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Copyright Statement

AAL2

Augmented Approaches to Land 2

This demonstration report is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 783112 under European Union's Horizon 2020 research and innovation programme.

Abstract

The Augmented Approaches to Land 2 (AAL2) project focused on increased access to airports for low visibility mixed fleet operations. It builds upon the results from the former award winning SESAR project AAL, and demonstrated augmented approach and landing operations based on the following SESAR solutions:

- GBAS (Ground Based Augmentation System) CAT II with CAT I airborne and ground equipment, enabling lower decision heights to CAT II minima (DH 100ft) (addresses hubs and medium size airports); and
- EFVS (Enhanced Flight Vision System) to Land using Head Up /or Head Wearable Display, with operational credit down to 300 meters RVR in non- CAT II/III airports (addresses medium and small size airports).

Over 60 flight trials in total were collected comprising revenue flights as well as flight test aircraft. Flights covered wide scope of airport categories - small/medium/large airports (Antwerp, Bremen, Frankfurt, Périgueux). This VLD project benefited from the involvement of very relevant stakeholders.

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1 Executive summary

SESAR Augmented Approaches to land 2 project led by Honeywell was launched in 2018 by joint initiative of 12 major partners from the aviation community.

- Airspace users: EBAA, Lufthansa, Ryanair,
- Airframe manufacturers: Airbus, ATR, Dassault-aviation,
- ANSPs: DFS, DSNA, skeyes, skyguide,
- Avionics manufacturers: Honeywell,
- flight procedure expert: DLR,
- and supported by EUROCONTROL.

The project aims at making a pre-deployment and raising market awareness of two SESAR technologies:

- GLS CAT II with CAT I airborne and GAST-C ground equipment
- EFVS to land with Ops credit

Two work packages were developed to support ultimate objective of increased access to airports for low visibility mixed fleet operations.

- WP2 focused on GBAS
- WP3 focused on EFVS to land

Trial flights were performed by wide variety of aircrafts at selected airports prepared for that purpose. During demonstration performed at Frankfurt, Bremen, Antwerp, Périgueux, more than 60 approaches were collected, analysed and evaluated.

For **WP2 GLS CAT II with CAT I equipment** the new RNP to GLS procedure was created in Bremen airport, the safety analysis supporting Honeywell's SLS-4000 Block IIS with SBAS option enabled approval was created, reviewed by independent auditor and submitted to regulatory body, paperwork and simulations supporting Airbus airworthiness approval was completed, as well as the documentation supporting the operational approval for GLS CAT II operations in Germany.

Based on that, the practiced GLS CAT II demonstrations were performed by 2 largest European airliners and following objectives were evaluated:

For safety KPIs the following results were collected:

- Horizontal flight accuracy (RNP to GLS) was within 0,5 NM
- Vertical flight accuracy (RNP to GLS) - Vertical FTE is within CTQ limit - no descend below FAP constraint 100ft
- Lateral flight accuracy of practice GLS CAT II Autoland during final approach - Lateral FTE is within CTQ limit – 1 dot

- Vertical flight accuracy of practice GLS CAT II Autoland during final approach - Vertical FTE is within CTQ limit – 1 dot

For Fuel/Environment Efficiency KPIs:

- Average fuel burned per approach set (GBAS compared to ILS) - Decreased fuel consumption for GBAS approaches compared to legacy ILS thanks to more stable signal was indicated by simulations results, but it was not confirmed on flight data on respective runway due to low amount of flights gathered
- CO2 emission per approach (GBAS compared to ILS) - decreased CO2 emissions for GBAS approach compared to legacy ILS thanks to more stable signal was indicated by simulations results, but it was not confirmed on flight data on respective runway due to low amount of flights gathered for analysis

For Human Performance KPIs:

- Perceived level of feasibility – pilots (RNP to GLS) - RNP to GLS approaches are feasible based on feedback form pilots
- Perceived level of feasibility – pilots (practice GLS CAT II Autoland) - Practice GLS CAT II Autoland approaches are feasible based on feedback form pilots - >95% appr. Successful

For Cost efficiency KPIs:

- Cost efficiency of GLS CAT II approaches on GBAS CAT I equipment was demonstrated on airspace users' cases in qualitative study

Support of GLS CAT II operation introduction on GBAS GAST-C which doesn't require avionics modification for GAST-D allows to start gaining benefits, both in airport capacity for large hub as indicated by FTS, fuel/CO2 savings and accessibility of regional airports by GLS CAT II approach coverage on all RWY ends, already **with current GBAS CAT I avionics.**

Recommendation is to continue international coordination and at ICAO level deliver appropriate framework to allow quick progress in GLS CAT II operations using GAST-C station. From RNP to GLS point of view, new demonstrated procedures in Bremen demonstrated CDO a-like vertical profile applied in order to reduce noise and fuel consumption. Recommendation is that RNP procedures that supports CDO operation should be published and promoted for usage.

By demonstrating practice GLS CAT II approaches, the AAL2 made significant step towards standardisation and deployment of full GLS CAT II in European airspace.

Also, while contributing to SESAR Solution 55 "Precision approaches using GBAS Category II/III"", WP2 provided new Solution of GLS CAT II operation using GAST-C.

With respect to **WP3**, the SESAR AAL2 is the first initiative to implement the ongoing **EFVS part of** EASA (NPA AWO 2018-06) at some pioneer EU aerodromes of Antwerp and Le Bourget. It is the first time non CATII/III aerodromes receives an experimental approval (Aerodrome/ runway suitable for EFVS ops credits) from their national authorities following appropriate studies performed by the ANSPs jointly with the aerodromes.

The AAL2 EFVS part of the project composed of ANSP including ATC, aerodrome operators and air operators from business and regional aviation, demonstrated EFVS with Ops credit operation in full ATM environment.

Ground segment stakeholders underlined the task needed for promulgation of the suitability of aerodrome/ runway for EFVS was fast and affordable compared to CATII/III. No increase of complexity or ATC excessive workload was perceived. They also concluded EFVS operation were a good solution for regional aerodromes for increasing accessibility in Low Visibility Conditions.

From air operator standpoint, SESAR AAL2 EFVS brings more flexibility, improves situational awareness and therefore contributes to increase Safety.

Based on pioneer demonstrations performed in Antwerp and Périgueux, the following objectives were evaluated:

For safety KPAs:

- Horizontal Flight accuracy (EFVS) - Horizontal TSE for EFVS approaches is within 1 dot
- Vertical Flight accuracy (EFVS) - Vertical TSE for EFVS approaches is within 1 dot
- Successful touchdown (EFVS) - Touchdown footprint for EFVS approaches is in touchdown zone
- Crew and ATC workload during EFVS operation remains acceptable
- Significant visual advantage with EFVS - Visual advantage compare to natural vision is greater than 200m (1/3 of actual RVR publishes)

For human performance KPA:

- Perceived level of feasibility – EFVS approaches are feasible based on feedback form from pilots and ATC

Based on study and simulations:

For Airport Capacity KPA:

- Increased access to secondary airports in low visibility (EFVS) - EFVS to land concept of operation in RVR as low as 300m (as permitted by regulation) would allow to retain access in more than 78% of the limiting weather conditions
- Equivalent level of performance on LED lights as on incandescent lights

As a result of the experimental approval, AAL2 EFVS makes recommendations for improving EFVS regulations. It recommends the declaration of suitability of the aerodrome/ runway for EFVS is made on the aerodrome side (i.e AIP) rather than letting each air operator doing it by its own. This will guaranty the highest level of safety as well as giving a very clear indication to the crew with respect to the limits of the EFVS operation at each aerodrome.

The AAL2 “pioneer” demonstrations highlight the benefits of the EFVS with Ops credit operations to aerodrome community and act as examples to be followed by other secondary aerodromes to get these privileges. Steps to be followed and partners to be involved have been described in detail through AAL2 project. The material produced is a key input to improve regulation and to support, to ease and to standardize the future EFVS approvals in Europe.

AAL2 paves the way to large deployment of EFVS operations in Europe allowing aerodromes to expand their accessibility on the one hand, and on the other hand Business and regional aviation to take benefit of the EFVS operational credits.

EFVS will supplement PBN IR 3D approaches and in particular LPV approaches broadly used by business and regional aviation.

This effort contributed to SESAR Solution 09: **“**Enhanced terminal operations with RNP transition to ILS/GLS”, and SESAR new Solution as described in draft contextual note supplementing solution 117: “Reducing landing minima in low visibility conditions using enhanced Flight vision systems (EFVS)”.

The AAL2 consortium thanks to SJU for a support and cooperation during project execution.

2 Introduction

This section provides the basic information for this document. Firstly, the purpose is be described in Section 2.1. Then intended readership followed by a structure of the document is mentioned in Sections 2.2 and 0. Finally, Glossary of terms, acronyms and terminology will be included in Sections 2.6 and 2.7.

2.1 Purpose of the document

This document provides the Demonstration Report for VLD1-06-2016 AAL2 Project targeting the contribution to:

- SESAR Solution 55 "Precision approaches using GBAS Category II/III",
- SESAR Solution 09: **"**Enhanced terminal operations with RNP transition to ILS/GLS",
- and SESAR new Solution as described in draft contextual note supplementing solution 117: "Reducing landing minima in low visibility conditions using enhanced Flight vision systems (EFVS)".

It describes the results of demonstration exercises, defined in SESAR 2020 AAL2 Demonstration Plan 01.01.00 2nd Review [56] and how the exercises have been conducted.

2.2 Scope

The scope of this project was targeted at demonstrating operation in representative environment-and paving the way to improve regulations and market take-up of technologies that will improve approach and landing at small and medium size airports as well as large airports.

The project focused on demonstration of augmented approach and landing operations based on the following SESAR solutions with the aim to bridge the gap between research and deployment, in order to speed up deployment of the following two SESAR technologies/ operations:

• GBAS (Ground Based Augmentation System) CAT II with CAT I airborne and ground equipment, enabling lower decision heights to CAT II minima (DH 100 ft); (addresses hubs and medium size airports),

• EFVS (Enhanced Flight Vision System) to Land operation based on IR-Visual airborne technology enabling EFVS landing with operational credit down to 300 meters RVR in non- CAT II/III airports; (addresses medium and small size airports).

Two technologies, multiple aircraft platforms, airlines, airport operators, air navigation service providers, and flight procedure designers supported the trial flights in such way to cover the scope of the project.

In AAL2, RNP to GLS procedures were designed in Bremen (improved based on AAL feedback) by DFS and enabling lower decision height to 100 ft - RNP to GLS CAT II. Those procedures have not been fully published yet into the AIRAC. These procedures were prepared and published by DFS as RNP to GLS CAT I procedures to Bremen in July 2019 AIRAC, for approach accuracy and feasibility demonstrations, for CAT II operations will be published once Block IIS approval is granted. The project focused on receiving System Design Approval for Honeywell's SLS-4000 Block II ground system from German Authority. Lufthansa and Ryanair planned to get operational approvals from their respective authorities and Airbus worked towards airworthiness approval from EASA. Lufthansa flown practiced GLS CAT II Autoland demonstration flights with Airbus 320 family (Bremen) and Boeing-747-8 (Frankfurt) on revenue flights. Ryanair executed practiced GLS CAT II autoland flight with Boeing 737 on non-revenue flight.

The GBAS (Ground Based Augmentation System) CAT II with CAT I airborne and ground equipment demonstration exercises took place at the airports of Frankfurt and Bremen which are equipped with a GBAS ground station. The involved parties were Lufthansa and Ryanair, well as DFS, supported by Airbus and Honeywell. DFS designed RNP to GLS CAT I/II procedures for the airports of Bremen. The RNP to GLS procedures were flown by Lufthansa and Ryanair aircraft equipped with GLS on revenue flights by selected aircrews and with weather conditions permitting. Over the course of the demonstration activity, **58 practice GLS CAT II Autoland and 18 RNP to GLS approaches** were flown in total, all except one approach were flown during airlines revenue flights. Data on accuracy of flight path were obtained digitally on-board the involved aircraft. Also, data from ground noise measurement equipment for the noise impact evaluation were obtained, analysed and results assessed and described in Appendix G. To ensure precise measurements with respect to fuel consumption under nominal conditions, measurements to support the demonstration report were performed using simulators for both business as well as mainline aircraft.

The AAL2 project allows EFVS-L operations to be in the pipeline towards deployment and generate further confidence to support buy-in from main stakeholders including Airspace users, ANSPs, Airports and regulators.
Several steps were achieved:

- Preparation to the homologation/ authorization/ approval of some pioneer aerodromes in consistency with EASA NPA AWO,
- Demonstration of EFVS to land operation feasibility and benefits
- Weather analysis for supporting decision making for EFVS deployment
- Analysis of EFVS visual advantage for pollutant atmospheres and LED lighting

The EFVS (Enhanced Flight Vision System) to Land demonstration exercise took place at 2 airports (Antwerp and Périgueux) in real operational environment. Demonstrations were performed by business aviation and regional aviation using HUD flight-deck vision systems (Dassault F8X) and HWD flight-deck vision systems (ATR -600 series).

2.3 Intended readership

This document is intended for audience interested in the benefits demonstration of GLS CAT II approach on CAT I equipment, including practice GLS CAT II or GLS CAT I Autoland respectively and EFVS technologies.

Main audience can be divided to those categories:

- End Users (Air operators, Aerodromes operators including AFIS),
- European decision makers,

- Organizational (EC, EASA, EUROCONTROL, ICAO, EUROCAE, GSA, ACI, ARC, Borealis Alliance…),
- National Authorities,
- Industrial (Airframe and Avionics, ATC Systems),
- ANSPs including ATC,
- Research Organisations and Universities.

The motivation is different depending on audience, however significant factors influencing interest are operational benefits, potential cost savings and improvement of ATM and contribution to standardisation and certification.

2.4 Background

A very large partnership of aviation stakeholders has been brought together for this project. Many of them were already involved in the former SESAR Large Scale Demonstration project AAL (Single European Sky Award 2017 winning project for Innovation-Technology).

The objective of AAL2 project was to show the complementarities between several approach solutions into different operational environments. It demonstrated that augmented vision and satellite-based augmented navigation can improve access while reducing the environmental impact of all types of Airspace Users into all types of airports.

The AAL2 project enjoys the involvement of very relevant stakeholders, giving the project high credibility of successful execution of the demonstrations, achievable results, good external communication, and collaboration.

Building on the former AAL project, mainline further focused on the demonstration of the GBAS system potential by extending to GLS CAT II operation while taking use of the currently deployed CAT I equipment, as well as connection to RNP with RF (radius-to-fix) legs with both CAT I and CAT II minima.

The AAL2 project worked on preparation of full scope of GLS CAT II approach operation demonstration with use of enhanced GBAS ground station and GBAS CAT I airborne equipment, and flight demonstration of practice GLS CAT II Autoland approaches. The project worked on receiving System Design Approval for Honeywell SLS-4000 Block IIS ground system from German Authority. Lufthansa and Ryanair worked on demonstration of enough practice GLS CAT II Autoland approaches to support operational approvals from regulatory authorities, while Airbus works towards airworthiness approval for A320 family. Benefits of more stable GLS vs ILS operations were evaluated by DLR. The new RNP to GLS procedures were designed in Bremen by DFS that enables lower decision height down to 100 ft for GLS CAT II operations. In the first step, procedures were published with CAT I minimums. Both Lufthansa and Ryanair demonstrated RNP to GLS approaches in Bremen. Lufthansa have already gathered almost 60 practiced GLS CAT II Autoland approaches in Frankfurt with B747-8 and A320fam, and in Bremen with A320fam, on the way to full GLS CAT II operation. Ryanair executed GLS Autoland approach with Boeing 737 NG on non-revenue flight. Both Lufthansa and Ryanair continue targeting GLS CAT II operation in their regular operation once OPS approvals will be obtained.

With respect to EFVS operations, SESAR AAL project (2016-2017) produced technical recommendations for ground segment in order to facilitate air operator approvals. These recommendations have been provided as an input for building the NPA AWO 2018-06. AAL2 conducted experimental approval of some pioneer aerodromes in consistency with the NPA AWO jointly with National Authorities. Feedbacks were collected from all stakeholders and recommendations were proposed for supporting regulation improvement and for speeding up the deployment of the EFVS operation.

2.5 Structure of the document

This document is structured into seven main sections. Section 1 Section provides executive summary of demonstrations that are further discussed in section 2 where is provided an introduction for this validation report and includes information about purpose and structure of this document, intended readership, glossary of terms and list of acronyms. Section 3 reminds the scope of the demonstrations, their purpose, describes related solutions and deviations with respect to demonstration plan. In Section 4, the summary of demonstration exercises results is presented followed by section 5 with conclusions and recommendations. Detailed exercises reports are described in appendix A and B. Section 6 summarises performed communication and dissemination activities, their purpose and targeted communication audience.

From size-wise point of view, all the appendixes are placed in separate documents – each appendix is a separate file.

Appendixes:

- Appendix A – GBAS CAT II with CAT I equipment – description of demonstration exercise EXE-VLD-V4-100
- Appendix B – EFVS – description of demonstration Exercise EXE-VLD-V4-200
- Appendix C and D – safety assessment report for both demonstrated exercises, the security assessment is not applicable
- Appendix E – Human assessment report for both AAL2 exercises
- Appendix F - Assessment of differences between approaches with ILS and GLS
- Appendix H - The new RNP to GLS procedures that were designed by DFS in the frame of AAL2 project and published in July 2019 AIRAC cycle can be found in this appendix.
- Appendix I - Compliance Matrix to SESAR Solution #55 - GLS CAT II operation on GAST-C/CAT I station that allows to utilize CAT I equipment to support CAT II operation.
- Appendix J - Weather Impact Analysis on EFVS Operations - the weather impact on landing operations performed by a CATI aircraft/ crew and determines to what extent the EFVS to land concept of operation can expand the accessibility in degraded weather conditions.
- Appendix K - De-generalizing Instrument Approach Minima to Non-Instrument Runways - Case Study for Payerne Airport, Switzerland
- Appendix L - Performance Prediction Analysis for EFVS - the appendix deals with the characterisation of the performance of EFVS for other than those most standard situations
- Appendix M - VLD progress towards TRL-7

2.6 Glossary of terms

Term	Definition	Source of the definition
AIR-REPORT	A report from an aircraft in flight prepared in conformity with requirements for position, and operational and/or meteorological reporting.	ICAO Annex
EVS	'enhanced vision system (EVS)' is an electronic means to provide the flight crew with a real time sensor-derived and enhanced image of the external scene topography (the natural or man-made features of a place or region especially in a way to show their relative positions and elevation) through the use of imaging sensors. An EVS that is not an EFVS cannot be used for EFVS operations and therefore does not attract an operational credit.	EASA NPA AWO
EFVS	'enhanced flight vision system (EFVS)' is an electronic means to provide the flight crew with a real-time sensor derived or enhanced display of the external scene topography (the natural or man-made features of a place or region especially in a way to show their relative positions and elevation) through the use of imaging sensors; an EFVS is integrated with a flight guidance system and is implemented on a head-up display or an equivalent display system; if an EFVS is certificated according to the applicable airworthiness requirements and an operator holds the necessary specific approval, then EFVS may be used for EFVS operations and may allow operations with operational credits. 'EFVS operation' means an operation in which visibility conditions require an EFVS to be used in lieu of natural vision in order to perform an approach or landing, identify the required visual references or conduct a roll -out	EASA NPA AWO
EFVS-L	An EFVS-Landing (EFVS-L) is a system that has been demonstrated to meet the criteria to be used for approach and landing operations that rely on sufficient visibility conditions to enable unaided roll-out and to mitigate for loss of EFVS function	EASA NPA AWO
HUD	'head-up display (HUD) or equivalent display system' means a display system which presents flight information to the pilot's forward external	EASA NPA AWO

	field of view (FOV) and which does not significantly restrict the external view	
HWD	A Head Wearable Display is a display system worn on the pilot's head that projects primary flight information (e.g. attitude, air data, and guidance) in alphanumeric and/or symbolic form to one or both pilot's eyes on a transparent screen (i.e., visor) along the pilot's dynamically changing line of sight. An HWD might also display vision system imagery. An HWD that is to be used as a HUD equivalent includes a head tracking function (HTF) to monitor the pilot's head location and line of sight so that the display can adjust in real time with head movements and enable the effective display of information over a wide field of regard	SAE ARP 6377 (draft)
All Weather Operation (AWO)	Any surface movement, take-off, departure, approach, or landing operations in conditions where visual reference is limited by weather conditions.	ICAO Doc 9365
LOW VISIBILITY OPERATIONS	low-visibility operations (LVOs)' means approach and landing operations in RVRs less than 550 m and/or with a DH less than 200 ft. or take-off operations in RVRs less than 550 m.	ICAO EUR Doc 13
LVP	'low-visibility procedures (LVPs)' means Specific procedures applied at an aerodrome for the purpose of ensuring safe operations during LVO.	ICAO EUR Doc 13
Aerodrome traffic density.	a) Light: Where the number of movements in the mean busy hour is not greater than 15 per runway or typically less than 20 total aerodrome movements; b) Medium: Where the number of movements in the mean busy hour is of the order of 16 to25 per runway or typically between 20 to 35 total aerodrome movements; and c) Heavy: Where the number of movements in the mean busy hour is of the order of 26 or more per runway or typically more than 35 total aerodrome movements. *Note 1 – The number of movements in the mean busy hour is the arithmetic mean over the year of the number of movements in the daily busy hour.*	ICAO Annex 14

