Final Project Report

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Abstract

The purpose of P06.08.05 was triple: confirming the maturity of GBAS CAT I for operational implementation, developing advanced operational concepts and procedures for GBAS CAT I and preparing GBAS CAT II/III future operational implementation. It was achieved by means of:

- Generating generic operational implementation plan to facilitate the implementation of GBAS CAT I operations.
- Developing "GBAS CAT I - RNP transition to GLS" concept by means of FTS (v2) and Flight Simulations (v3), and "Displaced Thresholds under GBAS CAT I" concept by means of FTS (v2).
- Developing "GBAS CATII/III operation" concept by means of FTS (v2) and RTS (v3).
- Gathering all the needs for GBAS standardization.

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This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ANSP	Air Traffic Management
ARINC	Aeronautical Radio, Incorporated
ATC	Air Traffic control
ATM	Air Traffic Management
CAT	Category
DT	Displaced Threshold
EASA	European Aviation Safety Agency
FAF	Final Approach Fix
FTS	Fast Time Simulation
GAST	GBAS Approach Service Type
GBAS	Ground Based Augmentation System
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning Service
G/S	Glide Slope
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
LOC	Localizer
LPV	Localiser Performance with Vertical guidance
LS	Landing System
LVC	Low Visibility Conditions
LVP	Low Visibility Procedures
OCA/H	Obstacle Clearance Altitude / Height
OFA	Operational Focus Areas
OSED	Operational Service and Environment Definition

PCP	Pilot common Project
RNP	Required Navigation Performance
RTS	Real Time Simulation
RWY	Runway
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency
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
WA	Working Area

1 Project Overview

The GBAS Operational Implementation project addressed the activities needed to achieve and facilitate the GBAS CAT I operational implementation and to develop and validate the operational concepts for GBAS advanced procedures as well as for GBAS CAT II/III procedures with the aim to improve the runway utilisation and throughput, environment and resilience to adverse weather as well as the SESAR safety goals, in the European airport network.

1.1 Project progress and contribution to the Master Plan

WA1 GBAS CAT I Generic Operational Implementation Plan

The GBAS CAT I operational implementation plan was generated by using the different real experiences. To achieve it the following activities were carried out:

- Preparation of guidance for the update of ANSP's documentation database.
- Determination of needs and/or requirements for mixed-mode operations (assessment of specific cases to develop generic material: Palermo / Malaga / Zurich); notably, ATC procedures, ATS changes in the air traffic management system, Contingency manual and ATC Interface.
- Identification of rulemaking evolution needs: adaptation of Doc8071 and ED-114 on ground and flight testing procedures, evolution of Annex 15 requirements for critical data (FAS), and research on new solutions for siting and protections areas.

WA2 GBAS CAT I Advanced Operational Concepts and Procedures

"GBAS CAT I – RNP Transition to GLS":

This activity was performed within the framework of OFA02.01.01 – Optimised 2D/3D Routes.

In order to demonstrate both the flyability of the transition from RNP intermediate approach to GLS (GNSS Landing System) final approach procedure based on GBAS and its benefits different validations exercises were executed:

- Fast Time Simulations (V2 validations) based on Palermo scenario:
    - AIRNAS1 suite: Preliminary procedure coding (path terminators) and relative flyability were evaluated.
    - RAMS Plus2: Performance assessment on capacity, environment and efficiency.
- Flight simulations on AIRBUS platform (V3 validations): Palermo Flight Procedures. Validating new Palermo procedures for transiting from RNP environment to GLS (GNSS Landing System) final approach procedure based on GBAS, considering in particular pilot's workload, curved path, minimum radius of Radius-to-Fix legs. More precisely, the exercise addressed the validation of :
    - procedure flyability,
    - operational acceptability and
    - the design and coding of the RNP to GLS procedure in a flight simulator environment.

1 AIRNAS is a Framework based on CAD and simulation techniques capable of dealing with problems related to e.g. the different phases of air navigation design.
2 RAMS Plus is an air traffic management (ATM) fast-time simulation model.

