Final Project Report

Document information	
Project Title	Enhanced Arrival Procedures Enabled by GBAS
Project Number	06.08.08
Project Manager	ENAV
Deliverable Name	Final Project Report
Deliverable ID	D01
Edition	00.01.01
Template Version	03.00.04
Task contributors	
ENAV.	

Abstract

The project defined and assessed enhanced arrival procedures of Increased Glide Slope, Adaptive Increased Glide Slope, Double Slope Approach, Multiple Runway Aiming Points and Curved RNP to GLS precision Approach through fast time simulation, real time simulation and flight trial techniques to assess the expected benefits and the feasibility and acceptability of the concepts. A V3 level of maturity was fully achieved for Curved RNP to GLS precision Approach reported within SESAR solution #9 Enhanced terminal operations with automatic RNP transition to ILS/GLS. The other solutions need further research activities to close the V3 pre-industrial development and integration phase.

Authoring & Approval

Prepared By - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] ENAV	[redacted]	14/11/2016

Reviewed By - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
[redacted] SEAC	[redacted]	21/09/2016
[redacted] HONEYWELL		27/09/2016
[redacted] EUROCONTROL		28/09/2016
[redacted] EUROCONTROL		28/09/2016
[redacted] EUROCONTROL		28/09/2016
[redacted] ENAV		28/09/2016
[redacted] AIRBUS		28/09/2016
[redacted] AIRBUS		28/09/2016
[redacted] AIRBUS		28/09/2016
[redacted] AIRBUS		28/09/2016
[redacted] NATS		28/09/2016
[redacted] DFS		28/09/2016
[redacted] THALES		28/09/2016
[redacted] NORACON		28/09/2016
[redacted] ALENIA (LEONARDO)		28/09/2016

Reviewed By - *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
[redacted] INECO	[redacted]	16/09/2016
[redacted] EUROCONTROL		28/09/2016
[redacted] NATS		28/09/2016

Approved for submission to the SJU By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
[redacted] ENAV	[redacted]	29/09/2016
[redacted] SEAC		28/09/2016
[redacted] AIRBUS		30/09/2016
[redacted] EUROCONTROL		29/09/2016
[redacted] ALENIA		30/09/2016
[redacted] NORACON		30/09/2016
[redacted] NATS		29/09/2016
[redacted] DFS		29/09/2016
[redacted] HONEYWELL		30/09/2016
[redacted] THALES		30/09/2016

Rejected By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date

<Name / Company>	<Position / Title>	<DD/MM/YYYY>

Rational for rejection
None.

Document History

Edition	Date	Status	Author	Justification
00.00.01	07/09/2015	Draft	ENAV	New Document
00.00.03	14/12/2015	Draft	ENAV	V2 Validation Activities Input
00.00.04	02/05/2016	Draft	ENAV	Integration of WP Leader comments
00.00.07	15/09/2016	Draft	ENAV	Integration of V3 elements
00.00.08	28/09/2016	Draft	ENAV	Integration of internal and external review comments
00.00.09	29/09/2016	Revised Draft	ENAV	Agreement on comments' answers
00.01.00	29/09/2016	Revised Draft	ENAV	Formal approval request
00.01.01	30/09/2016	Final	ENAV	Approved for submission
00.01.02	14/11/2016	Final	ENAV	Integration of SJU assessment report requested actions

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
AF	ATM Functionality
AMAN	Arrival Manager
AMC	Acceptable Means of Compliance
ATC	Air Traffic Control
ATM	Air Traffic Management
ARINC	Aeronautical Radio Incorporated
Curved RNP to GLS	Curved RNP transition to GLS precision approach
CWP	Controller Working Position
DS	Double Slope Approach
EASA	European Aviation Safety Agency
E-OCVM	European Operational Concept Validation Methodology
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAP	Final Approach Point
GBAS	Ground Based Augmentation System
GLS	GBAS Landing System
ICAO	International Civil Aviation Organization
IGS	Increased Glide Slope
ILS	Instrument Landing System
INTEROP	Interoperability Requirements
KPA	Key Performance Area
LPV	Localiser Performance with Vertical Guidance
MRAP	Multiple Runway Aiming Points
OSED	Operational Service and Environment Definition
PANS	Procedures for Air Navigation Service