	Note 2 – Either a take-off or a landing constitutes a movement	
VISIBILITY CONDITIONS 2	Visibility sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, but insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance).	ICAO EUR Doc 13
AFIS	Aerodrome flight information service (AFIS) is the term used to describe the provision of information useful for the safe and efficient conduct of aerodrome traffic at those aerodromes designated for use by international general aviation (IGA) where the appropriate air traffic services (ATS) authority determines that the provision of aerodrome control service is not justified, or is not justified on a 24-hour basis, AFIS is not intended to be used at aerodromes designated as regular or alternate aerodromes for international commercial air transport operations.	ICAO Circular 211-AN/ 128
GPS	A space-based positioning, velocity and time system composed of space, control, and user segments. The space segment, when fully operational, will be composed of 24 satellites in six orbital planes. The control segment consists of five monitor stations, three ground antennas and a master control station. The user segment consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user.	RTCA/DO 229 D Appendix O
GBAS	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 required navigation performance for the intended operation	ICAO SARPS Annex 10
GLS	The GLS is a system allowing precision approaches down to Cat I minima and foreseen to be used for Cat II/III operations. This system is composed of a GLS ground station (for reference approach path, satellite correction and integrity data uplink) and of an airborne part in order to receive and use the GLS signals to guide the aircraft down to the decision height (200ft in Cat I and down to no DH for Cat III)	SESAR 9.12.D02 Qualitative & Quantitative Functional, Performance and Safety Requirements, February 2011

QFU	Magnetic orientation of runway	PANS-OPS doc 8400 ICAO Abbreviations and Codes
SBAS	SBAS (Satellite Based Augmentation System) improves the accuracy of position measurements by sending out signals that correct GPS data and provide information on its reliability.	SESAR 9.12.D02 Qualitative & Quantitative Functional, Performance and Safety Requirements, February 2011
EGNOS	The EGNOS (European Geostationary Navigation Overlay Service) European implementation of SBAS, network includes about 40 reference stations in more than 20 countries. These reference stations pick up signals from GPS satellites, which are processed in Master Control Centres (MCC). The accuracy of the original signals is determined and confounding factors, such as electrical disturbances in the atmosphere, are corrected. These data are incorporated into EGNOS signals and sent to its three geostationary satellites. The satellites then relay the signals back to EGNOS-enabled receivers, thus providing far greater positioning accuracy than would be achieved through GPS alone. In Europe, ICAO recommends deploying APV approaches on all runways by 2016, and EGNOS is included in the regional PBN plan. EGNOS provides a cost-effective alternative to ILS CAT I, offering similar performance yet without the need for infrastructure installation and maintenance.	SESAR 9.12.D02 Qualitative & Quantitative Functional, Performance and Safety Requirements, February 2011

Table 1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
AAL	Augmented Approaches to Land
AC	Advisory Circular
ADP	Aéroport De Paris
ADP LB	Aeroport De Paris Le Bourget
AFDS	Autopilot Flight Director System
AGP	IATA code for Malaga airport
AMC	Acceptable Means of Compliance
ANSP	Air Navigation Service Provider
APCH	Approach
APV	Approach With Vertical guidance
ARC	Airport Region Conference
ARC	Airport Region Conference
ARINC	Aeronautical Radio, Incorporated
ATC	Air Traffic Control
ATCISS	Air Traffic Control Information Support System
ATCO	Air Traffic Controllers
ATIS	Automated Terminal Information Service
ATM	Air Traffic Management
ATMOPS	Air Traffic Management OPS ICAO panel
ATMRPP	Air Traffic Management Requirement and Performance Panel ICAO
AWO	All Weather Operations
BAF	Bundesaufsichtsamt für Flugsicherung (German Regulator)
BKN	Broken
BRE	IATA code for Bremen airport
CAT	Category
CDG	Charles De Gaulle (Airport)
CDO	Continuous Descent Operations
CONOPS	Concept of Operations
CR	Change Request
CS	Certification Specification
CTQ	Critical to Quality
CVS	Combined Vision System
DA	Decision Altitude
DEMOP	Demonstration Plan
DEMOR	Demonstration Report
DGPS	Differential GPS
DH	Decision Height
DMC	Display Management Computer

Acronym	Definition
DME	Distance Measurement Equipment
DMU	Data Management Unit
EASA	European Union Aviation Safety Agency
EATMA	European ATM Architecture
E-ATMS	European Air Traffic Management System
EBAW	ICAO for Antwerp airport
EBBR	ICAO for Brussels airport
EDDF	ICAO code for Frankfurt airport
EDDW	ICAO code for Bremen airport
EFB-ADR	Electronic Flight Bag Aircraft Data Recorder
EFIS	Electronic Flight Information System
EGNOS	European Geostationary Navigation Overlay Service
EPAS	European Plan for Aviation Safety
EPIS-CA	Evaluation Primaire d'Impact sur la Sécurité - Circulation Aérienne
ESEA AWO	EASA All Weather Operations
EU	European Union
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
FAP	Final Approach Point
FCAS	Flight Condition Approval Sheet
FCOM	Flight Crew Operating Manual
FMA	Flight Mode Annunciator
FMC	Flight Management Computer
FMGC	Flight Management and Guidance Computer
FRA	IATA code for Frankfurt airport
FTC	Flight Training Centre
FCTM	Flight Crew Training Manual
FPL	Flight Plan
FLTOPS	Flight OPS panel ICAO
FWC	Flight Warning Computer
GBAS	Ground Based Augmentation System
GLS	GBAS Landing System
GM	Guidance Material
GPS	Global Positioning System
GSA	European GNSS Agency
HUB	HUB airport
HUD	Head-up Display
HWD	Head Wearable Display

Acronym	Definition
IAA	Irish Aviation Administration
IAC	Instrument Approach Chart
IAP	Instrument Approach Procedure
ICAO	International Civil Aviation Organization
ID	Identification
IDVS	Informations-Daten-Verarbeitungs-System (Information Data Processing System)
IFR	Instrument Flight Rules
IGWG	International GBAS Working Group
IOC	Initial Operating Capability
IOC	Initial Operating Capability
ILS	Instrument Landing System
KPA	Key Performance Area
LANBLF	**L**inuxbasiertes **A**lpha-**N**umerisches **B**etriebsstufenanzeige- und **L**andebahnanwahl- **F**ernwirksystem (Linux based Alpa Numeric operational mode and runway remote select system)
LATO	Landing and Take-Off
LBA	Luftfahrt-Bundesamt (German Ops Regulator)
LDLP	Low-Drag-Low-Power
LED	Light Emitting Diode
LEMG	ICAO code for Malaga airport
LOC	Localizer
LPV	Localizer Performance with Vertical guidance
LVO	Low Visibility Operation
LVP	Low Visibility Procedure
MMR	Multi-Mode Receiver
MOS	Management Operating System
NAA	National Aviation Authority
NDB	Non-Directional Beacon
NLS	Navigations- und Landesystem (Navigation and Landing System)
OCS	Obstacle Clearance Surface
OFZ	Obstacle Free Zone
OI	Operational Improvement
OM	Operations Manual
OPAR	Operational Performance Assessment Report
ORE	Operational Risk Evaluation
ORI	Operational Requirements
OSED	Operational Service and Environment Definition
OVC	Overcast
PA	Precision approach

Acronym	Definition
PAR	Performance Assessment Report
PF	Pilot Flying
PFD	Primary Flight Display
PM	Pilot Monitoring
QoS	Quality of Service
QRH	Quick Reference Handbook
RAF	Risk Assessment Forum
REQ	Requirement
RESA	Runway End Safety Area
RNAV	Area Navigation
RF	Radius-to-Fix
RNP	Required navigation performance
RST	Recurrent Simulator Training
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
RWY	Runway
SAC	Safety Criteria
SAR	Safety Assessment Report
SBAS	Space Based Augmentation System
SDA	System Design Approval
SESAR	Single European Sky ATM Research Programme
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking
SPACC	Special Activity Coordination Cell
SPR	Safety and Performance Requirements
SW	Software
STAC	Service Technique de l'Aviation Civile
SWL	Sub-Work Package Leaders
SWP	Sub-Work Package
TMA	Terminal control area
TS	Technical Specification
TTA	Time To Alert
UNH	Umwelt- und Nachbarschaftshaus
US	United States
VDB	Very High Frequency Data Broadcast
VLD	Very Large Demonstrations
VLD	Very Large-Scale Demonstration
VOR	VHF Omni-directional Radio range

Acronym	Definition
VPL	Vertical Protection Level
VSS	Visual Segment Surface
WP	Work Package

Table 2: List of acronyms

3 Very Large Demonstration (VLD) Scope

This section introduces the scope of demonstrations, first the GBAS work package is introduced and then the EFVS to Land work package, detailing the technical aspects of each solution, continued by description of their relations to other SESAR related research projects.

WP2 – GBAS CAT II DEMONSTRATIONS

GBAS CAT II addresses the use of RNP procedures and will help further develop existing solutions including Solution 55: Precision approaches using GBAS Category II/III and Solution 9: Enhanced terminal operations with RNP transitions to GLS.

GBAS CAT II solution provides great advantages to the currently GBAS GAST-C/CAT I equipped airborne users, airport operators and ANSPs to further exploit the possibilities of the system and get to 100 ft Decision Height (DH) without having to upgrade to CAT II/III systems. For a number of airports, especially medium size airports, CAT II capability will fully meet their operational needs. This is an important benefit to all operators, and airlines by increasing landing and reducing diversions. Figure 1 shows the GBAS technology with its satellite, air, and ground subsystems, together with a GBAS tower as a part of the ground subsystem. On the way towards GLS CAT II operational approval, a significant number of practice GLS CAT II Autoland approaches were performed to demonstrate accuracy and feasibility of GLS CAT I Autoland operation.

Revenue flights by Lufthansa and Ryanair ensured that operations were demonstrated in a real environment. The demonstrations supported arguments towards GLS CAT II and served as an example for other airports and airlines to adapt the procedures (e.g. Frankfurt as an interested stakeholder in the project). The project worked on coordination between US and EU stakeholders and regulation, coordination with other airlines (e.g. United, Delta) and the US regulator (FAA) outside of the project.

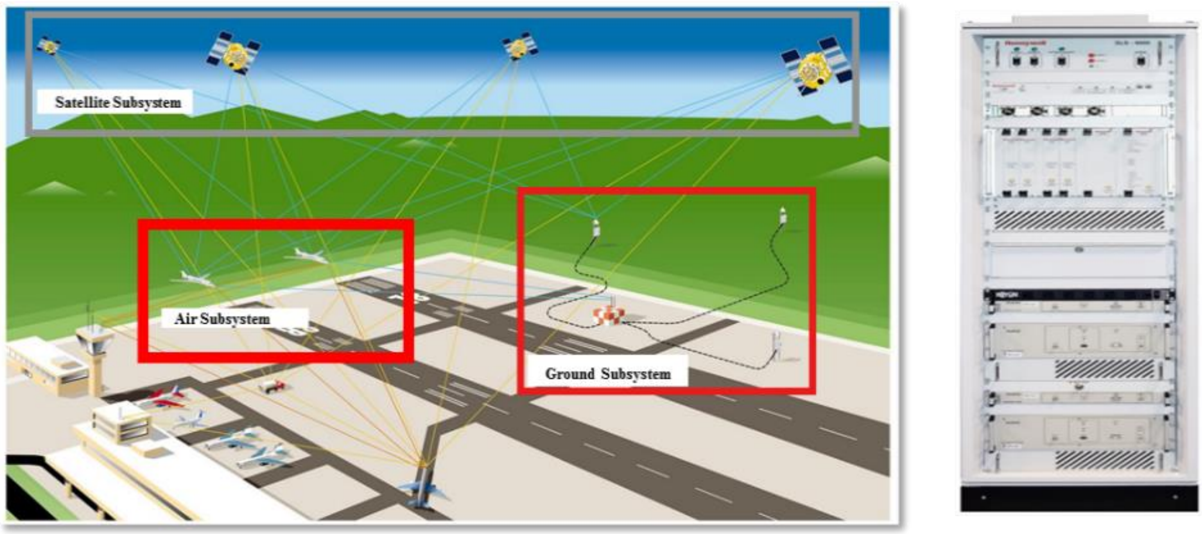

Figure 1: GBAS Technology: system overview graphics (left), ground subsystem Honeywell GBAS tower (right)

The concept behind GLS CAT II operation on GAST-C/CAT I system:

One of the biggest challenges for differential GPS systems is that they are sensitive to the spatial de-correlation due to variation in ionosphere delay between aircraft and correction source (GBAS ground station in this case). GBAS CAT I ground system thus has to be extremely conservative and assumes the presence of large ionospheric delay with probability of 1, even though such events in Europe and CONUS are very rare.

By **integrating the GBAS ground station with an SBAS receiver** (EGNOS capable receiver in Europe), GBAS can take advantage of SBAS's independent anomalous ionosphere monitoring. SBAS's network of dual frequency ground receivers is capable of producing a model of the ionosphere of the region which a single GBAS ground system is unable to do. GBAS brings on the other hand an improved performance (accuracy) due to local augmentation and improved Time-to-Alert (TTA). This makes the two systems complementary. The GBAS system monitors the level of ionospheric activity in the region thanks to the SBAS receiver, and when the ionospheric activity is low, the system does not need to be so conservative. This enables the GBAS to lower the protection levels and take advantage of big VPL (vertical protection level) performance improvements (e.g. ~ 2x **performance improvement** in Houston). This enables the station to serve CAT II operations with CAT I equipment. In case of increased ionospheric activity, the station will increase the safety margins, reverting to a performance with CAT I operations only. The CAT II approach would no longer be approved for operation and the station reverts to its CAT I capability. The required integrity is attained at all times.

On the ATC (Air traffic controllers) side, the operation is comparable to ILS CAT II operations (but without the constraints of protecting the ILS critical areas). Airplane requesting GLS CAT II approach will only be cleared by ATC if the ground station indicated of level of service supports GBAS CAT II operation. On the pilot side, operation is very close to ILS CAT II, relying on the GLS design already approved for CAT I operations.

This unique adaptation, taking advantages of both GBAS and SBAS, improves operational availability and enables CAT II operations against a GAST-C (CAT I) ground station with existing GLS CAT I airborne equipment. On the way towards GBAS CAT II operations and during coordination with national regulatory authorities for operator's approval there was identified need of additional flight demonstrations that consisted in demonstration of GLS CAT I Autoland approaches. These approaches are representative for CAT II Autoland operations intended for demonstrations and final operational approval towards GBAS CAT II operations.

The new RNP to GLS CAT I/II procedures were designed by DFS for Bremen airport. In the first step, procedures were published with CAT I minimums and provided in Appendix H.

GBAS CAT II Maturity:

With respect to GBAS CAT II operations on GAST-C/CAT I equipment, the Honeywell SmartPath GBAS Block II ground station has received the System Design Approval (SDA) from the FAA for the use with WAAS (US SBAS). This project worked towards European approval – in this case from the German regulator (BAF) with the use of the European SBAS system - EGNOS.

On the airborne side, the airline needed to apply and receive ops approval from their respective regulator to be able to fly these procedures. In the project, Lufthansa and Ryanair worked to get the approvals from their respective country regulators, the LBA (German regulator) and IAA (Irish regulator).

Concerning the aircraft, analysis showing compliance with CAT II criteria needs to be performed. This was done by Boeing for their 737-800, 787 and 747-8. Within the project, Airbus will work on A319, A320 and A321, in order to confirm their compliance.

Successful validation would improve availability and enable advanced approach and landing operations in the EGNOS coverage region for GBAS installations utilizing this capability through the proof of concept enabled by this project.

WP3 – EFVS TO LAND DEMONSTRATIONS

EFVS to land addresses the use of flight-deck vision-support systems which enables landings in low visibility conditions as currently only permitted by CAT II/III. WP3 addresses SESAR new Solution as described in draft contextual note supplementing solution 117: "Reducing landing minima in low visibility conditions using enhanced Flight vision systems (EFVS)".

All weather operations are a strong requirement for both Business /Regional aviation and aerodrome as they increase aerodrome accessibility, allow to retain traffic at secondary aerodromes (including AFIS) and consequently decreased congestion at nearby very few number of main hubs that only remain available for landing in low visibility conditions.

EFVS operation will allow to get operational credit in approach at most of 3D GNSS or ILS runway ends with precision or non-precision landing minima

AAL2 EFVS to land concept will allow operation in RVR as low as 300m.

EFVS capability is a key operational advantage both for the business aviation, and for the regional aviation community, operating at regional and local airports.

The operational credit provided by EFVS is particularly beneficial regarding those large number of aerodromes because they usually have CAT 1 or higher than CAT 1 minima and are therefore potentially more frequently impacted by adverse weather conditions.

Those aerodromes can also take benefit from the huge advantage of the EFVS operations, as enablers are mainly supported by the aircraft systems, whereas there is no need of additional ground infrastructure, compared to other operation such as CATII/III relying on complex and costly ground infrastructures.

Non EFVS operation:

From ATM, aerodrome and ATC perspective, low visibility operations require performant and complex navigation mean such as ILS CAT II/III, heavy lighting infrastructures such as touchdown zone lights and advanced procedures to be put in place to enable safe approach, landing and taxi operations when these conditions occur, i.e. below RVR of 550m. The list of these aerodromes is limited to few hundreds all over the world. They are all designed to respond to high level of continuity of service to accommodate aircraft whatever the conditions.

From air perspective, standard Instrument landing operations requires the pilot having enough visual reference in view at certain height above the runway (named as DH) to be authorized to continue the landing. The DA/DH that are published for a runway mainly depend on the navigation mean available (SBAS, ILS, RNAV, NDB, VOR…), and on the airport environment. The lowest DA/DH that is accessible to the crew depends on the aircraft capacity, the qualification/ training of the crew, and runway equipment. In adverse weather conditions, such as fog or low ceiling, pilot may not be able to see the visual references at the DA/DH and then be forced to abort the approach, with the possibility either to wait for weather improvement, or to divert to alternate airport with better weather conditions.

The following paragraphs will explain operational concept of the flight-deck vision-support systems. EFVS provides Visual advantage extending vision segment on approach (Figure 2).

WP3 EFVS to land concept:

The benefit of the new EFVS with operational credit concept (still under EASA AWO regulation process) proposed to be demonstrated in AAL2 will allow the pilot to descent below DA/DH taking credit of an EFVS system, which is composed of a **Head Up system (or equivalent HWD) and a multispectral camera** providing the capability to see in advance compare to naked eye in degraded weather conditions. This capacity of EFVS operation to provide a significant visual advantage in conditions such as fog or snow at DA/DH will enable a successful landing, which would be not possible otherwise. Such a concept is targeted to be used in **RVR as low as 300m** and covers most of the adverse situations to which business aviation is exposed in day to day operations, as demonstrated in SESAR AAL1.

This EFVS advanced operation concept differs from other standard CAT II/III concepts (usually available at main airports and used by airlines) as it allows operating in comparable weather adverse conditions, but at far many small medium airports than just a few numbers of fully equipped airports. The strength of EFVS with operational credit concept proposed is to take benefit of an advanced aircraft capacity based on technology rather than requiring heavy and costly aerodrome infrastructures that would be not affordable to other than main airports with high traffic density.