"Displaced Thresholds under GBAS CAT I":

This activity was performed within the framework of OFA 01.03.01 - Enhanced Runway Throughput.

The following exercise was executed in order to demonstrate the benefits of using Enhanced Arrival GBAS-based Procedures to Displaced Touch Down Zone:

- Fast Time Simulations (V2 validations):
  - AIRTOP: GBAS dual threshold operations with GBAS equipped aircraft at different levels (0%, 60%, and 90%) as well as different traffic mixes. Main focus on results for Zurich Airport but also for generic airports. Capacity, environment, safety, efficiency, and cost-effectiveness areas were assessed.

WA3 GBAS CAT II-III Operations

This activity was performed within the framework of OFA 01.03.01 - Enhanced Runway Throughput in close collaboration with projects 15.03.06 GBAS Cat II/III L1 Approach (ground equipment) and 9.12 GBAS Cat II/III (airborne equipment).

In order to demonstrate both the benefits and the operational feasibility of managing CATII/III and mixed GBAS/ILS operations under Low Visibility Conditions, the following validations exercises were executed:

- Fast Time Simulations (V2 validations) based on Barcelona airport:
  - AIRTOP3: GBAS CATII/III operation under Low Visibility Conditions was evaluated. Two different runway usages were analysed: mixed mode and segregated modes. 60% GBAS equipped aircraft was assumed during simulations.
- Real Time Simulations on Bretigny platform (V3 validations):
  - The validation exercise was performed using two EUROCONTROL Real Time Simulation platforms: Approach simulator (Escape) and Airport simulator (eDEP platform). The simulated airport environment was Paris CDG, but the runway configuration was generalised so that the results are applicable to various airport environments. The exercises assessed the following Key Performance Indicators: Capacity, Safety, Cost Effectiveness and Human Performance. The validation exercises included several operational scenarios such as: GBAS Cat II/III operations in segregated runway operations and mixed mode runway operations, with no GBAS equipped aircraft (reference scenario) and 60% and 100% GBAS equipped aircraft (solution scenarios).

WA4 Proposals for Standardizations Summary

A final report was produced by gathering all the needs for operational GBAS standards development that previously were generated under each Working Area

Additionally, here below it can be shown the contribution to the European Master Plan (following [1], [2], [3] and [4]):

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AOM-0605	Enhanced terminal operations with automatic RNP transition to ILS/GLS/LPV	The exercise partially demonstrated the V3 maturity of the operational improvement as the focus was on the airborne side. Project 06.08.08 will further address the ground element and shall ensure	V1	V3

3 AIRTOP is a Gate-to-Gate fast time simulator.

		full completion of the safety assessment.		
AO-0308	Enhanced Arrival Procedures using Displaced Touch Down Zone	It has been demonstrated that, by using GBAS to operate Enhanced arrival procedures using a displaced runway threshold, runway capacity can be increased while maintaining the delays and reducing also noise levels.	V1	V2
AO-0505-A	Improve Low Visibility Operation using GBAS Cat II/III based on GPS L1	The exercise demonstrated the V3 maturity of the operational improvement within the scope of OFA 01.01.01 “LVPs using GBAS”. The project has demonstrated that runway capacity resilience is increased in poor weather conditions with mixed operations ILS / GBAS without jeopardising existing safety levels. Additionally, a complete set of operational requirements and recommendations have been provided to enable an easier future deployment.	V1	V3

1.2 Project achievements

WA1 GBAS CAT I Generic Operational Implementation Plan

GBAS provides a cost efficient alternative to the current Instrument Landing System (ILS). A single GBAS station can serve multiple runway ends at an airport. The GBAS CAT I implementation and operational experience is a necessary step to gain confidence in the technology and ensure the emerging of advanced operations

WA2: GBAS CAT I Advanced Operational Concepts and Procedures

“GBAS CAT I – RNP Transition to GLS”:

The overall results of the performed exercises indicated that:

- The successful design, coding and charting of the RNP to GLS procedure was achieved. Coding of a Radius-to-Fix leg directly to Final Approach Point would require evolution of the ICAO PANS-OPS and ARINC 424 standards. The subject is already being discussed within ICAO Instrument Flight Procedures Panel (IFPP) Working Group.”.
- The procedure flyability and the operational acceptance were validated, as it was assessed as easily flyable by pilots, with crew operational procedure similar to current operations.