PCP	Pilot Common Project
PBN	Performance Based Navigation
RF	Radius to Fix
RNP	Required Navigation Performance
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking
SOIR	Manual on Simultaneous Operations on Parallel or Near-Parallel Instrument Runways
SOP	Standard Operation Procedure
SPR	Safety and Performance Requirements
TA	Transversal Area
TMA	Terminal Manoeuvring Area
TRL	Technology Readiness Level
VALP	Validation Plan
VALR	Validation Report
XLS	GLS-ILS

1 Project Overview

SESAR Project 06.08.08 developed and validated advanced approach procedures enabled by Ground Based Augmentation System (GBAS) to reduce noise impact, improve fuel efficiency and increase runway throughput. Specifically, the project focused on:

- Multiple Runway Aiming Points: a glide path anchored to shifted touch down points with respect to the standard threshold;
- Increased Glide Slope: a glide path with a glide slope angle value that can be set between the conventional approach angle (3°, as defined by ICAO PANS OPS Doc 8168) and the beginning of the “steep approach” domain (4.5°, as defined by FAA AC-25-7C);
- Adaptive Increased Glide Slope: an on-board functionality that calculates the best descent glide slope in accordance to the local conditions (e.g. wind, aircraft mass etc.) on the basis of an already published procedure;
- Double Slope Approach: a final descent path split in two different segments, a first increased segment (up to 4.49°) followed by a standard (shallower) one;
- Curved Required Navigation Performance (RNP) transition to GBAS Landing System precision approach: use of curved RNP initial / intermediate approach with continuous descent profile transitioning to a short GLS straight final approach (final turn may end as close as 5 NM to runway threshold).

1.1 Project progress and contribution to the Master Plan

The project followed an iterative process to define and refine concepts of operations to contribute as follows [44]:

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AO-0319	Enhanced Arrival procedures using multiple Runway Aiming Points (MRAP)	Contribution to the assessment of feasibility and acceptability in terms of Environmental Sustainability, Capacity, Predictability, Human Performance and Safety KPAs/TAs through fast time simulation, real time simulation and flight trail techniques focused on both ATC and flight crew segments	V1	V2-V3
A0-0320	Enhanced Arrival procedures using Increased Glide Slope (IGS)	Contribution to the assessment of feasibility and acceptability in terms of Environmental Sustainability, Capacity, Predictability, Human Performance and Safety KPAs/TAs through fast time simulation, real time simulation and flight trail techniques focused on both ATC and flight crew segments	V1	V2-V3
AO-0321	Enhanced Arrival procedures using Adaptive Increased Glide Slope (A-IGS)	Contribution to the assessment of feasibility and acceptability in terms of Environmental Sustainability, Capacity, Predictability KPAs through fast time simulation	V1	V2

		technique		
A0-0322	Enhanced Arrival procedures using double slope approach (DS)	Contribution to the assessment of feasibility and acceptability in terms of Environmental Sustainability, Capacity, Predictability, Human Performance and Safety KPAs/TAs through fast time simulation, real time simulation and flight trail techniques focused on both ATC and flight crew segments	V1	V2-V3
AOM-0605	Enhanced terminal operations with RNP transition to XLS/LPV	Contribution to the assessment of feasibility and acceptability in terms of Environmental Sustainability, Capacity, Predictability, Human Performance and Safety KPAs/TAs through fast time simulation, real time simulation and flight trail techniques focused on both ATC and flight crew segments. P06.08.08 contributes to mature solution 9 addressed by AOM-0605 for RNP to GLS/ILS part	V2	V3

Specifically, the project performed 2 cycles of validation and contributed to mature solution #09 "Enhanced terminal operations with RNP transition to ILS/GLS":

- V2 cycle with fast time simulations (AirTOp platform) on Frankfurt, Heathrow, Malpensa, and Stockholm airports and real time simulations on Malpensa, Schiphol airports and generic airport.
- A V3 cycle with real time simulation and flight trial at Malpensa airport and flight trial only at Heathrow airport.

Solution #09 is within “PCP AF#1 Extended AMAN and PBN in high density TMAs” scope that proposes ATM functionalities to improve the precision of approach trajectory and facilitate traffic sequencing with the main goal of reducing fuel consumption and environmental impact in the descent/arrival phases.