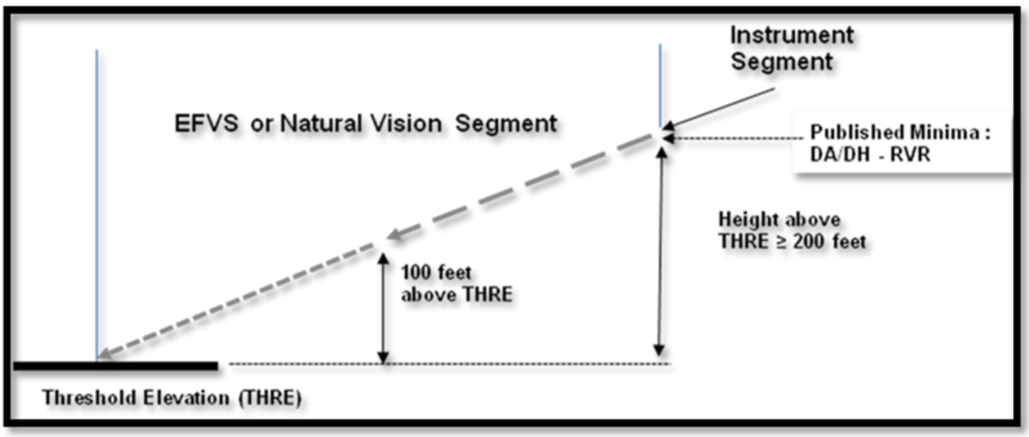

Figure 2: EFVS Operational Concept

EFVS Maturity:

With respect to EFVS technologies supporting the AAL2 advanced operation, they are either already certified (HUD) or have been certified during the AAL2 timeframe (HWD).

With respect to the advanced EFVS operation, AAL1 demonstrated through 60 FFS test cases in normal and abnormal conditions and few flights in partial environment that the EFVS to land operation using HUD is safe and feasible (TRL7).

Advanced EFVS systems were ready for full demonstration in complete ATM operational environment through AAL2 timeframe.

The Figure 3 below depicts EFVS Technology, including the Dassault-Aviation Dual Head Up Display-CVS and ATR's Head Wearable Display.

Figure 3: EFVS Technology: Dassault-Aviation Dual HUD-CVS (left), ATR's Head Wearable Display (right)

Per EASA OPS Applicable regulation (Commission Regulation –EU- No 965/2012), EVS allows to perform landing with an OPS credit of 30% and with an RVR as low as 350m. Natural vision is required at 100 ft HAT.

EFVS-L has been first introduced in EASA NPA 2018-06 published in July 2018 as a result of the RMT0379 activity related to All Weather Operations and taking into account AAL1 results. Compared to applicable EVS operation, EFVS-L allows to perform landing with OPS credit in RVR as low as 300m and without the need for transition to natural vision. As part of major improvement, and in consistency with the NPA AWO cross domain philosophy, NPA 2018-06 adds guidance materials to deal with declaration of suitability of the aerodrome for that operation. NPA 2018-06 is still under CRD process. According to EPAS 2020-2023, the Opinion is expected Q2 this year and European commission Decision Q3 2022.

3.1 Very Large Demonstration Purpose

The consortium comprises all relevant stakeholders, including Airspace users, ANSPs, and industry with airport operators supporting the project. The demonstrations were held at variety of airports in Europe and US, from small airports to large hubs.

The demonstrations were held at 4 European airports:

- 3 Medium/Small sized airports in France, Germany, and Belgium: Antwerp, Périgueux and Bremen;
- 1 large hub: Frankfurt.

The project provides all technical means for executing the envisaged flights, both for the ground based and for the airborne avionics, but also for the landing procedures and certifications needed. Here is what the consortium has catered:

- Airports with available GBAS stations for the project use: Bremen, Frankfurt
- Different type of aircraft: B747-8, B737 NG, F7X or F8X (experimental), Embraer 170 (experimental), ATR -600 series (experimental), Airbus A319, A320, A321;
- Aircraft with EFVS avionics: Dassault Falcon 7X or 8X experimental, ATR's ATR 600 experimental.
- Aircraft with GBAS avionics: Lufthansa B747-8, Ryanair B737 NG, Airbus A319, A320, A321.

This demonstrations project comprised a series of live flights, including both, mainline, regional and business aviation, in revenue/commercial flights using Lufthansa's Boeing 747-8, Ryanair's Boeing 737 NG, Lufthansa's Airbus A319, A320, A321 as well as in experimental flights including Dassault Falcon 7X or 8X and ATR-600 series.

Figure 4: Lufthansa B747-8 aircraft

Figure 5: Ryanair Boeing 737 NG

Figure 6: Lufthansa A320 family aircraft

Figure 7: ATR-600 series experimental aircraft

Figure 8: Dassault experimental Falcon 8X

The demonstrations project covered a range of GBAS and SBAS procedures and utilize flight deck-vision systems such as Enhanced Flight Vision System (EFVS) in order to improve access in degraded weather conditions. The project planned to fly the demonstrations down to CAT II equivalent minima with the focus on lowering decision height by extending either the instrument segment (WP2 GBAS) or the visual segment (WP3 – EFVS). The practice GLS CAT II Autoland approaches were included into the demonstration.

Concerning WP2, a data was collected during all the flights, ranging from pilot/crew/ATC questionnaires, as well as performance data that could be translated to fuel burnt and efficiency or feasibility of the operation.

With respect to WP3, a high level of significance was reached through the involvement of all the relevant ATM/ ADR stakeholders (Airspace users, ANSPs, industry with the major contribution of airport operators and authorities) who permitted the execution of the demo in full operational environment.

The project covered the full demonstration cycle, including this demonstration plan, design of procedures, approach plates, conduct of demonstrations, processing of relevant collected data, their interpretation as well as production of demonstration report and results dissemination at relevant forums (standardization, working groups and conferences). Technologies, prototypes were upgraded as needed in preparation for demonstrations. Aerodrome were checked to be capable of these low visibility operations and procedures were possibly adapted as needed for different technologies. The ATC personnel were properly trained for the demonstrations. Data were collected during live trials, analysed and demonstration report was provided based on the results, including recommendations on next steps, standardization, and further regulations. Communication activities were viewed as very important and comprised of leaflets, AAL2 project website and various dissemination events.

3.2 SESAR Solution(s) addressed by VLD

This project supports or complements following SESAR solutions:

Relation to SESAR Solution 55: Precision approaches using GBAS Category II/III.

WP2 focused on GLS CAT II operation that leverages current certified GBAS CAT I airborne equipment and enhanced GBAS GAST-C (CAT I capable) ground station to demonstrate GLS CAT II operations (with decision height of 100 ft) in the European environment using EGNOS, extending the benefits to the operators, as well as airports. The demonstrations intended to further support and speed up the deployment toward full GBAS CAT II/III operations.

WP2 solution of GLS CAT II approach operation aims at improving Low Visibility Operation using GBAS GAST-C/CAT I ground and airborne equipment on single frequency signals. The main benefit is the increased runway capacity in poor weather conditions as the glide path and azimuth signals will face hardly any interference from previous landing aircraft or other obstacles. More sustained accuracy in aircraft guidance on final approach. The GBAS (Ground Based Augmentation System) is a precision approach system relying on GNSS signals and composed of ground and airborne segments. GBAS supports enhanced level of service for approach phase. Enhanced GBAS GAST-C/CAT I ground station capability based on L1 single frequency signals is the outcome of the work done for GBAS CAT I outside SESAR for WAAS and the extended for EGNOS in frame of SESAR VLD - AAL2 project including airborne safety impact assessment of using enhanced GAST-C/CAT I station for GLS CAT II operation. The solution is based on the existing single frequency signals and is considered as step towards using wide usage of GBAS as primary means for navigation for precision approach in low visibility conduction.

The enhanced GBAS GAST-C/CAT I ground system and GBAS CAT I system should enable Automatic Approach and Landing down to CAT II for Mainline Aircraft and Automatic Approach and Landing down to CAT II minima for Business and Regional Aircraft with DH ≥ 100 & 300 m < RVR < 550m.

Relation to SESAR Solution 09: Enhanced terminal operations with RNP transition to ILS/GLS.

All project technical work packages support solutions that are compatible with the RNP to xLS concept. AAL2 Work package 2 delivers RNP to GLS procedures with last RF legs that are compatible with CDO technique. Project is not fully addressing the Solution 09 but rather demonstrates complementarity in the sense of curved approaches benefits such as CDO.

Relation to SESAR Solution 117: Reducing landing minima in low visibility conditions using enhanced Flight vision systems (EFVS).

Work package 3 EFVS is related to SESAR new Solution as will be described in draft contextual note and supplementing solution 117: “Reducing landing minima in low visibility conditions using enhanced Flight vision systems (EFVS)”. See deviation section here below.

SESAR 1 Solutions are summarized in Table 3. Only applicable airborne and ground enablers of Solution 55, or their elements, applicable for GBAS CAT II operation demonstration using GBAS CAT I equipment, are provided. Differences to the SESAR solutions are addressed in Chapter 3.2.1.

SESAR Solution ID and Title	SESAR Solution Description	OI Steps ref. (coming from EATMA)	Enablers ref. (coming from EATMA)

SESAR Solution 55	This SESAR Solution aims at improving Low Visibility Operation using GLS Cat II/III based on GPS L1 The main benefit is the increased runway capacity in poor weather conditions as the glide path and azimuth signals will face hardly any interference from previous landing aircraft or other obstacles. More sustained accuracy in aircraft guidance on final approach. The GBAS (Ground Based Augmentation System) is a precision approach system relying on GNSS signals and composed of ground and airborne segments. GBAS supports enhanced level of service for all phases of approach, landing and departure.	AO-0505-A	A/C-56a (BTNAV-0307) CTE-N07
SESAR Solution 09	RNP advanced transitions with curved procedures connecting directly to the final approach provide improved access in obstacle rich environments and reduce environmental impact.	AOM-0605	A/C-07
Solution 117	Reducing landing minima in low-visibility conditions using enhanced flight vision systems (EFVS)" enhances the pilot's visual field by displaying in a head-up display (HUD) with the most important flight information in real-time. With this technology, pilots have an augmented view of the what is up ahead and	AUO-0403	A/C-22

	can prepare for landing even in degraded weather conditions		

Table 3: Related SESAR Solution(s) and OIs connected with enablers used in demonstration flights

3.2.1 Deviations with respect to the SESAR Solution(s) definition

Compared to full scope of SESAR Solution 55 (GLS CAT II/III based on L1), technical scope of Work Package 2 solution focused on the demonstration of GLS CAT II Autoland approach using the flight management and guidance for GBAS precision approach currently available on mainline aircraft and enhanced GBAS GAST-C ground station, without the need to upgrade and comply with all airborne and ground station elements required for GAST-D operations under Solution 55. Only MOPS for GBAS receiver (BTNAV-0307) of A/C 56a enabler and CTE-N07 – in navigation system aspects limited to GBAS GAST-C (GPS L1) ground station with necessary standards and specification (e.g. BTNAV-0306 - MOPS for GBAS Cat I Ground Sub-System (ED-114A), STD-024 - DO-253D MOPS on GBAS Receiver) for GLS CAT II are needed. STD-023 - MOPS on GPS/GALILEO + multi-constellation, multi-frequency SBAS is not needed.

In flight demonstration, Work Package 2 focused on practice GLS CAT II Autoland approach demonstration on the way towards full GBAS CAT II approval that didn't require to have CAT II approach procedure and ATC tools and procedures update to GLS CAT I, although all three elements were prepared as a part of flight demonstration preparation activities.

Work Package 2 demonstrations complemented the SESAR Solution 09 (Enhanced terminal operations with RNP transition to ILS/GLS) in evaluation of procedures continuous descent characteristic as one of parameters targeted by Solution 09 for the design of RNP to GLS approaches. The RNP to GLS approaches were designed with RF legs optimized for CDO connected to intermediate fix, however, compared to the RF legs connected to final approach fix under Solution 09, manual transition instead of automatic was applied. However, approach was valuable in a sense that transition was followed by both manual landings and also one Autoland, and both flight accuracy and pilot feasibility were assessed in demonstrations.

As mentioned above, the WP2 focused on demonstration of enhanced GBAS ground GAST-C system capability and current airborne GAST-C capability to support GLS CAT II operation. As the scope of demonstration was not exactly matching Solution #55, in some instances for example, built on new enhanced capabilities not available in current Solution definition, upon agreement with SJU before DEMR delivery, and by considering criteria to establish new solution and technical achievements of the AAL2 project as well as work done before and outside SESAR project, the EXE-VLD-V4-100 provides new SESAR Solution of Enhanced GBAS GAST-C to support GLS CAT II operation.

Work package 3 EFVS is related to SESAR new Solution as will be described in draft contextual note and supplementing solution 117: "Reducing landing minima in low visibility conditions using enhanced Flight vision systems (EFVS)".

Solution 117 focuses on EVS 100ft operation as defined per EU No 965/2012 (2008) and addressed as EFVS-A in the future AWO regulation resulting from EASA NPA AWO 2018-06 (published 15th of July 2018). This solution relies on AUO 403 *"Reducing Landing Minima in Low Visibility Conditions using Enhanced Flight Vision Systems –IR-"*and is supported A/C 22 "*Enhanced Flight Vision System (EFVS)*". It applies to IR and Visual based EVS technologies. Deployment of that operation is in progress. No guidance materials for ground segments being available in the applicable regulation, only few air operators have been approved by their national Authorities after long and heavy individual process.

AAL2 WP3 activities aim at proposing recommendations for supporting drafting of such guidance material in the AWO regulation.

New Solution needs to be created to address EFVS-L operation that will be introduced in the new AWO regulation resulting from EASA NPA AWO 2018-06. This solution will be supported by a new AUO to be created to reflect the fact the solution applies to IR and Visual based technology only.

According to *EASA European Plan for Aviation Safety 2019-2023*, the EFVS-L regulation is expected Q2 2022. Therefore, initial operational capability (IOC) is targeted in 2023.

3.3 Contribution to PCP

Project supports SESAR solution 09 by demonstrating optimized continuous descent operation with use of RNP and RF legs design at RNP to GLS approaches.

3.4 Summary of Demonstration Plan

3.4.1 Demonstration Plan Purpose

Plan is detailed in Demonstration Plan 01.01.00 [57] in section 5. The project focuses on demonstration of the GBAS system extension to GLS CAT II operation while taking use of the currently deployed CAT I airborne and GAST-C ground equipment, as well as its connection to RNP with RF (radius-to-fix) legs to CAT I/II minima. On its way, project flight demonstration of practice GLS CAT II Autoland approaches was executed. The project addresses the application of Enhanced Flight Vision System (EFVS) to land using Head Up or Head Wearable Display in reduced visibility conditions in non-CAT II/III airports.

This project aimed to demonstrate the operational and technical scope of demonstration exercise and objectives through the comprehensive availability of all stakeholders in the consortium, and by setting up revenue demonstration flights in such variety of operational conditions that the obtained results will be appealing, relevant, and applicable for the majority of the European airports and airspace users.

The participants to the project (either consortium member or interested parties) were:

- 5 small/medium sized airports: Antwerp, Le Bourget, Payerne, Périgueux and Bremen
- 1 large airport: Frankfurt
- 6 Airspace Users: HOP!, EBAA, Lufthansa Group, Ryanair, Flying Group and Zurich Insurance
- 4 ANSPs: skeyes, DFS, DSNA, skyguide
- 3 airframe manufacturers: Airbus, ATR, Dassault-Aviation

- avionics manufacturer: Honeywell,
- 8 regulatory bodies: BAF (German CAA), BCAA (Belgium CAA), DSAC (French CAA), EASA, FOCA (Swiss CAA), BSA (Belgian Supervisory Authority), IAA (Irish CAA), LBA (German CAA)
- 2 European or Intergovernmental organizations: EASA and EUROCONTROL
- 1 Instrument Flight Procedure Expert: DLR.

3.4.2 Operating Method Description

Operating method on both technical work packages WP2 and WP3 is captured in the sections 3.4.2.1 WP2 - GBAS CAT II Advanced Operations and in 3.4.2.2 WP3 – EFVS Advanced Operations.

3.4.2.1 WP2 - GBAS CAT II Advanced Operations

Operating method description of GBAS CAT II operation under AAL2 demonstration is provided here bellow as a part of DFS implemented CONOPS for GBAS precision approach operation down to 100ft minimum decision height in Bremen and airlines operating procedures on Airbus and Boeing aircraft taking part in flight demonstrations. Practice GLS CAT II Autoland approach operating procedure used in flight demonstrations is provided in this section as well.

3.4.2.1.1 GLS CAT II Approach - Air Crew

Airbus aircraft:

Standard operating procedures should be used for GBAS CAT II demonstration. In the Airbus cockpit, the GLS is displayed on the PFD like an ILS, that means the known indications for LOC and GS deviations are shown. The general philosophy of GLS Approaches compared to ILS Approaches is the analogy of both systems for the pilots. There should be the similar indications in the PFDs FMA. If the GLS approach is selected in the FMGC, the GLS channel is tuned by the MMR instead of the stored ILS frequency on the RADNAV page.

The deviations are exactly analogous to the ILS approach. A GLS approach is an angular ("funnel-shaped") approach, that means the LOC and GS deviations, like the ILS, represent an angular deviation. Callouts and limitations according to OM-A and OM-B are identical to the ILS in the GLS approach.

All third-generation aircraft have a "LS" pushbutton on the EFIS Control Panel (formerly: "ILS"), they could basically be equipped for ILS, GLS and MLS approaches.

Normally, pilot will follow a decelerated approach pattern that in general support noise, fuel and CO2 emissions decrease compared to an early stabilized approach. Real A/C configuration setting can be influenced by actual traffic situation on every approach.

Boeing aircraft:

Standard operating procedures should be used for GBAS CAT II demonstration. In the cockpit, the GLS is displayed on the PFD exactly as an ILS. That means the known indications for LOC and GS deviations are shown. The deviations are analogous to the ILS approach. A GLS approach is an angular ("funnel-shaped") approach, that means the LOC and GS deviations, like the ILS, represent an angular deviation.

On Boeing 747-8 aircraft, the GLS approach is selected in the FMC, the GLS channel is tuned to the NAV RAD page instead of the stored ILS frequency. In contrast to the RNAV Approach, there is no need for any additional preparation for a GLS approach.

As an Approach Reference, the number of the GLS channel or the GLS identifier is displayed in the top line of the GLS Approach. That is the direct comparison to the display of an ILS.

The middle row contains RWY identifier as reference for the following value, the GLS Distance to RWY threshold.

The Approach is being armed in AFDS just like the ILS with the APP pushbutton. It is flown like an ILS.

Callouts and limitations according to OM-A and OM-B are identical to the ILS in the GLS approach.

For the ILS Approach, the reference would be the DME, followed by the value of the DME. Procedure and techniques are identical to those of an ILS. However, practical benefit of steadier and smoother approaches is expected on GLS approach compared to ILS.

On Boeing 737NG aircraft the GLS is selected in the FMC, the 5-digit channel number is tuned in the Multi-Mode Navigation Control (MMNC) and selected active. FMA annunciation and deviations indication for GLS will be identical to ILS. The Approach is armed in AFDS just like the ILS with the APP pushbutton. It is flown like an ILS. Callouts and limitations according to OM-A and OM-B are identical to the ILS in the GLS approach.

No new pilot training is needed to fly GLS CAT II on GAST-C.

3.4.2.1.2 GLS CAT II Approach - Aerodrome and ATC

3.4.2.1.2.1 ATC Tools, Interface, and Service Level Verification

AAL2 introduces mixed GLS and ILS operations under low visibility conditions at Bremen airport. Implementation of the new CAT II GBAS operation required changes on ATC side. ATC user interface in Bremen was updated to provide ATCOs in Tower and Approach Control information about the actual GBAS service available per runway end.

The DFS system for displaying the GBAS status information in the tower is called IDVS. The next figures illustrate the different GBAS status in IDVS. The green squares on the runway indicate the available approach service performance. Figure 9 shows that runway 09 is in use and CAT II is selected for both ILS (left side) and GLS (centre of runway). Figure 10 shows a situation where the GBAS is downgraded to CAT I.