“Displaced Thresholds under GBAS CAT I”:

From the performed validation it has been concluded that a possible increase of RWY throughput of 5% up to 11% could be obtained. The DT concept is able to generate better cost effectiveness on technology base considering especially costs for purchase, maintenance and yearly checks as well as

the capability of GBAS to transmit multiple Final Approach Segments. A single installation is able to provide the reference paths for two thresholds on a single runway.

WA3 GBAS CAT II-III Operations

The project addressed different scenarios related to the use of GBAS in Low Visibility Operations. Some of the results are described below:

- GBAS in LVP operations for segregated runways can bring the expected runway throughput benefits without negatively impacting safety and human performance.
- GBAS in LVP operations for mixed mode runway operations can bring also runway throughput benefits, although less relevant than with segregated runways. These benefits will strongly depend on the consecutive arrival separation value that will have to be calculated by each ANSP considering local airport environment and a procedural separation of aircraft performing a missed approach procedure.
- The mixed ILS and GBAS operations also provide for capacity benefits and are acceptable in terms of ATC workload and safety.
- Runway capacity resilience (Percentage of Airport and Airspace capacity loss avoided) is improved in poor weather conditions by using GBAS. It depends on local conditions of each airport but from 2 to 6 extra arrivals per hour could be managed under CATII/III conditions.
- The phraseology to be used with GBAS operations was extensively discussed and the recommendation is to have a significantly distinct phraseology between ILS and GBAS in in order to avoid misunderstandings.

WA4 Proposals for Standardizations Summary

Within the limited duration of the project several proposals for standardisation were submitted to relevant ICAO forums. The continuation of these standardisation activities at ICAO level is a long process but an important element for facilitating the deployment of the proposed concepts of operation. On the other hand, standardisation activities related to RTCA, EUROCAE, ARINC and EASA are detailed within Subchapter **Error! Reference source not found.**.

1.3 Project Deliverables

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

Reference	Title	Description
D02	Generic Operational Implementation Plan for GBAS CAT I	WA1 - This deliverable provides guidelines to facilitate the operational implementation of GBAS CAT I operations by ANSPs through Europe
D42	Concept of GBAS Advanced Operations Document (OSED- V3)	WA2 - This deliverable provides an update of the operational concept “RNP transition to GLS".
D46	Concept Validation Report for Advanced Procedures (RNP to GLS concept) for V3	WA2 - This deliverable provides the validation results obtained from Step 1 V3 exercise that was focused on validating TMA environment in the application of RNP to GLS Concept.
D04	Operational Service and Environment Definition (OSED) Displaced Thresholds	WA2 - This deliverable provides the description of the new operating method, use cases and operational requirements corresponding to “Displaced Thresholds under GBAS CAT I” with a V2 maturity level.
D55	Approach Procedures Charts and Path Terminators for RNP transition	WA2 - This deliverable contains all the design activities performed on GBAS RNP transition to GLS

	to GLS and Displaced Thresholds (Final version).	and DT for supporting the related V2 and V3 exercises.
D47	GBAS CAT II-III Functional Descriptions Update Report-update for V3	WA3 - This OSED describes the optimised operations in low visibility conditions by using GBAS. The corresponding Safety Assessment was performed within P15.03.06 [9].
D49	Concept Validation Report for GBAS CAT II-III for V3	WA3 - This document describes the results of the validation exercise that was performed with real time simulation and with main focus on results for Paris CDG Airport (LFPG). This activity was part of the Step 1 activities of P06.08.05 in OFA01.01.01 “LVP using GBAS”. The exercise evaluated GBAS Cat II/III operations.
D15	Proposals for Standardizations Report	WA4 - This document summarizes all the proposals for standardizations found as part of 06.08.05 project on several GBAS (Ground Based Augmentation System) based approach procedures.