1.2 Project achievements

V2 and V3 validation activities were successfully executed and reported good results in terms of noise reduction (except for double slope where noise benefits were not very clear) for all the concepts investigated in terms of number of impacted people (up to 96%) and/or surface areas (up to 46%) depending on concepts, observed iso-contours and indicators. CO2 / Fuel Burnt was not significantly affected (except for IGS with slopes higher than 3.5° in high density and high complexity environment) for the investigated solutions with obvious margin of reduction for Curved RNP to GLS/ILS approach (when shorten the approach path).

All the solutions were feasible and acceptable from a human performance and safety point of view, with the exception of Double Slope that was scarcely appreciated: workload and situational awareness for the other solutions were maintained at acceptable level although some issues and open points remain to be still addressed for IGS, A-IGS and MRAP, while recommendations are proposed for Curved RNP to GLS/ILS (for the integration in current operations).

Capacity was not affected (MRAP, A-IGS, Curved RNP to GLS/ILS), or slightly negatively affected (IGS, DS in high density and high complexity environments) in terms of runway throughput.

Predictability in terms of arrival delay/TMA duration was negatively affected for almost all concepts (except for MRAP and A-IGS where predictability was not affected).

Furthermore in terms of capacity and predictability indicators, an alternative reduction was measured in runway occupancy time or taxi-in time using MRAP approach procedures.

Despite the mentioned results, the capacity and predictability indicators as well as the acceptability and feasibility issues (in relation to wake turbulence separations) for Increased Glide Slope and Double Slope are subject to the assumption of an initial study on the wake vortex risk that was reviewed: this means that the results might need to be refined taking into account the new assumptions and performed review on the wake vortex risk.

In addition:

- Increased Glide Slope
  - IGS solution V3 level of maturity is not considered fully closed, although IGS solution was considered applicable and not invasive.
  - Above a certain glide slope value (around 3,5°), the following element are negatively impacted and might need mitigation means: performing and monitoring of the approach, crew workload and crew cooperation, visual perception, pilot confidence.
- Adaptive Increased Glide Slope
  - A-IGS research activities were based on fast time simulations and expert groups to address the feasibility and acceptability and investigate the benefits and impact on capacity, predictability and environmental sustainability and fuel efficiency. Further validation activities are needed to conclude on A-IGS that is considered in V2 level of maturity.
- Double Slope Approach
  - Findings during the concept validation and lifecycle lead to a review of the concept that affected the level of maturity that cannot be considered V3.
- Multiple Runway Aiming Points
  - Despite the fact that MRAP solution was appreciated by controllers and considered applicable, V3 level of maturity cannot be considered closed because of the open issue about the visual aids and the airborne segment that was not fully validated.
- Curved Required Navigation Performance (RNP) transition to GBAS Landing System precision approach
  - Curved RNP to GLS solution V3 level of maturity can be considered achieved although some recommendations are provided for the next validation cycle. In particular, the integration of curved procedure in the current operational environment is subject to an appropriate procedure design, a potential regulation of usage of such procedures and the fine-tuning of CWP. In particular the mentioned challenges of integration are relevant for mixed approach mode (i.e. curved RNP to GLS approaches mixed with standard approaches) in medium and high traffic density environments. Validation activities showed no issues for curved RNP to GLS approaches without mixed approach mode.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D07	Enhanced Arrival Procedures Enabled by GBAS - OSED Consolidation	This document describes the concept of operations, the operational environment and the operational requirements for IGS, A-IGS, DS, MRAP and RNP