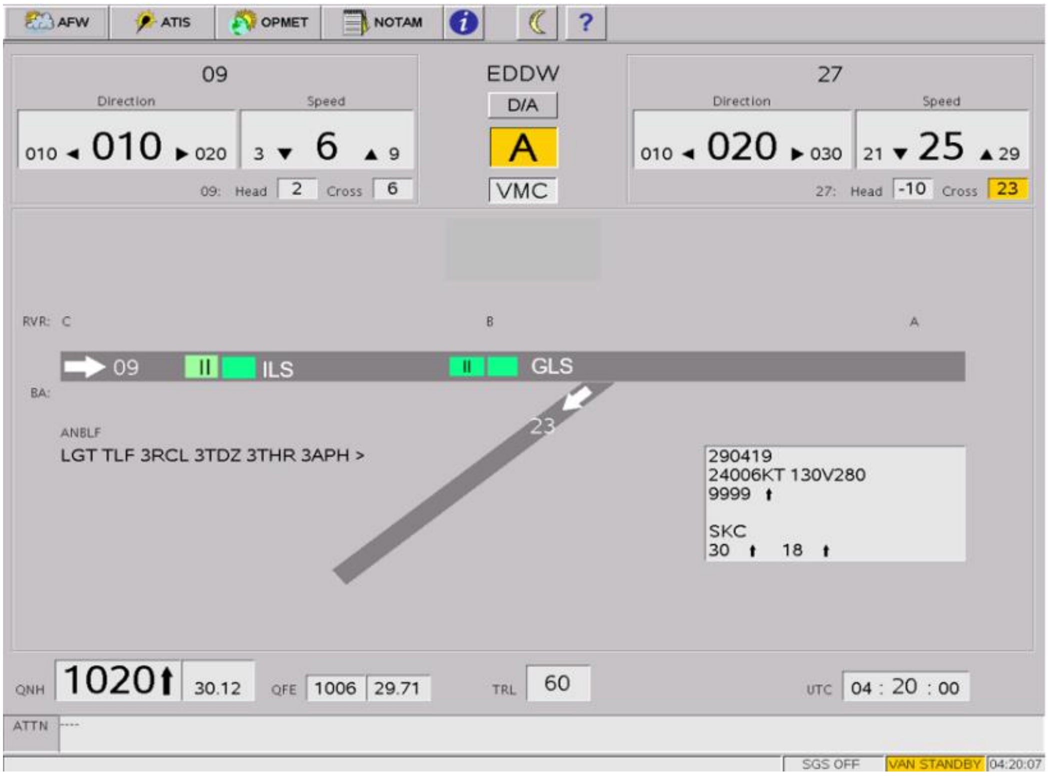

Figure 9: IDVS, CAT II Operation

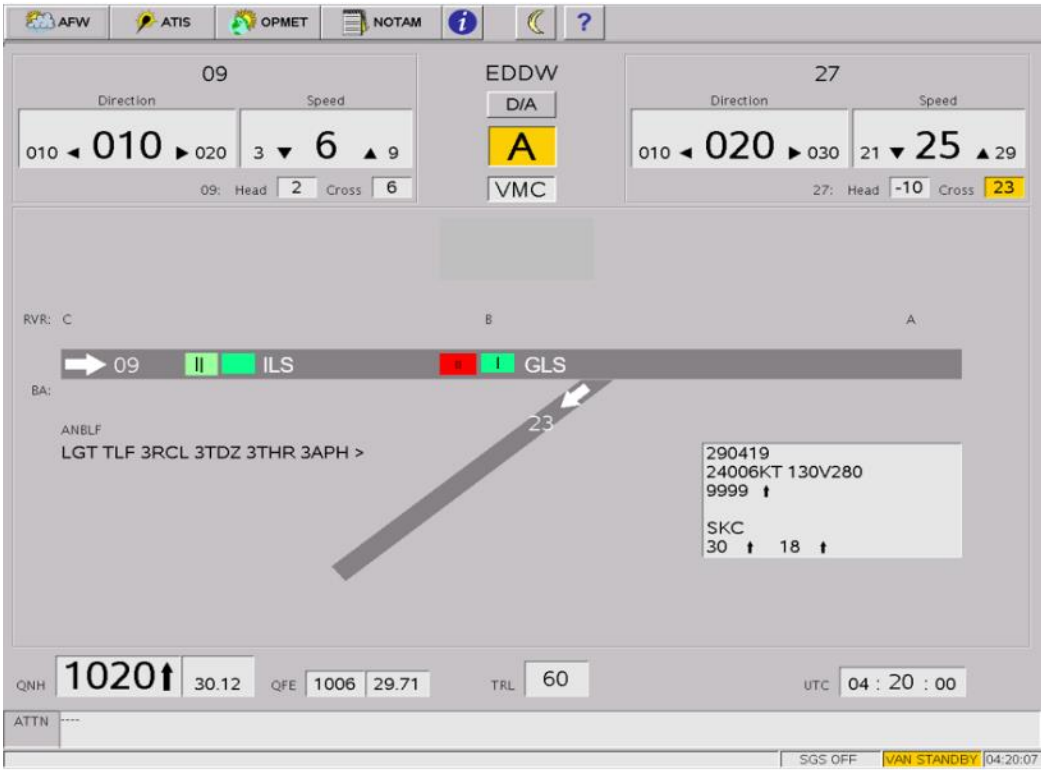

Figure 10: IDVS, CAT II Operation – GLS downgraded

IDVS is the ATC status display in the Tower. Approach Control uses the system ATCISS with similar GBAS status display.

During low visibility conditions the ATCO gives the pilot a clearance for a GLS approach once the ATCO verifies acceptable "Service Level" for GBAS operation for CAT II precision approach operation down to 100 ft (Figure 9).

If the Service Level changes after clearance given (Figure 10), the aircraft can complete the approach. No further CAT II clearances would be granted until Service Level supports CAT II operation again. Nevertheless, a CAT I operation will further be granted if available.

3.4.2.1.2.2 ATCO Operating Procedures GLS CAT I at Bremen airport

The following sections describe the actual controller working procedures for GLS operations at Bremen airport.

1. The obligation for separation between aircrafts remains unchanged.

2. In case an aircraft is for any reasons not able to incept the GLS final approach by following a standard procedure the Approach Controller shall provide an adequate vectoring for such an intercept.

   In order to ensure that an aircraft has received all approach messages from the GBAS Station a period of 12 second must be applied after clearance to intercept final approach has been granted and the aircraft actually is intercepting the final approach.

If the complete standard procedures are not flown the pilot must be informed about 'Approach Type' and 'Runway in Use' before or at the beginning of vectoring.

3. In case of GPS or GBAS failure, alternative approach procedures shall be cleared.

4. If a GPS or GBAS failure occurs during final approach, the aircraft shall commence a missed approach or, if possible, continue visually.

   Aircraft being on the RNAV initial or intermediate segment of a GLS procedure may in case of a GBAS failure continue and change to an RNP approach. If there is a GPS failure, all aircraft must use a conventional approach procedure.

5. It is a special circumstance if the GBAS fails between NOTAM briefing and arrival in the TMA. Thus, every GBAS outage must be announce on the ATIS.

6. All GBAS related topics shall be considered within a local regulation documentation. Specific roles, processes and responsibilities shall be addressed. In addition, all aspects to integrate GLS procedures shall be considered.

7. Mixed Mode Operations for ILS and GLS to the same runway end are allowed. The Approach Controller shall inform the Tower Controller about the cleared approach type. This information is essential for the Tower Controller in case of NAVAID failures or aircraft commencing a Missed Approach.

   Detailed handover procedures between Tower and Approach units shall be documented in the local operating procedures.

   Additional ATCO training for GLS CAT II on GAST-C is needed, however no new license is required.

3.4.2.1.2.3 ACTO Operating Procedures GLS CAT II at Bremen airport

Some of the above mentioned GLS CAT I operating procedures are not applicable for GLS CAT II in Bremen:

1. Vectoring as mentioned in 3.4.2.1.2.2 - 2 is only partly applicable for GLS CAT II with RNP/RF-Leg segments. A vectoring to the waypoint at the beginning of a RF-Leg is not allowed because in this case the RF-Leg and the final approach may not be flown correct. If an aircraft is vectored direct to the extended final approach (not using the RNP/RF-Leg portion) it must be assured that it is established before the intermediate fix (IF).

2. An approach type change to ILS shall only be cleared if no other alternate procedure is available.

3. A downgrade of the GBAS service from CAT II to CAT I does not imply a rapid degradation (increase of horizontal and vertical error) of the GBAS service. Thus, a cleared GLS CAT II approach may continue to land if the aircraft has passed the Final Approach Point (FAP) at the time the downgrade occurs. If the aircraft has not passed the FAP the clearance shall be withdrawn.

3.4.2.1.2.4 Similarities between GLS CAT II and ILS CAT II

GLS CAT II shall be used in analogy to ILS CAT II in the following fields:

a. ATIS

b. Low Visibility Operations

c. Switching of Runway Lightings

CAT II/III Holding Positions are not applicable for GBAS only flight operations. For Mixed Mode (ILS/GLS) CAT II/III Holding Positions must be considered.

3.4.2.1.2.5 GBAS Service Level Downgrade

A downgrade of the GBAS station to 'Service Level A' or CAT I can be caused by following conditions:

- The satellite constellation is not sufficient to support CAT II.
- The actual vertical error caused by the ionosphere exceeds a certain level.
- A technical malfunction of the GBAS station.

All the above-mentioned conditions have only a small probability of occurrence, nevertheless the downgrade situation must be displayed to the ATCOs.

3.4.2.1.2.6 Procedure Design

The existing GLS CAT I, including missed approach, could be re-used for the AAL2 GLS CAT II demonstrations. However, as the missed approach begins at a lower altitude, the obstacle clearance has been assessed once again.

The initial and intermediate approach segments have been designed as RNP1 routes with RF-Legs. This design allows a short final approach and an overall shorter procedure path. The intermediate segment has the same track than the final segment and is long enough to ensure a smooth transition to final approach. The requirements of ICAO Doc 8168 have been considered.

In case of a system failure (e.g. GPS outage) the RNP1 routes are also available with an ILS (CAT I/II/III) final segment.

If several aircrafts use different RNP to xLS routes simultaneously, it may not easy for the ATCO to estimate the sequence and separation the aircrafts will have on final approach. Thus, it is mandatory to implement distance markers with a 6NM spacing on the radar screen.

3.4.2.1.2.7 Procedure Publication

The publication of GLS CAT II procedures is similar to GLS CAT I. The only difference is an additional line for the CAT II minimum.

The requirement for a continuous descent beginning at IAF is published as a shaded block and described in a text box on the charts.

As xLS is not a known terminology to onboard systems like FMS the procedures have to be published separately as GLS and ILS procedures.

3.4.2.1.3 Practice GLS CAT II Approach

Flight demonstration covered practice GLS CAT II Autoland which allowed to focus primarily on airborne aspects same as demonstration objectives (pilot feasibility and flight accuracy). The description of method applied for practice GLS CAT II approach is provided bellow. Demonstrations build on current GLS CAT I Autoland capability, published GLS procedures and ATC method for operations down to CAT I.

Rational - Aircraft:

There is technically no difference in conducting GLS CAT I Autoland operations for the aircraft systems compared to a GLS CAT II Autoland. Only the certification criteria would be different. As airlines Operations Manual – Part A (OM-A) does not foresee an automatic landing so far under CAT I conditions, based on risk assessment a practice GLS CAT II Autoland was possible to conduct on the GLS CAT I Autoland baseline by using current airlines SOP. Also, approaches were only done in highly protected environment (e.g. minimum visibility and ceiling much above CAT I minimums, dedicated crew members).

From the cockpit procedure for practice GLS CAT II perspective airlines insert in the FMS in the field „DH“ (Decision Hight) CAT II minimums of 100 ft and fly IMC down to CAT I minimums in better than CAT I conditions and then continue with practice CAT II approach while using the pilot call outs for CAT II in VMC.

Rational – Ground System

Under nominal conditions (generally expected for planned VLD flight demonstration), regardless the used Honeywell’s GBAS ground station service level (Level A or B) the GLS signal and the measured aircraft flight accuracy on the GLS approach doesn't depend on the ground station service level in use (either supporting CAT I or CAT II). Also, as provided above, there is technically no difference in conducting GLS CAT I Autoland operations for the aircraft systems compared to a GLS CAT II Autoland.

Rational - ATC:

The ATC applies standard GLS CAT I approach procedures. Although GBAS Ground Station was upgraded to Block IIS targeting to allow GLS CAT II operation, service was not opened for public flight usage as BAF approval was not obtained during AAL2 preparation phase. Therefore, full GLS CAT II Operating method as described in 3.4.2.1.2 couldn’t be applied during demonstrations.

3.4.2.2 WP3 – EFVS Advanced Operations

This section describes the existing operating method related to CAT 1 instrument approach and landing, then describe the approaches using EFVS with operational credit.

3.4.2.2.1 Approach and Landing (CAT 1)

3.4.2.2.1.1 Standard instrument approach

The standard approach is flown as follows:

- At first contact, the ATC informs the crew of the runway in use (possibly propose an approach type) and pass the latest weather information if the crew does not confirm receiving of the ATIS information. After the crew announced his intentions for the approach, ATC communicate the missed approach procedure.
- The crew selects an approach procedure in accordance with the information communicated by ATC taking into account the aircraft limitations/ performances and crew qualifications.
- Crew establishes appropriate monitoring procedure for the type of approach, landing and missed approach that is in charge.

Down to the DA/ DH, the crew flies the instrument approach procedure using **instruments**. Typical call-outs used for CAT 1 approach monitoring are included.

- No later than 1000ft HAT, the crew checks that the actual RVR is greater than the RVR published for the approach that is flown. Otherwise, the pilot has to abort the approach, as the probability he would have visual cues in sight at DA/ DH would be low. After the go around, the crew will decide to divert or to wait for weather improvement.
- At DA/ DH, required visual references[1] must be in sight and maintained to be authorized to continue the landing.

Below DA/ DH, **visual references seen by natural vision** is used as the primary information to control or monitor (in case autopilot is used) the aircraft trajectory.

During the approach, the ATC monitors the trajectory (using a radar, if available) and communicates by R/T with the crew.

3.4.2.2.1.2 Instrument approach with EFVS operational credit (EFVS to land operation)

The intended function of an EFVS is to provide enhanced visibility allowing to start an approach and descent below the DA/DH in low visibility conditions it will be not possible otherwise. EFVS operational credit provided by EFVS can be granted on some suitable straight-in instrument approaches in reduced visibility as low as 300m RVR (airworthiness requirement for allowing landing in case of EFVS failure. RVR 300m is the lowest RVR value permitted for CATII and allows performing a safe manual and visual landing). Published DA/H is not changed during EFVs operations.

Compared to standard approach (see Figure 2):

- Although the landing decision is the responsibility of the pilot-in-command, the crew may inform the ATC of his intention to perform an EFVS approach. This way, the ATC will expect the

[1] Element of the Approach lighting system, or Threshold, or TDZE, or VGSI as requested per CAT.OP.MPA.305 of EASA AWO regulation

aircraft will continue the approach and land while weather is below published minima, which is only possible using an EFVS,

- **Down to DA/ DH**, the EFVS approach is flown using the same method as for standard non EFVS approach, except operation is conducted in HUD or HWD and the RVR considered for the check at 1000ft will take credit of visual advantage provided by EFVS (min 30%),
- **At DA/ DH**, the approach can be continued if visual cues are seen in HUD/EFVS or HWD/ EFVS (in lieu of in natural vision) and EFVS is consistent with the other HUD or HWD flight information used for the approach. Go around must be initiated otherwise,
- **Below DA/ DH**, the crew uses **EFVS** image in HUD or HWD in lieu of natural vision to land and perform the rollout. During Flare, prompt or guidance is provided to assist the pilot.

The EFVS to land Operation:

- Can only be conducted on 3D straight in approaches, with offset limited to 3 degrees,
- Requires a minimum RVR of 300m/ 1000ft,
- Provides operational credit as demonstrated in certification. Operational credit is applied to reduce the runway visual range (RVR) by at least one third of the published RVR,
- Requires a HUD or equivalent system such as HWD, an RA, and a flare feature available to the PF,
- Requires an EVS image is displayed to the PF and to the PM.

Historically only EFVS Operations to 100 Feet above the TDZE were permitted by EU 965/2012 (EASA) and 14-CFR §91.175 (FAA). Since December 2016, EFVS Operations to Touchdown and Rollout are also allowed by FAA through 14-CFR §91.176[2]. Same kind of operation (EFVS-L) is being to be introduced in the new EASA AWO regulation (NPA216/2008) expected to be published Q4 2018. EFVS to land operation was demonstrated for the first time by Dassault in Europe in SESAR LSD02.02 (AAL) using a Dual HUD display/ CVS configuration/ multispectral IR sensor based.

In the frame of AAL2 and as part of the aerodrome preparation (see Appendix C), safety assessment will be conducted for continuation of the approach below minima, go around below minima and EFVS operation during LVO.

Comparison with AAL

	AAL	AAL2

[2] Supported by AC 20-167A and AC 90-106A guidance materials

Operation	EFVS to Land (EFVS-L)	EFVS to land (EFVS-L)
ADR preparation	Based on French aerodrome regulation Perigueux and Bergerac	Based on EASA NPA AWO 2018-06 Le Bourget; Antwerp
Pioneer demos	Out of Low Vis, in Périgueux and Bergerac	In Low Vis, In Antwerp
Involvement of NAA	No	Yes
Participation of Air operator in Flight	No	Yes
Feasibility of EFVS-L	In FFS: in normal and abnormal conditions	In flight in normal conditions
Achievements	Recommendation for EASA NPA 2018-06	Deployment of EFVS-L at some pioneer aerodromes. Experimental approval issued by NAA for Antwerp and Le Bourget Production of a guide for supporting deployment at some other aerodromes

3.4.3 Summary of Demonstration Objectives and Success Criteria

This section provides overview of demonstration CTQs. Tables below presents Work Package 2 and Work Package 3 demonstration CTQs per KPAs and KPIs. These are followed by detailed demonstration objectives definition and criterions tables.

KPA	KPI	CTQ definition	Where & how	CTQ value	Who
Safety	Horizontal flight accuracy (RNP to GLS)	Horizontal FTE is within CTQ limit	Bremen	Within 0.5 NM	Lufthansa, Ryanair
	Vertical flight accuracy (RNP to GLS)	Vertical FTE is within CTQ limit	Bremen	No descend below FAP constraint - 100ft	Lufthansa, Ryanair

	Lateral flight accuracy of practice GLS CAT II Autoland during final approach	Lateral FTE is within CTQ limit	Bremen, Frankfurt	1 dot	Lufthansa, Ryanair
	Vertical flight accuracy of practice GLS CAT II Autoland during final approach	Vertical FTE is within CTQ limit	Bremen, Frankfurt	1 dot	Lufthansa, Ryanair
Fuel/ Environment Efficiency	Average fuel burned per approach set (GBAS compared to ILS)	Decreased fuel consumption for GBAS approaches compared to legacy ILS thanks to more stable signal	Frankfurt – revenue flights	By at least 3%	Lufthansa, DLR
	CO_2 emission per approach (GBAS compared to ILS)	Decreased CO_2 emissions for GBAS approach compared to legacy ILS thanks to more stable signal.		By at least 3%	Lufthansa, DLR
Human Performance	Perceived level of feasibility – pilots (RNP to GLS)	RNP to GLS approaches are feasible based on feedback form pilots	Bremen - pilot questionnaires (revenue flights)	YES,	
	Perceived level of feasibility – pilots (practice GLS CAT II Autoland)	Practice GLS CAT II Autoland approaches are feasible based on feedback form pilots	Bremen, Frankfurt pilot questionnaires (revenue flights)	>95% appr. successful	Lufthansa, Ryanair
Cost efficiency	Cost efficiency of GLS CAT II approaches on GBAS CAT I equipment	Cost efficiency of GLS CAT II approaches on GBAS CAT I equipment	Study	YES, Qualitative outputs	DFS, Lufthansa, Ryanair

Table 4: Overview of demonstration targets for WP2 – EXE-VLD-V1-100

Work Package 3 – EFVS to land demonstration CTQs per KPAs and KPIs are provided in the bellow.