All these deliverables have been produced assuring the proper alignment with the corresponding higher level concept and validation framework documents (i.e. [5], [6], [7] and [8]) developed at airport and TMA level.

1.4 Contribution to Standardisation

06.08.05 project has provided a significant amount of proposals for standards evolution to cover from an operational and procedure design perspective all the concepts developed in this project: GBAS CAT I, GBAS RNP transition to GLS, Displaced Thresholds and GBAS CAT II/III.

The evolution of the standards considering these proposals should help a globally harmonised deployment of above GBAS operations.

Some of the discussed aspects have been already presented to ICAO Instrument Flight Procedures Panel (IFPP) and ICAO EUR All Weather Operations Group (AWOG) and are under consideration.

Usually the process of updating the standards at ICAO level is quite long and complex. As such the proposed changes should be considered as a first step to trigger the evolution the standards.

Additionally, the evolutions in P06.08.05 address operational implementations feasible with the current technical GBAS CAT I and planned GAST-D systems. Therefore initially there is no need to perform additional standardisation at RTCA or EUROCAE level besides the contributions already performed through 9.12 (GBAS Cat II/III - Airborne System) and 15.3.6 (GBAS Cat II/III L1 Approach - Non Avionic Navigation System).

Moreover, ARINC is concerned at a later stage as regards the equipment information exchange, but that will have to be driven by the manufacturers for the concrete implementations in production aircraft – not yet in the validation stage covered by SESAR.

Even although EASA does not play the role of a standardisation group, it is worthy to highlight that its involvement is actively on-going by reviewing the key deliverables produced within the framework of WA3 GBAS CAT II-III Operations. This "EASA coordination process" will be managed, and therefore can be traced, within P15.3.6.

1.5 Project Conclusion and Recommendations

ANSPs can now implement GBAS CAT I operations according to SES regulation in a more effective way by following the Operational Implementation Plan.

WA2: GBAS CAT I Advanced Operational Concepts and Procedures

"GBAS CAT I – RNP Transition to GLS":

Design, coding and charting of the RNP to GLS procedure was achieved. The procedure flyability and the operational acceptance were validated. Pilots confirmed that RNP-GLS procedure would bring benefits in terms of environmental impact (fuel burn and noise reduction), minima (OCA/H) reduction, safety, pilot situational awareness and flight crew workload.

These results have contributed to SESAR Solution #9 "Enhanced terminal operations with automatic RNP transition to ILS/GLS". It belongs to PCP AF#1 Extended Arrival Management and Performance Based Navigation in the High Density Terminal Manoeuvring Areas.

"Displaced Thresholds under GBAS CAT I":

It has been validated that Displaced Threshold concept can provide benefits in terms of runway capacity (DT).

The work performed under this WA is being evolved by P06.08.08 "Enhanced arrival procedures to reduce occupancy time using GBAS" and will be an input to SESAR Solution PJ.02-02 "Enhanced arrival procedures" that will be evolved within SESAR 2020.

WA3 GBAS CAT II-III Operations

GBAS CAT III provides for optimised low visibility operation allowing to overcome a major limitation of ILS in low visibility, which is protection of larger Critical and Sensitive Areas. Consequently, an increase in runway throughput without negatively impacting safety and human performance can be achieved. Validation results as well as the produced operational concept and requirements have contributed to SESAR Solution #55 "Precision approaches using GBAS CAT II/III based on GPS L1", whose status is "V3 Achieved"

WA4 Proposals for Standardizations Summary

See Subchapter **Error! Reference source not found.**.

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 B.01 Integrated Roadmap Dataset DS14

[5] P06.02, Airport Validation Strategy Step 1, D105, 00.01.00, March 2015

[6] P06.02, STEP 1 Airport DOD, D122, 00.01.01, March 2015

[7] P05.02, WP5 TMA Step 1 DOD, D84, 00.01.01, April 2015

[8] P05.02, WP5 Validation Strategy for Concept Step 1 - Time Based Operations, D85, 00.00.03, October 2014

[9] P15.03.06, OFA 01.01.01 GBAS CAT III L1 Safety Assessment Report, D22, 00.01.00, January 2015

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