		to GLS
D04	Enhanced Arrival Procedures Enabled by GBAS - SPR - Consolidation	This document provides the safety and performance requirements for IGS, A-IGS, DS, MRAP and RNP to GLS. It includes the safety assessment report built to consolidate the safety requirements
D05	Enhanced Arrival Procedures Enabled by GBAS - INTEROP - Consolidation	This document provides the interoperability requirements for IGS, A-IGS, DS, MRAP and curved RNP to GLS
D17	Enhanced Arrival Procedure Enabled by GBAS - VALR - V2 Last iteration	This document describes the validation activities executed and the results obtained through fast time simulation and real time simulation techniques at V2 E-OCVM level of maturity. Specifically it collects the results obtained in Environmental Sustainability and Fuel Efficiency, Capacity, Predictability, Human Performance and Safety KPA/TA
D11	Enhanced Arrival Procedure Enabled by GBAS – VALR V3 – Last iteration	This document describes the validation activities executed and the results obtained through flight trial techniques at V3 E-OCVM level of maturity. Specifically it collects the results obtained in Environmental Sustainability and Fuel Efficiency, Human Performance and Safety KPA/TA
D02	Enhanced Arrival Procedures Enabled by GBAS - Applicable Regulatory Framework - Consolidation	This document provides an analysis of the existing standard/regulatory framework applicable to the GBAS enhanced arrival procedures (IGS, A-IGS, DS, MRAP and RNP to GLS). It also proposes standard/regulations evolutions, when omissions or incompatibilities are identified
D06	Enhanced Arrival Procedures Enabled by GBAS - Consolidation	This document provides the main outcomes of the procedure design activities performed for the validation test environments: Frankfurt, Heathrow, Malpensa, Schiphol and Stockholm airports. It collects the procedure design assumptions, conclusions and recommendations

1.4 Contribution to Standardisation

The project investigated the existing standard/regulatory framework and identified the omissions or incompatibilities for GBAS enhanced arrival procedures. Main conclusions, contributions and standardisation are summarised in P06 08 08 D02 Regulatory framework [13]. The scope covers: airborne side, procedure design and coding, ATC, aerodromes and environmental aspects. The following areas were successively covered: Interoperability, Safety, HMI/Human Factor, Landing performances, Handling qualities, flight guidance, data recording, operating limitation.

1.5 Project Conclusion and Recommendations

All investigated concepts complied with the expected benefits in terms of noise reduction, except for double slope where the benefits were not so evident and still to be refined.

None of the concepts did significantly impact capacity in terms of runway throughput while potential benefits were observed for MRAP in terms of runway occupancy time or taxi-in time.

RNP to GLS could be an enabler for significant benefits in terms of fuel consumptions depending on the specific design.

For IGS, A-IGS, DS, and MRAP further validation activities are recommended in order to refine the concepts to achieve full acceptance from air traffic controllers and flight crew. Additionally the role of supporting tools and the impact on airport and TMA performances should be further investigated.

For MRAP it is recommended to investigate MRAP visual cue (physical or virtual) that should be agreed, assessed and proposed for standardization.

For curved RNP to GLS it is recommended to minimise the impact on the integration on current operations when mixing curved RNP to GLS with standard straight in approaches, in particular for medium and high density environments.

For all concepts appropriate and adequate training period and training contents are recommended in order to familiarize air traffic controllers and flight crew with new concepts and their integration in the current operations.

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan

[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] SESAR Project 06.08.08, Enhanced Arrival Procedure Enabled by GBAS - VALR V3 - First iteration, Edition 00.01.01, D16, 30 June 2016

[5] SESAR Project 06.08.08, Enhanced Arrival Procedures Enabled by GBAS - SPR – Consolidation, Edition 00.01.02, D04, 14 November 2016

[6] SESAR Project 06.08.08, Enhanced Arrival Procedure Enabled by GBAS - VALR V3 - Last iteration, Edition 00.01.01, D11, 15 September 2016

[7] SESAR Project 06.08.08, Enhanced Arrival Procedures Enabled by GBAS - Consolidation, Edition 00.01.01, D06, 29 September 2016

[8] SESAR Project 06.08.08, INTERIM Version - Enhanced Arrival Procedures Enabled by GBAS - INTEROP Updating - V2, Edition 00.01.01, D14, 21 January 2016

[9] SESAR Project 06.08.08, INTERIM Version - Enhanced Arrival Procedures Enabled by GBAS - OSED V2, Edition 00.01.01, D15, 15 January 2016

[10] SESAR Project 06.08.08, INTERIM Version - Enhanced Arrival Procedures Enabled by GBAS - SPR Updating - V2, Edition 00.01.01, D13, 03 February 2016

[11] SESAR Project 06.08.08, Enhanced Arrival Procedures Enabled by GBAS - INTEROP – Consolidation, Edition 00.01.02, D05, 14 November 2016