KPA	KPI	CTQ definition	Where & how	CTQ value	Who
Safety	Horizontal Flight accuracy (EFVS	Horizontal TSE for EFVS approaches is within CTQ limit.	Antwerp, Périgueux, Le Bourget and Payerne airports - experimental flights	within 1 dot	Dassault and ATR
	Vertical Flight accuracy (EFVS)	Vertical TSE for EFVS approaches is within CTQ limit.	Antwerp, Périgueux, Le Bourget and Payerne airports - experimental flights	within 1 dot	Dassault and ATR
	Successful touchdown (EFVS)	Touchdown footprint for EFVS approaches is within CTQ limit.	Antwerp, Périgueux, Le Bourget and Payerne airports - experimental flights	in touchdown zone	Dassault and ATR
	Crew and ATC workload during EFVS operation remains acceptable.	Crew and ATC workload are within CTQ limit.	Antwerp, Périgueux, Le Bourget and Payerne airports - experimental flights & questionnaires	7/10 on Adapted Cooper Harper Scale	Dassault and ATR (crew)
					ATC skeyes, skyguide, DSNA
	Significant visual advantage with EFVS.	Visual advantage compare to natural vision is greater than CTQ during EFVS approach.	Antwerp, Périgueux, Le Bourget and Payerne airports - experimental flights	1/3 of actual RVR publishes	Dassault and ATR (crew)
Human Performance	Perceived level of feasibility – pilots and ATC (EFVS)	EFVS approaches are feasible based on feedback form from pilots and ATC.	Antwerp, Périgueux, Le Bourget and Payerne airports - experimental flights & questionnaires	7/10 on Likert scale	Dassault and ATR (crew)

					skeyes, skyguide, DSNA (ATCOs)
Airport Capacity	Increased access to secondary airports in low visibility (EFVS)	EFVS operation in RVR as low as 300m (as permitted by regulation) will allow to retain access in CTQ values of observed low visibility conditions.	Antwerp, Périgueux, Le Bourget and Payerne airports - experimental flights	60%	Dassault

Table 5: Overview of demonstration targets for WP3 - EXE-VLD-V1-200

Individual demonstration objectives are provided further following the template with performance ambitions and their success criteria listed in the following sections: WP2 and WP3 demonstration objectives.

3.4.3.1 WP2 Demonstration Objectives

[OBJ]

Identifier	OBJ-VLD-V4-011
Objective	To demonstrate feasibility of RNP to GLS approaches
Title	Feasibility of RNP to GLS approaches
Category	<human performance>
Key environment conditions	Nominal conditions, Medium complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#55
<COVERS>	<Sub-Operating Environment>	APT - Small

[OBJ Suc]

Identifier	Success Criterion

CRT-VLD-V4-011-001	RNP to GLS approaches are perceived feasible by pilot at 95% of successful approaches

[OBJ]

Identifier	OBJ-VLD-V4-012
Objective	To demonstrate feasibility of GLS CAT II approaches with GBAS CAT I airborne and ground equipment
Title	Feasibility of GLS CAT II approaches
Category	<human performance>
Key environment conditions	Nominal conditions, Medium complex TMA, High complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#55
<COVERS>	<Sub-Operating Environment>	APT - Very large, Small

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-012-001	GLS CAT II approaches are perceived feasible by pilot at 95% of successful approaches

[OBJ]

Identifier	OBJ-VLD-V4-014
Objective	To demonstrate feasibility of practice GLS CAT II Autoland approaches with GBAS CAT I airborne and ground equipment
Title	Feasibility of practice GLS CAT II Autoland approaches
Category	<human performance>
Key environment conditions	Nominal conditions, Medium complex TMA, High complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#55
<COVERS>	<Sub-Operating Environment>	APT - Very large, Small

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-014-001	Practice GLS CAT II approaches are perceived feasible by pilot at 95% of successful approaches

[OBJ]

Identifier	OBJ-VLD-V4-021
Objective	To demonstrate horizontal and vertical path accuracy of RNP to GLS approaches
Title	Accuracy of RNP to GLS approaches
Category	<safety>
Key environment conditions	Nominal conditions, Medium complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#55
<COVERS>	<Sub-Operating Environment>	APT - Small

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-021-001	Horizontal FTE of GBAS approaches is within 0.5NM
CRT-VLD-V4-021-002	Vertical path does not breach FAP constraint minus 100 ft limit

[OBJ]

Identifier	OBJ-VLD-V4-028
Objective	To demonstrate lateral and vertical path accuracy of practice GLS CAT II Autoland approach with GBAS CAT I airborne and ground equipment
Title	Accuracy of practice GLS CAT II Autoland approach
Category	<safety>
Key environment conditions	Nominal conditions, Medium complex TMA, High complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#55
<COVERS>	<Sub-Operating Environment>	APT – Very large, Small

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-021-001	Lateral FTE of GLS approach is within 1 dot
CRT-VLD-V4-021-002	Vertical FTE of GLS approach is within 1 dot

[OBJ]

Identifier	OBJ-VLD-V4-022
Objective	To demonstrate fuel efficiency benefits of GLS approach compared to legacy ILS
Title	Fuel efficiency of GLS approach compared to legacy ILS
Category	<environment/fuel efficiency>
Key environment conditions	Nominal conditions, High complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#55
<COVERS>	<Sub-Operating Environment>	APT - Very large

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-022-001	Fuel burnt on GLS approach is decreased compared to legacy ILS by at least 3%

[OBJ]

Identifier	OBJ-VLD-V4-023
Objective	To demonstrate environment benefits of GLS approach compared to legacy ILS
Title	Environment efficiency of GLS approach compared to legacy ILS
Category	<environment/fuel efficiency>
Key environment conditions	Nominal conditions, High complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#55
<COVERS>	<Sub-Operating Environment>	APT - Very large

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-023-001	CO_2 emissions on GLS approach are decreased compared to legacy ILS by at least 3%

[OBJ]

Identifier	OBJ-VLD-V4-031
Objective	To demonstrate cost efficiency of GLS CAT II approaches using GBAS CAT I equipment
Title	Cost efficiency of GLS CAT II approaches using GBAS CAT I equipment
Category	<cost efficiency>
Key environment conditions	Nominal conditions, Medium complex TMA, High complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#55
<COVERS>	<Sub-Operating Environment>	APT - Very large, Medium, Small

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-031-001	Costs efficiency of GBAS CAT II operation on CAT I equipment demonstrated by flight demonstration and qualitative analysis.

3.4.3.2 WP3 Demonstration Objectives

[OBJ]

Identifier	OBJ-VLD-V4-013
Objective	To demonstrate feasibility of EFVS to land approaches using HUD or HWD equipment
Title	Feasibility of EFVS to land approaches
Category	<human performance>
Key environment conditions	Nominal conditions, Medium complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier

<COVERS>	<SESAR Solution>	#117
<COVERS>	<Sub-Operating Environment>	APT – Medium, Small, Other

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-013-001	EFVS to land approaches are perceived feasible by pilot (≥7/10 on Likert scale)

[OBJ]

Identifier	OBJ-VLD-V4-024
Objective	To demonstrate horizontal and vertical path accuracy of EFVS to land approaches
Title	Accuracy of EFVS to land approaches
Category	<safety>
Key environment conditions	Low complex TMA, Medium complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#117
<COVERS>	<Sub-Operating Environment>	APT – Medium, Small, Other

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-024-001	Horizontal TSE of EFVS to land approach is within 1 dot or equivalent in meters, when relevant
CRT-VLD-V4-024-002	Vertical path of EFVS to land approach is within 1 dot or equivalent in meters, when relevant

[OBJ]

Identifier	OBJ-VLD-V4-025
Objective	To demonstrate the landing performance of EFVS to land approach
Title	Landing performance of EFVS to land
Category	<safety>
Key environment conditions	Low complex TMA, Medium complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#117
<COVERS>	<Sub-Operating Environment>	APT – Medium, Small, Other

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-025-001	Safe landing occurs in touchdown zone area during EFVS to land approach

[OBJ]

Identifier	OBJ-VLD-V4-026
Objective	To demonstrate crew and ATC workload remain acceptable during EFVS to land approach
Title	Crew and ATC workload during EFVS to land approach
Category	<safety>
Key environment conditions	Low complex TMA, Medium complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#117
<COVERS>	<Sub-Operating Environment>	APT – Medium, Small, Other

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-026-001	Crew workload is assessed as less than 7/10 on an adapted cooper harper scale
CRT-VLD-V4-026-002	ATC workload is assessed as less than 7/10 on an adapted cooper harper scale

[OBJ]

Identifier	OBJ-VLD-V4-027
Objective	To demonstrate Visual Advantage provided by EVS during an EFVS to land approach in degraded weather conditions
Title	Visual advantage of an EFVS system
Category	<safety>
Key environment conditions	Low complex TMA, Medium complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#117
<COVERS>	<Sub-Operating Environment>	APT – Medium, Small, Other

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-027-001	Visual Advantage is at least 200m (1/3 of RVR published)

[OBJ]

Identifier	OBJ-VLD-V4-032

Objective	To demonstrate EFVS to land operation will allow to retain traffic at secondary airports in limited weather conditions
Title	Aerodrome accessibility increase using EFVS to land operation
Category	<airport capacity>
Key environment conditions	Low complex TMA, Medium complex TMA

[OBJ Trace]

Relationship	Linked Element Type	Identifier
<COVERS>	<SESAR Solution>	#117
<COVERS>	<Sub-Operating Environment>	APT – Medium, Small, Other

[OBJ Suc]

Identifier	Success Criterion
CRT-VLD-V4-032-001	EFVS to land allows aerodrome to remain accessible in 60% of limited weather situations

3.4.4 Demonstration Assumptions

Following table provides AAL2 demonstration assumptions for GBAS CAT II and EFVS to land demonstrations.

Identifier	Title	Type of Assumption	Description	Justification	Flight Phase	KPA Impacted	Source	Value(s)	Owner	Impact on Assessment
ASS-AAL2-EXE100-1	GBAS CAT II Type Approval	Regulation	The exercise will be conducted assuming that the German regulator will provide Type Approval for GBAS station (GAST C) allowing GLS CAT II operations.	The CAT II operations require unique approval different from the current CAT I approval.	Approach	safety, human performance	Type Approval Requirements	N/A	AAL2	High
ASS-AAL2-EXE100-2	Number of ILS and GLS approaches for comparison study	Approach number	Over 100 ILS and 100 GLS valid approaches needs to be flown on Lufthansa A320 family aircraft to evaluate fuel and environment efficiency	DLR expects 100 valid approaches per approach type as sufficient for evaluation	Approach	fuel and environment efficiency	Expert opinion	200	AAL2	Low
ASS-AAL2-EXE100-3	Using current airborne	Regulation	GBAS CAT II operation will be	Demonstration will show GLS CAT II on	Approach	safety, human performance	Validation objective	N/A	AAL2	High

	GBAS equipment		demonstrated using currently available GBAS airborne equipment	current fleet revenue flights						
ASS-AAL2-EXE100-4	ATC CONOPS	ATC Procedures	The exercise will be conducted assuming ATC CONOPS will be updated	ATC CONOPS needs to be updated to cover GLS CAT II approach operation	Approach	safety, human performance	Regulation	N/A	AAL2	High
ASS-AAL2-EXE100-5	Approach procedures	Regulation	The exercise will be conducted assuming approach procedures will be published or updated till demonstration flight timeframe	New RNP to GLS procedures (Bremen) and GBAS procedures with CAT II minima (Bremen, Newark) need to be available	Approach	safety, human performance	Type of validation	N/A	AAL2	Medium
ASS-AAL2-EXE100-6	Airline aircraft base	Airline operations	Aircraft base in Bremen is considered to fly high number of GLS CAT II Autoland	Number GLS CAT II approaches depend on number of Ryanair aircraft operated to Bremen	Approach	safety, human performance	Airline	N/A	AAL2	Medium
ASS-AAL2-EXE100-7	OPS approval	Regulation	The exercise will be conducted assuming OPS approval will be obtained by Lufthansa from LBA and by Ryanair from IAA	OPS approval needed to fly GBAS CAT II approaches	Approach	safety, human performance	German and Irish Regulator	N/A	AAL2	High

ASS-AAL2-EXE100-8	OP-SPEC approval	Regulation	The exercise will be conducted assuming OP-SPEC approval was obtained by Lufthansa	Approval needed for Lufthansa fly to Newark airport	Approach	safety, human performance	U.S. regulator	N/A	AAL2	Medium
ASS-AAL2-EXE100-9	Airworthiness approval	Regulation	Airworthiness approval will be obtained by Airbus from EASA for A320 family	Need of airworthiness approval for A320 family expected	Approach	safety, human performance	European regulator	N/A	AAL2	Medium
ASS-AAL2-EXE100-10	Airline operational evaluation	Airline rule	Airline internal operational evaluation will allow to fly demonstration flights	Before introduction of new operation, airline conducts internal operational evaluation	Approach	safety, human performance	Airline	N/A	AAL2	Medium
ASS-AAL2-EXE100-10	ANSP FTS	Traffic	ANSP FTS assumed 100% aircraft GBAS equipped for the RWY 25R in EEDF	Comparison of 100% ILS CAT II traffic scenario with GLS CAT II traffic scenario in LVC	Approach	Cost efficiency	Fast Time Simulations	100%	AAL2	Medium
ASS- AAL2-EXE200-1	Test aircraft	Equipment	Availability of Falcon and ATR aircraft for the demonstrations	Aircraft ready and available needed to conduct flight demonstrations	Approach	safety, human performance	Aircraft operator and aircraft manufacturer	N/A	AAL2	Medium scope of demos impacted

AAL2-EXE200-2	Aircraft operator	Aircraft operator	Aircraft operators (Flying group, Zurich Insurance and Hop!) available and properly trained for EFVS demo	Three companies will conduct demonstrations and need to have EFVS training for demo finished before start of demonstrations	Approach	safety, human performance	Aircraft operator and aircraft manufacturer	N/A	AAL2	Medium significance of results of demos impacted
AAL2-EXE200-3	Aerodrome approval	Regulation	Aerodromes approved by national authorities for the restricted use of the AAL2 demo	Aerodrome infrastructure and procedure needs to be adapted for low visibility landing operations, ATC are properly trained, approach and missed approach instrument procedures have been checked as suitable, and aerodrome is available for the demos	Approach	safety, human performance	Aircraft operator and aircraft manufacturer	N/A	AAL2	High (if all aerodromes) Demos not allowed Medium to low if one aerodrome Scope of demos impacted
AAL2-EXE200-4	Weather conditions	Weather	EFVS to land demonstrations will be conducted in poor weather conditions	Poor weather supports representativeness of EFVS demonstrations	Approach	safety, human performance	Aircraft operator and aircraft manufacturer	N/A	AAL2	High if no weather conditions encountered at all. Quality of demos impacted

Table 6: Demonstration Assumptions overview

3.4.5 Demonstration Exercises List

EXE-VLD-V4-100 WP2 GBAS CAT II

GBAS CAT II solution presented in this demonstration provides great advantages to the currently GBAS CAT I equipped airborne users, and also airport operators and ANSPs to further exploit the possibilities of the system and get to 100 ft Decision Height (DH) without having to upgrade to CAT II/III systems. On the way towards GLS CAT II operations, practice GLS CAT II Autoland operations as defined in 3.4.2.1.1 are conducted to demonstrate GBAS Autoland operations. For a number of airports, especially medium size airports, CAT II capability will fully meet their operational needs. This is an important benefit to all operators, and airlines by increasing landing and reducing diversions. Figure 1 shows the GBAS technology with its satellite, air, and ground subsystems, together with a GBAS tower as a part of the ground subsystem.

[EXE]

Identifier	EXE-VLD-V4-100
Title	Demonstration of GLS CAT II approach procedures feasibility and benefits
Description	Flight demonstration of GLS CAT II approaches using CAT I equipment and RNP procedures
Demonstration Technique	<Live Trial>
KPA/TA Addressed	<Safety><Human Performance><Environment/Fuel efficiency><Cost efficiency>
Number of flights	75
Start Date	1/5/2018
End Date	30/06/2020
Demonstration Coordinator	Honeywell
Demonstration Platform	Aircraft
Demonstration Location	Bremen (practice GLS CAT II Autoland + RNP to GLS), Frankfurt (practice GLS CAT II Autoland and data collection for fuel/CO2 evaluation)
Status	Completed
Dependencies	N/A

WP3 EFVS to land

EFVS to land solution presented in this demonstration will provide great advantages to the currently non- CATII/III equipped airborne users, aerodrome operators (including AFIS) and ANSPs to expand accessibility in low visibility conditions. The use of flight-deck vision support systems and EFVS to land operation will secure access to small and regional airports in low visibility conditions, retaining traffic and relieving major hubs that are congested in those conditions, while ensuring connectivity for the population.

EFVS to land operation exploits the capacity of the HUD/ EFVS system to see in advance compare to naked eye in degraded weather conditions and be capable to descent below DA/H using EFVS in lieu of natural vision. This capability, called as operational credit will give a significant operational advantage to all aerodromes (including AFIS) that are not equipped with CATII/III systems and that are limited by degraded weather conditions, causing flight cancellation, go around or diversion to alternate aerodromes.

Depending on the maturity of the technology, EFVS operation is targeted to operate in RVR as low as 300m and covers most of the adverse situations to which business aviation is exposed in day to day operations, as demonstrated in SESAR AAL1.

The EFVS to land operation differs from other standard instrument operations as it allows maintaining an enhanced visual segment in weather comparable to CATII/III conditions, but at far many small medium airports than just at fully equipped HUB airports. The strength of EFVS with operational credit proposed is to take benefit of an advanced aircraft capacity based on technology rather than requiring heavy and costly aerodrome infrastructures that would be not affordable to other than main airports with high traffic density.

[EXE]

Identifier	EXE-VLD-V4-200
Title	Demonstration of EFVS to land operation feasibility and benefits
Description	Flight demonstration of EFVS to land approaches using Head Up Display/ EFVS and Head Wearable Display/EFVS systems
Demonstration Technique	<Live Trial> <Analysis>
KPA/TA Addressed	<Safety><Human Performance><airport capacity>
Number of flights	3 missions
Start Date	02/2018
End Date	12/2019
Demonstration Coordinator	Dassault Aviation
Demonstration Platform	Bizjet: F8X, Regional: ATR-600

Demonstration Location	Antwerpen, Périgueux
Status	<completed>
Dependencies	N/A

Traceability of demonstration objectives and exercises is provided bellow.

Demonstration Exercise	Demonstration Objectives
EXE-VLD-V4-100	OBJ-VLD-V4-011
	OBJ-VLD-V4-012
	OBJ-VLD-V4-014
	OBJ-VLD-V4-028
	OBJ-VLD-V4-021
	OBJ-VLD-V4-022
	OBJ-VLD-V4-023
	OBJ-VLD-V4-031
EXE-VLD-V4-200	OBJ-VLD-V4-013
	OBJ-VLD-V4-024
	OBJ-VLD-V4-025
	OBJ-VLD-V4-026
	OBJ-VLD-V4-027
	OBJ-VLD-V4-032

Table 7: Traceability of demonstration exercises and objectives

3.5 Deviations

3.5.1 Deviations with respect to the SJU Project Handbook

Project did not find any deviation with respect to SJU Project Handbook.

3.5.2 Deviations with respect to the Demonstration Plan

3.5.2.1.1 EXE-VLD-V4-100 (WP2)

Significant progress was made in WP2 on both ground and airborne safety case preparation to support GLS CAT II proof of concept flights demonstrations. However, due to delay in certification of Honeywell GBAS Block IIS upgrade, Lufthansa and Ryanair operation approvals and Airbus A320 family airworthiness approval, full GLS CAT II approach demo could not be performed before the end of the AAL2 project and thus pilot feasibility OBJ-VLD-V4-012 was not evaluated.

