
- Increased noise mitigation, through avoiding periods of excessive level flight, particularly at low altitude and the ability to concentrate noise distribution to specific non-sensitive areas where appropriate.
- Increased airport accessibility through the provision of Instrument Approach Procedures to runway ends with no existing published instrument approach, and offering reduced approach minima compared to NPA.
- Provides benefits of curved approaches with RNP down to 0.3, without the cost and burden of the aircraft approval and Flight Crew training requirements of RNP AR.
- Unchanged or decreased Flight Crew and ATC operational workload compared to current operations (however, at busy, more complex environments the implementation of such procedures may require new ATC functions).

The solution is applicable in any low density/complexity (L/L) TMA/APP environment. Higher density/complexity ATM environments may require new/supporting procedures, definition of responsibilities between the actors, and systems (e.g. AMAN) in order to prevent negative impact on capacity and predictability and are likely to require a high proportion of RNAV equipped aircraft to integrate such procedures. This should be further explored in follow-on activities such as the *'Enhanced Terminal Operations using RNP based Operations'* VLD within SESAR2020.

'To maximise the benefit, the Final Approach Segment (FAS) should be available not only as an APV-SBAS procedure but also as an APV-Baro procedure, making it available to more Airspace Users and reducing the burden of a mixed traffic.' [4]

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan (Reference Data Set 14)

[3] Multilateral Framework Agreement ("MFA") signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012

[4] Enhanced terminal operations with LPV procedures Contextual Note 51, Optimised 2D/3D Routes, Guidance, OFA02.01.01, Edition 00.00.02.

[5] Common Safety Criteria Report (EASA and NA) responses

[6] Advanced Procedures Identification Report (OSED), Approach Procedure with Vertical Guidance, P05.06.03, D08, AENA (ENAIRE), Edition 00.01.02

[7] European Regulatory Processes for LPV Implementation Report – Phase LPV, Approach Procedure with Vertical Guidance, P05.06.03, D09, EUROCONTROL, Edition 00.01.00

[8] Common Criteria for Procedure Design and Coding and Flight Verification Report, Approach Procedure with Vertical Guidance, P05.06.03, D10, ENAV, Edition 00.01.00

[9] LPV Procedures, Approach Procedure with Vertical Guidance, P05.06.03, D11, ENAV, Edition 00.01.01

[10] Advanced Procedures (GEN), Approach Procedure with Vertical Guidance, P05.06.03, D12, NATS, Edition 00.01.00

[11] ATC Procedures and Training Report, Approach Procedure with Vertical Guidance, P05.06.03, D13, NATS, Edition 00.01.00

[12] NOTAM Implementation Report, Approach Procedure with Vertical Guidance, P05.06.03, D14, AENA (ENAIRE), Edition 00.01.00

[13] Common Safety Criteria Report, Approach Procedure with Vertical Guidance, P05.06.03, D15, EUROCONTROL, Edition 00.01.01

[14] LPV Safety Cases, Approach Procedure with Vertical Guidance, P05.06.03, D16, NORACON, Edition 00.01.01

[15] Aircraft Assessment Report (INTEROP), Approach Procedure with Vertical Guidance, P05.06.03, D19, Thales, Edition 00.01.00

[16] V3 SPR, Approach Procedure with Vertical Guidance, P05.06.03, D38, NORACON/Helios, Edition 00.01.03

[17] V3 OSED, Approach Procedure with Vertical Guidance, P05.06.03, D40, Thales, Edition 00.01.02

[18] V3 INTEROP, Approach Procedure with Vertical Guidance, P05.06.03, D41, Thales, Edition 00.01.01

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