[12] SESAR Project 06.08.08, Enhanced Arrival Procedures Enabled by GBAS - OSED Consolidation, Edition 00.01.01, D07, 21 September 2016

[13] SESAR Project 06.08.08, Enhanced Arrival Procedures Enabled by GBAS - Applicable Regulatory Framework – Consolidation, Edition 00.01.01, D02, 28 September 2016

[14] SESAR Project 06.08.08, Enhanced Arrival Procedure Enabled by GBAS - VALR - V2, Edition 00.01.01, D09, 30 November 2015

[15] SESAR Project 06.08.08, Enhanced Arrival Procedure Enabled by GBAS - VALP - V2, Edition 00.01.02, D08, 30 June 2015

[16] SESAR Project 06.08.08, Enhanced Arrival Procedure Enabled by GBAS - VALR - V2 Last iteration, Edition 00.01.01, D17, 30 June 2016

[17] SESAR Project 06.08.08, Enhanced Arrival Procedures Enabled by GBAS - OSED Initial, Edition 00.01.02, D03, 31 March 2015

[18] SESAR Project 06.08.08, Enhanced Arrival Procedure Enabled by GBAS - VALP - V3, Edition 00.01.01, D10, 03 February 2016

[19] EASA CS-25, Large Aeroplanes

[20] EASA AMC 20-26 "Airworthiness Approval and Operational Criteria for RNP Authorisation Required (RNP AR) Operations"

[21] EASA AMC 20-27 "Airworthiness Approval and Operational Criteria for RNP APPROACH (RNP APCH) Operations Including APV BAROVNAV Operations"

[22] EASA AMC 20-28 "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"

[23] FAA AC 20-138D "Airworthiness Approval of Positioning and Navigation Systems"

[24] EASA CS-AWO – All Weather Operations

[25] FAA AC 25-11A Electronic Flight Displays

[26] RTCA DO–200A/ED–76 - Standards for processing aeronautical data

[27] ICAO Doc 8168 'Aircraft Operations (PANS-OPS) - Volume I – Flight Procedures, 5th edition 2006, Amendment 13/11/14

[28] ICAO Doc 8168 'Aircraft Operations (PANS-OPS) - Volume II - Construction of Visual and Instrument Flight Procedures', 6th edition 2014, Amendment 16/4/15

[29] ICAO Doc 4444 'Procedures for Air Navigation Services - Air Traffic Management (PANS-ATM)'

[30] ICAO Doc 9643 - Manual on Simultaneous Operations on Parallel or near parallel Instrument Runways (SOIR)

[31] ARINC 424 'Navigation System Database Specification'

[32] P09.09, Regulatory analysis, D04, 00.01.00, 15/05/2012

[33] ICAO Annex 14

[34] DIRECTIVE 2002/30/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 26 March 2002on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Community airports

[35] ICAO DOC 9829 Guidance on the Balanced Approach to Aircraft Noise Management Ed 2

[36] ECAC.CEAC Doc 29 - Report on Standard Method of Computing Noise Contours around Civil Airports, second edition

[37] SESAR WP16.06.03 Environment Reference Material Level 1 and 2, version 008

[38] Regulation (EU) No 598/2014 of the European Parliament and of the Council of 16 April 2014 on the establishment of rules and procedures with regard to the introduction of noise-related operating restrictions at Union airports within a Balanced Approach and repealing Directive 2002/30/EC

[39] Directive 2001/42/EC of the European Parliament and of the Council on the assessment of the effects of certain plans and programmes on the environment.

[40] Commission Regulation (EU) No 691/2010 of 29 July 2010 laying down a performance scheme for air navigation services and network functions and amending Regulation (EC) No 2096/2005 laying down common requirements for the provision of air navigation services

[41] Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise

[42] DIRECTIVE 2008/50/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 21 May 2008 on ambient air quality and cleaner air for Europe

[43] FAA PARC recommendations for RNP-xLS https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/afs/afs400/parc/parc_reco/media/2014/140828_PARCRecs_RNPtoxLS.pdf

[44] SESAR Project B.01, IR Dataset16 Release Note, D84, Edition 00.01.00, 16/06/2016

-END OF DOCUMENT-