In support of GLS CAT II Autoland demonstrations with current GBAS GAST-C/CAT I systems, on the way forward project identified the means to bridge the gap between currently flown GLS CAT I manual approaches and full GLS CAT II deployment, through demonstration of practice GLS CAT II approaches. As practice GLS CAT II approaches build on GLS CAT I Autoland baseline, this approach allowed airlines to get operational experience to obtain operation approval for full GLS CAT II operation as GLS CAT I Autoland operations are not standardly used due to piloting experience and landing currency needs. This approach enabled AAL2 project to get pilot operational experience of new operation by leveraging current ground and airborne GBAS Autoland capabilities on revenue flights. These demonstrations had thus delivered extensive GLS Autoland experience that can be utilized globally during certification of operation targeting GLS Autoland operation down to both 200ft and 100ft DH. Demonstrations thus helps activities related to GBAS Autoland operation in US towards GLS CAT II OpSpec that is supported by the International GBAS Working Group – CAT II Sub-group.

For this reason, EXE-VLD-V4-100 demonstrations were focusing on practice GLS CAT II approaches described in Chapter 3.4.2.1 of DEMR. Thus, as building on GBAS CAT I and focusing on GLS Autoland approach demonstration, project added two demonstration objectives. First was a safety related parameter of Autopiloted GLS approach of flight path accuracy specified in OBJ-VLD-V4-028, where CTQ value of 1 dot was determined following Lufthansa and Ryanair operating procedures. Second was a pilot feasibility assessment specified in OBJ-VLD-V4-14.

Also, as initial targeted Newark airport for GLS CAT II demonstration didn't provide any commitment to publish relevant approach procedure during the project timeline, it was decided during the preparation phase to select Frankfurt airport as alternative representation of large hub airport operating GBAS, that would allow to conduct demonstration of both initially targeted Lufthansa B747-8 and extend them with A320 family demonstration and thus allow to gather more flights. On Ryanair side, although progress was made from very introduction of GBAS operation at the early part of the project, through gathering over 300 GLS CAT I manual approaches over the course of AAL2 project on Irish regulator approved GLS approach trials, finished safety analysis for demonstration flights, due to significant delay in process of obtaining operational approval and fleet grounding due to COVID-19 outbreak, Ryanair had made use of only possibility to fly a non-revenue practice GLS CAT II approach during acceptance flight of new B737 in US to be introduce in Ryanair fleet.

With respect to RNP to GLS approaches, no approach category was specified in objectives as it does not have effect on RNP to GLS transition phase neither in level of feasibility, nor flight accuracy during RNP part of approach including transition. As neither of airlines aircraft taking part in EXE-VLD-V4-100 flight demonstrations are equipped with the receiver to determine TSE, FTE parameter was used with tighter CTQ value of 0.5 NM for RNP to GLS approaches to Bremen as designed as RNP 1 and project follow ICAO Doc 9613 (PBN Manual) [8] which require to satisfy the accuracy requirement that the 95 percent FTE should not exceed 0.5 NM.

For GLS CAT II cost efficiency evaluation, historical data record with good statistics, fast time simulation and operational experience were used to extend the coverage of sources for the qualitative study that initially targeted evaluation based on flight data collection only.

3.5.2.1.2 EXE-VLD-V4-200 (WP3)

With respect to WP3, deviations are described here below in comparison with the amendment AMD_783_112-8.

Pioneer Demos:

Demo Flights were performed at 2 aerodromes (Antwerp and Périgueux) instead of the 4 expected in the demo plan.

- No Demo flights were performed in Le Bourget due to the absence of adequate weather in the available period of demos satisfying all the required constraints for such demo (see B1.1.6).
- No demos were performed in Payerne due to the lack of approval for that aerodrome.

However, the impact is Low for two reasons. On one hand, the preparation of the demo in Le Bourget was finalized, in particular the challenging coordination with CDG was properly addressed by the ANSP. Only the flights were pending from weather. On the other hand, Payerne is a very specific aerodrome (see C.2.5.4) with non-instrument runway and is not representative of most of aerodrome candidates for EFVS-L.

Some of demos had to be performed in simulated weather conditions due to absence of adequate weather. Obscurant panel was placed on the windshield to simulate conditions on board and LVP were fully or partially simulated by aerodromes.

Readiness Demos:

Due to unforeseen delay in the development by System Provider of the upgrade camera needed to be used for such demos, Falcon readiness demos were not performed in 2019. When available in 2020, COVID19 occurred and flights were stopped. In consequence, readiness demos were not performed, and EFVS performance analysis was conducted using simulation data only. Expected flight data were replaced by ground measurements in real conditions coming from other activities.

Aerodrome experimental approval for demos:

Payerne has not received the approval following non-authorization from Military authorities for demos in the period considered. The consequence was that no demo was performed in Payerne and approval process was interrupted. The impact is low as Payerne is a very specific aerodrome is not representative of most of aerodrome candidates for EFVS-L.

Aircraft configuration:

Falcon pioneer demos were conducted in partial configuration. Flare feature required for the operation as per the NPA was not available due to late delivery by the System provider.

There was no impact on results as Regional aviation demos were performed with flare feature. Moreover, demos were more focused on the operation from an ATM standpoint. This item was identified as a mitigation risk (714).

4 Demonstration Results

4.1 Summary of Demonstration Results

Following table summarizes the results of EXE-VLD-V4-100 and EXE-VLD-V4-200 demonstration exercise with respect to demonstration objectives and their successful criteria.

The results were assessed against the success criteria and it was decided if the Demonstration objective analysis status is OK, POK or NOK:

- OK: Demonstration objective achieves the expectations (exercise results achieve success criteria),
- POK: Partially OK. Demonstration objective achieves the expectations to a certain extent. (exercise results partially achieve success criteria),
- NOK: Demonstration objective does not achieve the expectations (exercise results do not achieve success criteria).
- N/A: Not Applicable

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Demonstration Results	Demonstration Objective Status
OBJ-VLD-V4-011	Feasibility of RNP to GLS approaches	CRT-VLD-V4-011-001	RNP to GLS approaches are perceived feasible by pilot at 95% of successful approaches	RNP to GLS approaches were perceived feasible by both Lufthansa and Ryanair pilots in operational, safety, workload and working methods focus areas. Although there was observation made by Lufthansa pilots, this was not related to procedures, but to FMS. Approach procedures were assessed as well designed and pilot friendly by Ryanair.	OK
OBJ-VLD-V4-012	Feasibility of GLS CAT II approaches	CRT-VLD-V4-012-001	GLS CAT II approaches are perceived feasible by pilot at 95% of successful approaches	Not assessed	N/A
OBJ-VLD-V4-014	Feasibility of GLS CAT II Autoland approaches	CRT-VLD-V4-014-001	Practice GLS CAT II Autoland approaches are perceived feasible by pilot at 95% of successful approaches	Practice GLS CAT II Autoland approaches were perceived feasible by all pilots during all approaches except one.	OK
OBJ-VLD-V4-021	Accuracy of RNP to GLS approaches	CRT-VLD-V4-021-001	Horizontal FTE of GLS approaches is within 0.5NM	All the approaches were successful. Lateral and vertical FTE performance of all the RNP to GLS approaches to Bremen airport was well within the CTQ limit and approaches were well captured when coming from different directions.	OK
		CRT-VLD-V4-021-002	Vertical path does not breach FAP constraint minus 100 ft limit		OK

OBJ-VLD-V4-028	Accuracy of practice GLS CAT II Autoland approach	CRT-VLD-V4-028-001	Lateral FTE of GLS approach is within 1 dot	During all practice GLS CAT II Autoland approaches, FTE was well within CTQ without non-standard observation in the data analysis as visible from the figures, which demonstrates GLS CAT I/II Autoland readiness for wider deployment.	OK
		CRT-VLD-V4-028-002	Vertical FTE of GLS approach is within 1 dot		
OBJ-VLD-V4-022	Fuel efficiency of GSL approach compared to legacy ILS	CRT-VLD-V4-022-001	Fuel burnt on GLS approach is decreased compared to legacy ILS by at least 3%	Although there were found differences between GLS and ILS approaches in fuel burnt, these were found not to be directly related to approach type, therefore any decrease in fuel cannot be attributed to GLS based on available data. Criterion is therefore not met. However, it is expected that if larger amount flight data is available, positive influence of GLS approach type due to better stability than on ILS approach (ILS beam bends) for heavier aircraft types (e.g. A320, A321) for specific ILS installations such as analysed EDDF RWY25R would be observed.	NOK

OBJ-VLD-V4-023	Environment efficiency of GLS approach compared to legacy ILS	CRT-VLD-V4-023-001	CO2 emissions on GBAS approach are decreased compared to legacy ILS by at least 3%	With constant factor between fuel consumption and CO2 emission, relative changes in fuel consumption can be considered as relative changes in CO2 emission. While differences between CO2 emissions on GLS and ILS approaches can be observed, there is not sufficient evidence to claim that these can be attributed to approach type. However, it is expected that if larger amount flight data is available, positive influence of GLS approach type due to better stability than on ILS approach (ILS beam bends) for heavier aircraft types (e.g. A320, A321) for specific ILS installations such as analysed EDDF RWY25R would be observed.	NOK
OBJ-VLD-V4-031	Cost efficiency of GLS CAT II approaches using GBAS CAT I equipment	CRT-VLD-V4-031-001	Costs efficiency of GBAS CAT II operation on CAT I equipment demonstrated by flight demonstration and qualitative analysis	Study provided evidence based on active GBAS airspace users that GBAS is efficient mean to establish new operation with both fuel/CO2 (airlines) and capacity (ANSP/airport) benefits for operations down to CAT II minimums when using GAST C/CAT I equipment.	OK
OBJ-VLD-V4-013	Feasibility of EFVS to land approaches	CRT-VLD-V4-013-001	EFVS to land approaches are perceived feasible by pilot (≥7/10 on Likert scale)	EFVS to land operation is feasible by pilot	OK
OBJ-VLD-V4-024	Accuracy of EFVS to land approaches	CRT-VLD-V4-024-001	Horizontal TSE of EFVS to land approach is within 1 dot or equivalent in meters, when relevant	TSE of EFVS to land approaches were kept within 1 dot	OK
		CRT-VLD-V4-024-002	Vertical path of EFVS to land approach is within 1	Vertical path of EFVS to land approach was kept within one dot	OK

			dot or equivalent in meters, when relevant		
OBJ-VLD-V4-025	Landing performance of EFVS to land	CRT-VLD-V4-025-001	Safe landing occurs in touchdown zone area during EFVS to land approach	All landing resulting from EFVS to land were safe and occurred in the TDZ.	OK
OBJ-VLD-V4-026	Crew and ATC workload during EFVS to land approach	CRT-VLD-V4-026-001	Crew workload is assessed as less than 7/10 on an adapted cooper harper scale	Crew Workload was assessed as acceptable during EFVS to land operation by all pilots	OK
		CRT-VLD-V4-026-002	ATC workload is assessed as less than 7/10 on an adapted cooper harper scale	Workload was perceived as equivalent to normal non EFVS operation	OK
OBJ-VLD-V4-027	Visual advantage of an EFVS system	CRT-VLD-V4-027-001	Visual Advantage is at least 200m (1/3 of RVR published)	Visual advantage of more than 1/3 of RVR published was demonstrated at Antwerp	OK
OBJ-VLD-V4-032	Aerodrome accessibility increase using EFVS to land operation	CRT-VLD-V4-032-001	EFVS to land allows aerodrome to remain accessible in 60% of limited weather situations	Weather analysis study demonstrated that EFVS to land allows aerodromes to remain accessible more than 78% of limited weather conditions (see Appendix J.2.4)	OK

Table 8: Summary of Demonstration Exercises Results

4.2 Detailed analysis of Demonstration Results per Demonstration Objective

EXE-VLD-V4-100: WP2 DEMONSTRATION RESULTS

4.2.1 OBJ-VLD-V4-011 Results

Feasibility of new designed and published RNP to GLS approaches with RF legs to EDDW from both approach directions were demonstrated by Lufthansa on A320 family and by Ryanair on B737-800 aircraft in total on 13 revenue flights. Lufthansa crews were briefed with handout and/or CBT. Ryanair crews undertook an e-learning course and each crew were briefed about the approach by RYR GLS coordinator and asked to fill out a questionnaire via EFB email. Pilot questionnaires were designed to address feasibility of both practice GLS CAT II and RNP to GLS approaches.

Post demonstration pilot assessment was based on pilot questionnaires that were divided into 5 key areas: Operational side, Safety, Workload, Working methods and other comments from pilot used in the final assessment and conclusions. In case of Lufthansa, some crews flew approach several times, during Ryanair demonstrations, each crew was different, and no pilot flew the approach twice. The RNP to GLS CAT I approaches in Bremen and the GLS CAT I approaches in Frankfurt were published in the AIP.

Lufthansa flight crews experienced low performance of the A320 Autoflight caused by FMS SW not designed for continuous descent approaches and there were some changes required in cooperation with ATC as the descent was initiated at a pilot desired Top of Descent From monitoring the fully managed descent profile. However, the additional workload experienced when flying the transition for the first time, but that decreased as pilots flew the transition multiple times. This had no impact on flight safety as the workload always remained at a very acceptable level. In general, the transition can be well managed with the knowledge of Constant Descent Operations that has been in place at FRA and MUC for many years now. There is no change in working methods required. The outcome of Lufthansa overall assessment was that new RNP to GLS approaches in Bremen were feasible at 95% of successful approaches.

The Ryanair has flown 6 RNP to GLS Revenue Flights at Bremen airport with Boeing 737-800 aircraft flown via different RNP to GLS approach procedure (EMIV, PIXUR, VERED) to Bremen and to different runway 09/27. Some approaches were affected by ATC constrains. From operational point of view, the RNP approach to BRE was considered very efficient in comparison to other RNP approaches. This efficiency leads directly to fuel and time savings. No adverse safety concerns were noted in terms of safety and workload. Workload was exactly the same as other RNP approaches and no differences to normal Ryanair standard operating procedures. The RNP to GLS approach to EDDW was having the same behaviour as RNP to ILS approach from pilot point of view. Ryanair found the shortened RNP approach efficient and time saving, well-constructed approach and very pilot friendly. All of flown RNP to GLS approaches were assessed by pilots as feasible and the criterion of feasibility at 95% of successful approaches was reached based on overall Ryanair assessment.

4.2.2 OBJ-VLD-V4-012 Results

Objective not addressed by flight demonstrations.

4.2.3 OBJ-VLD-V4-014 Results

The core objective from the human factors perspective evaluation of practice GLS CAT II Autoland approach was to collect subjective data on pilot and system performance as well as the perception of the practice GLS CAT II Autoland approaches in support of the evaluation of pilot feasibility with a different kind of aircraft (long and short haul) and at different airports onto varying runways.

The approaches performed on Lufthansa revenue flights were flown by following GLS equipped aircraft: Airbus A319, Airbus A320, Airbus A321 and Boeing 747-8. All flights were performed with dedicated crews (mainly training Captains or other management pilots) that were briefed with handout and/or CBT either. Approaches with A320 family were flown to both Frankfurt (EDDF) and Bremen (EDDW) airport, approaches with B747-8 were flown to Frankfurt (EDDF).

The flight Crews (CPT/SFO/FO) were allocated and briefed (F2F and Handout) by the AAL2 Team together with the respective fleet management (B748 and A320). All crew members had the required information package supplied via e-mail and hardcopy in their crew mailboxes. This package contained the Handout and the crew feedback form focusing on Operation, Safety, Workload and Working methods (see Appendix F). The filled-out forms were returned via Company Mail to the AAL2 team where they have been analysed and kept for further clarification with the crew that have been necessary. In such cases the Demo team contacted the crews and the F2F Feedback also found its way into the HF.

In total, 43 practice GLS CAT II Autoland approaches were performed by Lufthansa with A320 Family and 14 with B747-8 on revenue flights.

To fly the practice GLS CAT II approach in Autoland Mode, a DH of 100ft was inserted into the FMS. All flights were cleared for a GLS CAT I Approach by ATC and weather conditions were better than for CAT I conditions (according to Operational Risk Evaluation). Pilot operating method is described in 3.4.2.1.1.

All Boeing 747-8 flight crews reported a smooth and good performance of the Autoflight function during the Autoland Approach. There were no anomalies reported and no difference to an ILS based Autoland was experienced. All A320 flight Crews reported safe landings in Autoland mode but made some observations which is under investigation by Lufthansa and Airbus. First analysis showed that the performance of the Autoflight system is the same that flight crews experienced when flying an ILS Autoland. The crew workload when flying the GLS CAT I Autoland remained low as the procedure was almost identical to the conventional ILS CAT II/III Autoland procedure at DLH. The only visible difference for pilots on A320 family was the Mode designator in the FMA (Autoland vs. CAT III Dual). System behaviour did not change and when flying the approach several times, the workload remained at this level. Autoland approaches were within the required limits and out of 58 practice GLS CAT II Autoland approaches, only once pilot felt that approach may be too long and landed manually. Therefore, it can be concluded that practice GLS CAT II approaches were perceived feasible by pilots during more than 95% of successful approaches required by criterion set up for OBJ-VLD-V4-014 demonstration objective.

One Lufthansa approach flown to Bremen airport was autopiloted in RNP segment and followed practice GLS CAT II Autoland, which demonstrated the autopiloted advanced procedures, RNP and GLS Autoland. No non-standard deviations were observed by pilots.

Ryanair pilots flown 1 practice GLS CAT II Autoland approach using Ryanair practice CAT II procedures in the USA at Grant county international Airport (KMWH) during aircraft acceptance flight, i.e. non-revenue flight on B737-800 aircraft that was not yet registered on Ryanair. Ryanair pilots flown 1 practice GLS CAT II Autoland approach using Ryanair practice CAT II procedures in the USA at Grant county international Airport (KMWH) during aircraft acceptance flight, i.e. non-revenue flight on B737-800 aircraft that was not yet registered on Ryanair.

Therefore, flight data were not recorded for AAL2 and are not included in flight accuracy demonstration objective evaluation. Based on feedback from flight crew during approach no non-standard behaviour was experienced, and approach was found feasible following evaluation of pilot questionnaires focus areas (operational, safety, pilot workload and working methods).

4.2.4 OBJ-VLD-V4-021 Results

This demonstration objective focused on accuracy evaluation of approaches flown by Lufthansa and Ryanair on revenue flights on newly designed RNP to GLS procedures in Bremen. The parameter used for evaluation was the Flight Technical Error (FTE) as no truth reference system to determine TSE is usually installed on airlines aircraft during revenue flights. The Horizontal FTE CTQ value for RNP to GLS approaches was set to ±0.5 MN following ICAO PNM manual for RNP 1 approaches. For the Vertical FTE evaluation, the constrain of 'No descend below FAP more than 100 ft' was used as provided in Demonstration Plan.

During evaluation of RNP to GLS demonstration flights to Bremen observed accuracy performance (horizontal) was well within the CTQ value of ±0.5 NM. The lateral deviation was practically always within ±0.1 NM. In the vertical domain the FTE values were well within the CTQ constrain at FAP, the usual ± tens of feet, ±50 feet at maximum. For detailed description of results and analysis see the Appendix A (Section A.3.2-4).

Operator	Aircraft type	EDDW
DLH flown	A320fam	12
DLH analyzed		9
RYR flown	B737-800	6
RYR analyzed		4
Total flown		**18**
Total analyzed		**13**

Table 9: Total number of RNP to GLS demonstration flights

4.2.5 OBJ-VLD-V4-028 Results

The objective of demonstration exercise OBJ-VLD-V4-028 is focused on FTE evaluation of the Practice GLS CAT II Autoland approaches. The FTE CTQ value for the Practice GLS CAT II Autoland is set to 1 dot.

In total 58 successful practice GLS CAT II approaches were flown. Lufthansa performed 87 approaches to Frankfurt and Bremen by Lufthansa until April 2020. Out of 58 practice GLS CAT II Autoland approaches, the flight data for 32 approaches of A320fam were available for accuracy assessment because of limited data access due to COVID-19 outbreak. For details about exact number of flights performed see table below.

Operator	EDDF		EDDW		Other	Total
	A320 fam	B747-8	A320 fam	B737-800	B737-800	
DLH flown	31	14	12	N/A	0	**57**
DLH analyzed	24	0	8	N/A	0	**32**
RYR flown	N/A	N/A	N/A	0	1	**1**
RYR analyzed	N/A	N/A	N/A	0	0	**0**
Total flown	**45**		**12**		**1**	**58**
Total analyzed	**24**		**8**		**0**	**32**

Table 10: Total number of practice GLS CAT II Autoland demonstration flights

Observed accuracy performance (lateral and vertical FTE) was well within the CTQ value of ±1 dot. The lateral deviation was practically always within ±0.1 dot. The vertical deviation was usually within ±0.3 dot with absolute maximum within ±0.4 dot. For detailed description of results and analysis see the Appendix A (Section A.3.2-5).

Ryanair pilots flew 1 Practice GLS CAT II Autoland approach using Ryanair practice Cat II procedures in the USA at Grant county international Airport MWH during aircraft acceptance flight, i.e. non-revenue flight and aircraft, while aircraft was not yet registered on Ryanair.

4.2.6 OBJ-VLD-V4-022 Results

Execution of the fuel and CO2 demonstrations started with a simulation study that was conducted using a six-degrees-of-freedom simulation model of an A320 in order to investigate general effects of final approaches with a GBAS-like, perfectly straight glideslope and bended glideslopes with different amplitudes and frequencies of bending as it might occur with ILS. The simulation study revealed a potential of fuel consumption reduction, although the aircraft weight and especially of the amount of head wind indicated to have much higher influence on the fuel consumption than the effects from glideslope bends.

Data collection for real flight data analysis was conducted first on Lufthansa revenue GLS and ILS approaches to Frankfurt on B747-8 and A320fam. Analysis of gathered flight data was performed for approaches with Boeing 747-8 on runway 25L and 07R in Frankfurt/Main (EDDF) in order to analyse fuel efficiency benefits of GLS approach compared to legacy ILS. In total, 574 GLS/ILS approaches of different Boeing 747-8 aircraft on runway 25L and runway 07R were selected for the analysis.

The analysis was based on different parameters, namely fuel consumption (also applied as indicator for CO2 emissions), approach duration, approach stability and noise. The analysis of the flight data showed for the full approach (evaluation distance of 12 nm in Appendix A) an about 5 % lower fuel consumption for GLS approaches in westerly landing direction (25L) and about 2 % more fuel consumption for GLS approaches in easterly landing direction (07R). Westerly landing direction was more frequent for airlines operating to Frankfurt airport due to prevailing wind direction.

The differences in fuel consumption were found not to be directly attributed to the approach type. They can only be explained by a different behaviour of the pilots in terms of flap deflection and landing gear deployment. In the analysis of the B747 flight data no general differences in the stability of ILS and GLS approaches could be observed. The amount of flight data was considered statistically significant.

For A320 family flight data collection, 1334 approaches with A319, A320 and A321 on different runways of EDDF were gathered and analysed in groups per each runway, approach type and the three aircraft types of the A320 family. As characteristic differences between ILS and GLS are runway-related, the flight data were analysed for each aircraft type and each runway separately. The only identified runway of interest in EDDF from fuel and CO2 savings point of view when comparing GLS and ILS approach was RWY 25R with 3.0° and 3.2° approach, as only on this runway considerable differences in the glideslopes of ILS and GLS due to ILS glideslope bends exist.

Only A319 groups of approaches were large enough to provide reliable statistical results. Both relative differences were in the same order of magnitude, slightly below 2% fuel consumption, but with different sign. The same tendency was observed for runway 25L with 3.0°, where the GLS approaches used less fuel in average than the GLS, and 07L with 3.2°, where the GLS approaches used more fuel in average than the ILS. These findings indicated that the reason for the different average fuel consumptions is not the approach type but other causes, e.g. operational issues, such as the configuration of the aircraft or wind.

The analysis of flight data from the A320 family revealed no characteristic differences between approaches with ILS and GLS as A319 is light aircraft, for which reason the aircraft mostly fly in idle during the approach and unfortunately there were not enough A320 and A321 (may fly with a thrust setting above idle for a longer period of time during the approach) flight data gathered to be statistically significant. The analysis was mainly performed for A319 on runway 25R with approach glideslope of 3.0° and 3.2°. However, this aircraft type is expected not to be the most interesting one for the analysis as it is the lightest one of the three aircraft types. The differences found in average fuel consumption (as a measure for CO2 emission) could be attributed to other causes than the approach type. Mainly wind and operational issues such as configuration of the aircraft caused differences between approaches with ILS and GLS.

Concluding, it is expected that larger amount of flight data on heavier aircraft possibly change these findings and reveal a general difference between ILS and GLS, with fuel benefit on GLS approach as analysis of the glideslope deviations revealed indeed bends in the glideslope of the ILS of runway 25R (both glideslope angles). However, given the available amount of data on A320 and A321, positive influence on fuel in the range of 3% set up by demonstration objective criterion that can be attributed to GLS approach type was not validated by gathered data of A319 aircraft type.

4.2.7 OBJ-VLD-V4-023 Results

From the evaluation of fuel demonstration objective EX1-OBJ-VLD-V4-022 of the gathered B747-8 flight data follows that for evaluation distance of 12 nm about 5% lower fuel consumption for GLS approaches in westerly landing direction (25L) and about 2% more fuel consumption for GLS approaches in easterly landing direction (07R), CO2 results can be derived as CO2 (as well as other greenhouse gas emissions) correlates with fuel consumption. The fuel demonstration objective evaluation of A319 approaches reveals that both relative differences between ILS and GLS approaches of 3.0° and 3.2° on EDDF runway 25R are in the same order of magnitude, slightly below 2% fuel consumption, but with different sign.

Neither the used simulation model nor the analysed flight data give direct numbers of CO2 emissions. Therefore, SESAR ENV Assessment Process 4 [55] was followed where constant factor between fuel consumption and CO2 emission is assumed, so the relative changes in fuel consumption can be considered as relative changes in CO2 emission. While differences between ILS and GLS approaches can be observed, there is not sufficient evidence to claim that these can be attributed to approach type.

4.2.8 OBJ-VLD-V4-031 Results

Study provided evidence based on examples of active GBAS airspace users that GBAS is efficient means to establish new airspace operation with both fuel/CO2 (airlines) and capacity (ANSP/airport) benefits for operations down to CAT II minimums when using GAST C/CAT I equipment.

ANSP view

Results of the FTS simulations on large hub airport EDDF RWY25R focused on GBAS CAT II operations scenario compared to a solely ILS CAT II operations scenario indicated that increase of capacity runway is most likely when using GLS CAT II approach procedures instead of ILS CAT II as can be seen on figure of capacity vs demand in Appendix H, where GBAS approaches better address airport capacity demand compared to ILS approaches. Various assumptions were applied in simulation (e.g. GBAS equipage rate 100%). Capacity increase is given by the missing protection zones for GBAS and the Landing Clearance Line concept that allows the aircrafts to be clear of the runway at an earlier point of time. The capacity gain depends on the number of aircraft WTC HEAVY that cause most of the restrictions when using ILS. In addition, the taxi speeds of the aircrafts when vacating the runway is relevant for the results.

Airline view – Large Hub airport

Airlines focused on benefits expected at large hub and regional airport as well. At specific case of Frankfurt Airport, majority of approaches flown is still ILS. However, it was identified that ILS approaches require a level flight of several nautical miles (NM) before flight crews are allowed to initiate the further descent in an altitude of 5000 or 4000ft. In order to reduce the environmental impact (e.g. CO2 emission, noise level) and increase flight efficiency (e.g. reduced fuel burn) during an approach a late continuous descent from a high altitude is required. GLS approaches carry the advantage that GLS Glideslope certification is already available up to 23 nautical miles. As a consequence of this, ATC towers can clear an approach from an altitude up to 7000ft. This is 2000 to 3000ft higher in comparison to the ILS approach. Lufthansa simulator and flight data analysis with a Boeing 747-8 has shown fuel savings of approximately 20kg per approach that started from 7000ft (instead of a level flight in 4000ft before commencing the ILS approach). A real Airbus A380 GLS approach from 7000ft to Frankfurt airport confirmed the fuel saving calculation from simulator. Considering SESAR ERM methodology [103] where direct link between fuel burn and the amount of CO2 produced is provided (i.e. 3.15 times the mass of fuel burnt), fuel savings result in 63 kg savings of CO2.

A fuel saving analysis for GLS approaches on short-range aircraft (e.g. Airbus A320) could not be accomplished until now. A first estimate (without confirmation) is a fuel saving of approximately 8-10 kg per GLS approach with a short-range aircraft.

If the GBAS landing system (GLS) would be certified to support CAT II and CAT III operation, these savings could be achieved during Low Visibility Conditions as well. In the case of certified GLS CAT II operation with GAST C equipment, currently available GBAS airborne equipment for CAT I operation would be sufficient to gain these benefits in LVC down to CAT II minimums. Since no protection and safety areas for GLS approaches are required, a higher throughput of two to three aircraft per hour (during LVO) could be achieved. This higher throughput could avoid delays, holdings, diversions, and cancellations which would imply lower cost for an airline. Both the fuel savings due to higher altitude of approach start, and reduction of delays, holdings, diversions, and cancellations, are achievable with current airborne GBAS CAT I equipment which implies overall good cost efficiency for both non-LVC and LVC conditions.

Airline view - Regional airport

GLS CAT II approaches will be available without the cost of extra aircraft equipment. Considering an example of Ryanair fleet, approximately 42 aircraft are equipped with GBAS and all new arriving aircraft will have GBAS fitted with over 100 B737 Max aircraft ordered with options for a significant number more. No retrofit of the existing fleet with GBAS planned at this time. Depending on B737 Max deliveries fleet of approximately 142 GBAS equipped aircraft over the next few years would benefit from GLS CAT II operation introduction without need of any extra equipment to carry out which brings cost benefit.

GLS CAT II approaches will be available without additional training costs. Often when new procedures or new equipment are introduced into the aircraft crews need to first do a training programme in the simulator before they can use the procedure/equipment. In the case of large regional airport operator like Ryanair, 5000 pilots would need to go through a simulator programme.

GLS CAT II approaches should become available to smaller airports that currently find ILS CAT II approach equipment prohibitively expensive. Operators like Ryanair fly to many smaller regional airports, typically with ILS one side and non-precision approach on the other. GLS CAT II operation gives the opportunity to operate CAT II approaches to both runways. This has a cost benefit to the airline with far less diversions from regional airports. Diversions can be very expensive; passengers have to be normally bussed to and from the original destination. The aircraft is not doing its planned rotation leading to follow on delays and in the worst-case cancellations. Airline customers are also greatly in inconvenienced and may be slow to travel with the airline again. GBAS CAT II approaches would help mitigate against this.

Ryanair conducted a detailed analysis of diversions in 2018. In 2018 this year Ryanair had 761 diversions. About 50% were due to the weather being below minima at the destination (Non-precision or CAT 1). GBAS CAT II approach would have mostly allowed the aircraft to land. Each diversion costs about 75,000 euro. This includes the cost of EU Regulation 261/2004 (EU law relating to flight delay compensation), handling, coaches, airport charges, fuel etc. This costs about 28 million a year. The cost of having aircraft out of position is difficult to quantify, if a flight is diverted the follow-on flights either need to be completed by a spare aircraft, a different line of flying needs to be disrupted, the flight is delayed and completed by the delayed aircraft or the flight is cancelled. Ryanair estimate the cost to the operation of about 12 million euro a year so the total saving would be in excess of 40 million a year to Ryanair. There are also specificities related to airport location. Considering Ryanair case, GLS CAT II operation are particularly useful in Poland considering character of weather systems and number of flights to Polish regional airports. Due to the nature of fog in Poland affecting large areas of the country the aircraft often need to divert to airports that are a considerable distance away, so diversion cost is higher due to the distances to bus passengers and the time spent waiting for passengers to arrive at the aircraft. In Poland, Ryanair estimates diversion costs closer to 100,000 per flight.

Therefore, with use of GAST C ground station and airborne equipment for GLS CAT II operations, increased capacity would bring ANSPs, Airports and Airlines higher cost efficiency.

4.2.9 OBJ-VLD-V4-013 Results

The feasibility of the EFVS-L operation was assessed through the use of human factor questionnaires and in comparison, with standard landing operations performed without the use of EFVS (as per reference scenario in B.1.3).

As a general conclusion, EFVS-L operation was assessed as feasible by both regional and business aviation end users' crews who participated to the demos flights. Each pilot acted at least as a PF and did several approaches. All the approaches were successful. Demos of regional aviation were performed by the PF using HWD and a repeater was available for the PM. Those of Business aviation were achieved in dual HUD configuration.

The pilot of a main regional air operator performed the ILS/ LNAV-VNAV flight demos in simulated degraded weather conditions using an obscurant panel on the windshield. He reported that:

- The ease of the operation is improved for approach and landing and is equivalent for taxi and rollout compared to non EFVS operations.
- No difficulty was perceived. The EFVS improves situational awareness for all phases of flight (approach, landing, rollout, and taxi) and workload is not increased except for taxi (realized in more dimensioning conditions than in reality due to the zero-visibility resulting from the obscurant panel),
- Decision making in case of aborted approach is equivalent and may be even improved by the use of EFVS,
- Crew coordination was assessed as acceptable.

The pilot of the business aviation air operator performed the flight demos as PF and PM in real weather conditions, at night, and in full ATM/ANS/ADR environment. He stated that:

- The ease of operation is equivalent to non EFVS comparable operation although it was the first time, he performed EFVS operation in such Low Visibility conditions
- EFVS improved situational awareness except for rollout where it was assessed as equivalent. For taxi, pilots even reported that EFVS should be recommended in clear night condition for assisting in obstacle detection. Workload was equivalent or slightly increased during landing phase mainly because of the short term of visual acquisition in these extreme weather conditions of the demo (EFVS allowed to acquire visual reference just before the DA/H where decision to continue the approach has to be taken). Pilot indicated this point could be improved by recommending the use of EFVS as much as possible in day to day operations. Dassault test pilot who was the other crew member concurs to that statement and explained training and experience will decrease the extra workload that may be perceived.
- Crew coordination and Decision making to continue or go around are equivalent to other operations.

See questionnaires in the appendix E.

4.2.10 OBJ-VLD-V4-024 Results

With respect to flight accuracy demonstration, lateral and vertical path accuracies were kept within one dot during all the EFVS-L approach and landing.

No significant deviation of trajectory was observed. Approaches were stabilized well before the EFVS segment. Aircrafts crossed the threshold close to 50ft (as expected) and landing occurred in the expected area.

4.2.11 OBJ-VLD-V4-025 Results

This objective focused on landing performance demonstration. All landing terminated close to the expected aiming point and well before the end of the touchdown zone.

4.2.12 OBJ-VLD-V4-026 Results

With respect to Crew Workload: see EX1-OBJ-VLD-V4-013 Results here above.

With respect to ATC workload, it was perceived as equivalent to non EFVS operations by Antwerp controller in real weather conditions and in full OPS environment.

In Périgueux, same statement was made for demos performed in full simulated environment (with LVP in force).

4.2.13 OBJ-VLD-V4-027 Results

This objective focused on system visual advantage demonstration. Three successful approaches were achieved in actual RVR of 500m although the min published RVR was 750m for this approach. This demonstrates the EFVS system used for demo is capable of an Ops credit of 1/3 which is the maximum visual advantage (30%) allowed by the current OPS regulation.

During demo in Antwerp while other aircraft needed to perform missed approaches at EBAW and EBBR due to the low visibility, the demo flight could continue.

Figure 11: Falcon 8X during SESAR demos in Antwerp in LVC

4.2.14 OBJ-VLD-V4-032 Results

Weather analysis focused on airport accessibility. Study demonstrated that the EFVS to land concept of operation would allow aerodromes to remain accessible in more than 78% of the limiting weather conditions they had face to in the 2008-2018 period (see Appendix J section J.2.4).

4.3 Confidence in Results of Demonstration Exercises

4.3.1 Limitations and impact on the level of Significance

In spite of deviations, SESAR AAL2 results present a high level of significance.

With respect to trials Demos, EFVS flights were successfully achieved at aerodromes where an experimental approval has been issued by the authorities in the frame of that project (see Appendix C). Some Demos were carried out in full OPS environment and in real low visibility conditions corresponding to the maximum value of OPS credit allowed by the regulation (and figuring out the EFVS technology available in 2020).

With respect to aerodromes, main types of aerodromes where EFVS is intended to be deployed have been addressed in the project. CAT I controlled and uncontrolled (AFIS) aerodromes with ILS and/or GNSS approaches were covered by the AAL2 flight demos.

The experimental approval process has been successfully conducted for aerodromes where demos were carried out. Process was also successfully achieved in Le Bourget which is the first aerodrome for business aviation traffic in Europe moreover localized in the suburb of the CDG HUB. Results from experimental approval process were capitalized by skeyes who produced a guidance manual for supporting future EFVS approval of other Belgium aerodrome and possibly EFVS regulation improvements.

With respect to stakeholders, all relevant stakeholders were involved in flight demos including end users of air and ground segments. Major regional air operator dealing with scheduled operations as well as business aviation air operator dealing with non-scheduled operations were involved alongside the ATC and ANSP departments (procedure design, weather office…). Aerodrome operators and authorities who were both not part of the SESAR AAL2 stakeholders contribute nevertheless to the success of the project.

Stakeholders involved in the execution of the demos provided feedbacks that have been collected through dedicated human factor questionnaires and some recommendations were made for regulation maker bodies (Appendix B section B.3.1.3).

With respect to the aircrafts involved in the demos, a large scope of configurations was addressed. ATR 42 -600 (CAT B aircraft, propeller) was equipped with the very new HWD (the first in service) and Falcon 8X (CAT C aircraft, heavy business jet –EBAA classification-) was fitted with dual HUD. Camera used for the trials was the same on both aircrafts (multi-sensors with fusion algorithms). It was representative of the EFVS technology available in 2020.

At last, a large scope weather analysis spanning 10 years was performed for assisting the decision makers (aerodrome, states, ANSP, air operators) in the assessment of the potential benefit of the EFVS-L concept of operation (Appendix J).

With regards to the objective of the project the main two limitations are the absence of flight demonstrations in an airport such as le Bourget with traffic regulations constraints. The other minor limitation is the absence of OPS approval at aerodrome with non-instrument runways.

Limitations of demos have been described in Appendix B section B.2.

4.3.1.1 Quality of Demonstration Exercises Results

Quality acceptance criteria were satisfied during the demonstrations (see EX1-OBJ-VLD-V4-024 & 25 Results in Appendix B section B.3.2).

4.3.1.2 Significance of Demonstration Exercises Results

4.3.1.2.1 EXE-VLD-V4-100

Demonstration flights were performed on revenue flights in various environment and with various aircraft platforms including the airports in Europe comprising major hubs as well as regional airports (Frankfurt - EDDF, Bremen - EDDW). Flight test data analysis were performed in a very detailed way and enabled to critically assess the analysis results.

Demonstration flights campaign was preceded by pilots in the loop simulations on practice GLS CAT II and was followed by flight demonstration of both practice GLS CAT II and RNP to GLS with human factors assessments on the feasibility of procedures and operations and the assessment of flight accuracy. Simulations and analysis of collected data for the evaluation GLS vs ILS approach environmental benefits (such as fuel consumption and CO2 emission) were complemented.

4.3.1.2.2 EXE-VLD-V4-200

4.3.1.3 Significance of Demonstration Exercises Results

4.3.1.3.1 EXE-VLD-V4-100

Demonstration flights were performed in real operational environment in the EU ensuring good operational significance. Total number of flight demonstration within EXE-VLD-V4-100 is 76. The table below provides details per aircraft type and flown operation. Amount of trials by different aircraft types, operators at different airports ensures good operation and statistical significance. Demonstration exercise was significant as well from view of cooperation with regulatory stakeholders, both on GBAS ground station part when preparing safety case, airborne side when preparing A320 airworthiness certification and airline operation side, when preparing documentation for operational approval for GLS CAT II operation. RNP to GLS procedures with RF legs designed for Bremen were reviewed by airspace users and CDO capabilities were confirmed by pilots and as such remains published in AIP after AAL2 demonstration.

Operator	Aircraft type	Number practice GLS CAT II approaches	Number of RNP to GLS CAT I approaches
Lufthansa	A320 fam	43	12
	B747-8	14	N/A
Ryanair	B737-800	1	6
Total flown		**58**	**18**

Table 11: Total number of EXE-VLD-V4-100 flight trials

As practice GLS CAT II approaches were demonstrated using GLS CAT I approach and ATC procedures, significance of flight demonstration lies especially on airborne side. It clearly demonstrated pilot feasibility of practice GLS CAT II approach operation and accuracy of GLS CAT I Autoland approach capability with support of current GBAS CAT I equipment as a step towards full GLS CAT II approach. CONOPS extension for GLS CAT II procedure, ATC tools update, GLS CAT II procedures were prepared and GBAS Ground station upgrade with SBAS extension was completed/tested and aircraft safety impact assessment including simulator session was finished. Limitation consists in the fact that full the GLS CAT II demonstration could not take place within AAL2 as the required approvals were not granted in the AAL2 timeframe.

4.3.1.3.2 EXE-VLD-V4-200

EFVS Demos were performed in Full OPS environment with all relevant end users involved (see Appendix B sections B.3.4.2 and B.3.1). Some of demos were performed in the real low Visibility conditions demonstrating the highest level of OPS credit allowed by the current regulation.

A large scope Weather statistical analysis was conducted as part of the OBJ-VLD-V4-032 (appendix J) related activities. This study analyzed 10 years of weather data for 29 European aerodromes of interest for business aviation and regional aviation. In particular, this study confirmed the high potential of EFVS-L operation as a solution to reduce drastically the number of low visibility situations limiting landing (>78%).

A comprehensive but concise guidance manual was produced by skeyes based on the experience they gained from AAL2 to explain in particular to ANSP and Aerodrome community what EFVS operation is and to describe the detailed steps to follow for getting the authorization of the use of the aerodrome for EFVS operation according to NPA 2018-06 criteria. This document that was not part of the initial deliverable of SESAR AAL2 project is however a key element for large deployment of EFVS.

5 Conclusions and recommendations

5.1 Conclusions

Within the SESAR programme, this project demonstrated the benefits for the aviation community with respect to lowering decision minima, reducing environmental impact, saving fuel cost, and increasing the traffic throughput at airports. Through those very large-scale demonstrations, and the participation of all possible stakeholders, the AAL2 project brought a positive impact to the speed of deployment of SESAR technologies. By this increased deployment, the market will enjoy much faster the actual realization of the benefits, and thus support the goal of ATM modernization.

This project addressed the operational and technical scope of the targeted focus areas. It did that through the comprehensive availability of all stakeholders in the consortium, and by setting up the demonstration flights in such variety of operational conditions that the obtained results will be appealing, relevant, and applicable for most of the European airports.

The demonstrated technologies were GBAS CAT II solution with GBAS GAST-C ground system and CAT I equipped airborne and EFVS to land addressing the use of flight-deck vision-support systems enabling landings in low visibility conditions.

With over 70 successful demonstration flights the project has shown the feasibility of WP2 GBAS CAT II Demonstrations, WP3 – EFVS to Land Demonstrations

Sections 5.1.1 and 5.1.2 will detail next steps, conclusions, and recommendations separately for each WP/technology.

5.1.1 EXE-VLD-V4-100

Project demonstrated the benefits for the aviation community by progressing on GLS CAT II operation on enhanced GBAS CAT I ground station and current GBAS CAT I airborne systems towards deployment of this operations, that focuses on lowering the minimums on GLS precision approaches down to 100ft DH while allowing to bring fuel/CO2 benefits and increasing traffic throughput at airports in LVC.

Large scale demonstration and the participation of all relevant stakeholders enabled AAL2 project to bring a position impact to the speed of deployment of new technologies. By deployment of this new solution market will enjoy much faster the actual realization of GBAS LVC operation and thus support the ultimate goal of efficient and green ATM modernization. Both airborne and ground navigation elements demonstrated GBAS GAST-C technical capability to support GLS CAT I Autoland and GLS CAT II Autoland approaches at pilot feasibility and approach flight accuracy demonstration level, same as at system safety assessment level.

In support of GLS CAT II demonstration preparation, significant effort was made by WP2 in preparing necessary safety case including assessment of GBAS enhancement with EGNOS data, airborne safety assessment with respect to impact at aircraft level for airworthiness assessment at operational level as a part of operational approval. Individual safety assessment was submitted to regulators CONOPS was updated to allow GBAS operation in LVC. Cockpit and Integration simulator supported safety assessment and operating method. FTS simulations focused on capacity gains due to missing protection zones for GBAS and the Landing Clearance Line concept that allows the aircrafts to be clear of the runway at an earlier point of time, compared to ILS. GLS/ILS study focusing on more stable signal with GLS approaches reveals potential benefits on specific ILS runways, however low number of evaluated flights did not allow to confirm expected level of fuel savings.

With over 70 successful demonstration flights the project has confirmed feasibility and accuracy of practice GLS CAT II operation using GBAS GAST-C/CAT I capability to support Autoland operation, so demonstrating GLS CAT I Autoland capability and aircraft and ground readiness towards full GLS CAT II operation. The approaches demonstrated as well accuracy and feasibility of the new designed RNP to GLS procedures, including RNP to GLS Autoland. The new designed RNP to GLS procedures with RF legs to Bremen under AAL2 will remain in the German AIP after completion of the project. Flight demonstrations were conducted with different aircraft types (A320 family, B747-8, B737-800) on Lufthansa and Ryanair revenue flights in two different environments represented by Bremen and Frankfurt airport. One approach was non-revenue flight. All trials were analysed in detail by the respective partners and data collection as well as feedback from pilots and demonstrated very good accuracy of practice GLS CAT II Autoland that were using deployed GBAS GAST-C/CAT I ground station, approaches as well as the new RNP to GLS approaches. With respect to GLS/ILS comparison, while detailed study was conducted that indicated possible fuel/CO2 benefits, there was not enough flights to support demonstration target.

The exercise EXE-VLD-V4-100 worked on demonstration of enhanced GBAS ground GAST-C system capability and current airborne GAST-C capability to support GLS CAT II operation. As the scope of demonstration was not exactly matching Solution #55, in some instances for example, built on new enhanced capabilities not available in the current Solution definition, upon agreement with SJU before DEMR delivery, and by considering criteria to establish new solution and technical achievements of the AAL2 project as well as work done before and outside SESAR project, the EXE-VLD-V4-100 provides new SESAR Solution of Enhanced GBAS GAST-C to support GLS CAT II operation.

5.1.2 EXE-VLD-V4-200

First of all, AAL2 demonstrated once again that EFVS technology available in 2020 is capable of 30% of Ops credit allowing for example landing in conditions of 500m instead of 750m usually required without EFVS. During demos, while other aircraft needed to perform missed approaches at EBAW and EBBR due to the low visibility, the demo flight could continue. In addition, Demos confirmed the benefit of EFVS for situational awareness and therefore safety for all phases of flight.

As part of the performance prediction study based on simulation data consolidated by real ground measurements, it was showed that the EFVS system tested (multi-sensors with fusion algorithm) has the same level of performance on LED lights as on incandescent light. In addition, an informal inquiry of pilot conducted as part of that study about other than weather causes of low visibility indicated that smoke condition may reduce visibility and impact landing operations. Method for quantifying the benefit of EFVS in such situation was explored.

With respect to aerodrome experimental approval for EFVS, EASA NPA AWO 2018-06 requires the suitability of aerodrome/ runways is verified for EFVS operations and stipulate that "*in case a runway has been promulgated as suitable by the State of the aerodrome (i.e. in the AIP), then no further investigation is required from each air operators*". AAL2 demonstrated that proceeding this way will

guaranty the highest level of safety of the operation and will give a clear and non-ambiguous indication of EFVS operation to all ATM stakeholders i.e. aerodrome operator, ATC, and air operator.
The alternative consisting in letting each air operator to determine by its own the suitability of the runway for EFVS operation has been assessed as too long and too much complicated, especially for business aviation. Belgium ANSP who conducted the experimental approval for Antwerp explained that several stakeholders must be involved in the authorisation of the aerodrome for EFVS operation (see Appendix B section B.3.1.3.b).

A coordinated approach by all the stakeholders (airport operator, ANSP, procedure design office, etc.) to determine if a runway is compliant with the EFVS criteria stated in NPA AWO 2018-06 when promulgated is the most safe and efficient way of proceeding. This will allow a safe and large deployment of an operation that was introduced in the European regulation in 2008.

In accordance with that principle, the SESAR AAL2 project achieved all the necessary safety assessment allowing the issuance of experimental approval for EFVS-L demos at some pioneer aerodrome such as Antwerp and Le Bourget. The project involved all the necessary stakeholders, i.e. aerodrome operator, ANSP and authorities. The most advance draft of regulation i.e. the EASA NPA AWO 2018-06 was used for that purpose. The result of that activity is detailed in Appendix C for each aerodrome. Beyond the SESAR initial objective, the experimental approval process activity performed in Antwerp was transcribed in a guidance manual produced by skeyes for describing the steps for getting authorization of aerodromes for the use of EFVS.

As part of AAL2 objective, the question of the benefit compared to the affordability and complexity to deploy EFVS operation was asked to aerodromes and ANSP who achieved approval. Based on the experimental approval and results of flights demos:

- The ANSP who led the authorization request confirmed the clear benefits of EFVS operation and estimates it is a good solution for regional aerodromes for increasing accessibility in Low Visibility conditions. They stated an effort is needed for promulgation of the suitability of runways; however, they estimate this task is fast and affordable compared to CATII/III.

- The aerodrome operator who performed demo flights expressed strong interest for the operation and considered it is easily accessible with a low complexity level to deal with. Aerodrome operator estimated the operation is affordable with no significant additional cost. Beyond SESAR, Antwerp aerodrome even reported being in favour of applying for EFVS-L operation (Appendix E).

As part of conclusion of AAL2, we can emphasize the fact EFVS will complement the instrument approach procedures that are already published at an aerodrome and add credit to most of non CATII/III procedures, whatever the infrastructure of the aerodrome is. When considered in combination with GNSS based approaches such as LPV, AAL2 demonstrated EFVS is an efficient and safe solution for expanding access at these non CATII/III aerodromes, whenever the minimum requirements for EFVS credit is achieved.

Figure 12: Falcon 8X EFVS/ CVS during LPV approach

5.2 Recommendations

5.2.1 Recommendations for industrialization and deployment

5.2.1.1 EXE-VLD-V4-100

Large number of demonstration approaches was conducted with different aircraft types (A320 family, B747-8, B737-NG), on revenue flights with Lufthansa and Ryanair on practice GLS CAT II approaches and RNP to GLS. All trials were analysed in detail by the respective partners, and data collection as well as feedback from pilots show the practice GLS CAT II as very well feasible with recommendations summarized below. Safety case was prepared both for GBAS ground and airborne part demonstration. Demonstration showed the technology readiness for broader deployment of GBAS GAST-C solution allowing GLS CAT II approaches. Within the AAL2 project there were not identified any recommendation for further R&D of the GBAS GAST-C/CAT I equipment serving for GLS CAT II approaches.

Recommendations with respect to GLS CAT II approaches using GBAS GAST-C/CAT I equipment:

- Lufthansa crews are familiar with practice GLS CAT II Autoland operation in Frankfurt and Bremen airports, approaches that will support approval process were gathered. Recommendation is to proceed in approval process to allow full GLS CAT II operation in LVC.
- Support of GLS CAT II operation introduction on GBAS GAST-C which doesn't require avionics modification for GAST-D allows to start gaining benefits, both in airport capacity for large hub as indicated by FTS, fuel/CO2 savings and accessibility of regional airports by GLS CAT II approach coverage on all RWY ends, already with current GBAS CAT I avionics.
- From cost efficiency point of view, GBAS GAST C/CAT I that supports operation down to 100ft DH is efficient way of how to address better capacity and accessibility of airports by introduction of GBAS LVC operation, where there are not enough CAT III weather conditions. Also, as leveraging current GBAS technology, this can be intermediate steps towards until GAST-D ground and airborne equipment deployment at sufficient equipage rate is available.
- GBAS airport capacity benefits in LVC down to CAT II are expected to be achieved on hub and large regional airport while on small/regional airports that usually have only ILS CAT I installation on one RWY, benefit comes through availability of GLS CAT II operation on all

runway ends with currently available CAT I technology. GBAS can also support approaches from higher altitudes CO2 reductions as already today GBAS glide path can support approaches from 23 NM that would be allowed in LVC as well.

- Procedure design should consider all the required stakeholders: ATC, operators, airframe manufacturers to provide safe and optimal procedures.
- Train and motivate pilots to execute GLS approaches (see benefits in Appendix G).
- Airline GBAS LVC Autoland OPS approval.
- From RNP to GLS point of view, new demonstrated procedures in Bremen demonstrated CDO a-like vertical profile applied in order to reduce noise and fuel consumption, implementation of distance markers to support ATCOs and pilots. Procedures were assessed as well designed by pilots and will remained deployed (published in AIP) after AAL2. Recommendation is that RNP procedures that supports CDO operation should be published and promoted for usage.

Suggestions at consortium level:

- Strive for high GBAS equipage rates of aircraft crucial to realize beneficial effects and to decrease ATC controller's workload (traffic differentiation).
- Support Airlines (Air) and ANSPs/Airports (Ground) to create business cases for investments and align Ground/Air efforts.
- Implement concepts of operations, that deliver benefits to Airlines to push equipage rate (e.g. Best Equipped Best Served concept). It is expected that the methods how to prioritize the flights operated by equipped aircraft in air traffic management will be selected by the Airport/ANSP.
- Contribution of all stakeholders is needed to make decisions aimed at GBAS deployment (Airspace users, Airports, ANSPs, etc). GBAS will be one of the critical components for future airspace development taking the GLS CAT II as first step in transition to replace ILS with GBAS. Operational advantage such as earlier start of approach or reduced delays, diversions and cancellation can bring clear fuel and CO2 benefits if operational advantage of new satellite technologies is leveraged. Airport capacity increase is dependent on GBAS equipage rate. Another means could bring not only capacity increase but environmental impact reduction as well, could be incentive program such as the on at Frankfurt airport that supports the equipage of aircraft with GBAS technology.

5.2.1.2 EXE-VLD-V4-200

The guidance manual produced by skeyes for Antwerp should serve as example for states/ ANSP to establish a list of similar aerodromes authorizing the use of EFVS in the perspective of large deployment of the operation (see Appendix B.4 and Appendix C) and as part of *promulgation of aerodrome for EFVS* activity.

Extensive Work conducted in Le Bourget and resulting in the issuance of experimental approval by authorities for SESAR demos (Appendix C) should serve as an example for deployment of EFVS operations at those aerodromes with higher traffic density and where the traffic regulation constraints are shared with a HUB airport.

The large scope weather analysis produced in AAL2 is a key input that should be considered to assist all the stakeholders in their assessment of the real benefit of that new operational capacity (i.e. States, AIR operator, aerodrome operator, ANSP).

All the recommended actions should support, ease, and speed up deployment of EFVS operation that is however part of the regulation since 2008.

EFVS operation is an efficient and safe complement to existing GNSS based approaches as stated in GSA/*GNSS Market Report | Issue 6, 2019*. In order to expand ATM stakeholders' awareness of what EFVS is, and to prepare the deployment of the new AWO regulation (European Commission Decision targeted Q2 2022 according to *EASA European Plan for Aviation Safety 2019-2023*), we recommend EFVS is addressed in PBN based approach activities and reflected in associated documentations.

In order to support the deployment of EFVS at non-controlled aerodrome (AFIS), AAL2 recommends the experimental approval process conducted at Périgueux is deployed at one other AFIS aerodrome with higher traffic constraints.

There are no recommendations for R & D additional activities. Regulation is almost finalized. The R&D is covered by active sensor in PJ02.

5.2.2 Recommendations on regulation and standardisation initiatives

5.2.2.1 EXE-VLD-V4-100

With respect to operation approval, project recommends staying on track with EASA AWO NPA regulation (NPA 2018-06) timeline and prevent unnecessary delays, so it is ensured that regulatory baseline for GLS AWO operation is fixed for all operators which would helped progress on operation approval side.

With respect to international coordination, **International GBAS Working Group – CAT II Sub-group was created during AAL2.**

At I-GWG/20 it was decided to create a subgroup with the objective to publish the present issue paper, submit it to the relevant authorities with the objective that industry has a need, a plan and the willingness to implement the CAT II operation as there are clear business benefits. It was clarified that while Autoland is a prerequisite for CAT II in the current operational concept. I-GWG would try to act as catalyst and a subgroup was formed to progress activities between meetings.

Recommendation is to continue international coordination and at ICAO level deliver appropriate framework to allow quick progress in GLS CAT II operations using GAST-C station.

5.2.2.2 EXE-VLD-V4-200

The work achieved in SESAR AAL2 could serve as from now for supporting approvals of existing EVS operations as defined per the applicable regulation (Commission Regulation (EU) No 965/2012).

Beyond this, it will serve for supporting all types of EFVS operation approvals including EFVS-L as soon as introduced by EASA through new AWO regulation resulting from NPA 2018-06 (European Commission Decision targeted Q2 2022 according to *EASA European Plan for Aviation Safety 2019-2023*).

AAL2 make two major recommendations for improving AWO EFVS regulation.

- AAL2 recommends the declaration of suitability of the aerodrome/ runway for EFVS is made on the aerodrome side (i.e. AIP) rather than letting each air operator doing it by its own. This will guaranty the highest level of safety as well as giving a very clear indication to the crew with respect to the limits of the EFVS operation at each aerodrome.
- AAL2 recommends the RVR capabilities of an aircraft/ crew resulting from EFVS is mentioned in the flight plan for traffic regulation purpose. Field 18 of the FPL has been successfully used in AAL2 demos. Field 10 could be also envisaged.

See Appendix B Section B.3.1.3.

5.2.3 Recommendations for updating ATM Master Plan Level 2

This section is not applicable for AAL2 project.

6 Summary of Communications and Dissemination activities

6.1 Summary of communications and dissemination activities

During 2,5 years of AAL2 duration, the consortium participated in substantial number of communication activities. To achieve significant communication impact, the following communication goals were derived and followed:

- **Create a wide awareness of its specific solutions, their applicability and benefits brought to operations, through conference papers and multimedia communication channels,**
- **Showcase results to the ATM industry** stakeholders
- **Accelerate operational acceptance and deployment** through professional forums, conference, articles, and open days to show case maturity of operational improvements and technical capabilities.

In the early stage of the project, the consortium formed an agreed basis for any open communication to secure consistency between all partners. The AAL2 kick-off press release was performed in February 2018. More than 500 leaflets were produced and distributed on various occasions and events, where either AAL2 was presented or representatives of AAL2 consortium, participated (for example WAC, SESAR Innovation days, LATO, IGWG, EBACE, LATO, and others). PDF version of that leaflet was uploaded to Stellar Communication section. In the early stage of the project, the consortium paid attention to inform wide ATM community about the project existence, objectives, timeline and expected benefits.

By targeting wide airspace community, AAL2 was presented in WAC Madrid 2018 and 2019, European Business Aviation Conference and Exhibition 2018 and 2019, International GBAS Working Group Conference, LATO, etc. The consortium was also active on SESAR organized events such as SESAR Innovation days.

In execution phase, the focus was to provide more detailed information, present achievements and provide technical information to interested audience and important stakeholders. To support this, the AAL2 website was created, published, and regularly updated: **aal2demo.eu.** Communication materials were also shared with SJU communication department before publishing.

With valuable support of Eurocontrol, the consortium hit also targeted audience in regulatory environment (ICAO NSP group in Montreal, AWPG sub-group of Flight Operations Panel in Brussels.

One of the most important communication tasks was communication to regulatory bodies.

- Several online workshops were done with BAF to support approval of Honeywell's SLS-4000 Block IIS ground station.
- Online workshop with EASA to explain timeline, concept, and deal with Q&A regarding Honeywell's SLS-4000 Block IIS ground station.
- Several online workshops with LBA to support operational approval for Lufthansa

- F2F meeting with Irish regulator IAA to support operational approval for Ryanair
- AAL2 also became a valuable member of new sub-group under International GBAS Working.Group. The motivation of this sub-group is described in Appendix A, 5.2.
- F2F meeting with French authority DSAC to support operational approval for Le Bourget
- F2F meeting with Belgium Authorities BCAA, BSA
- F2F meeting with Swiss authorities FOCA
- EASA rulemaking was regularly kept informed of the AAL2 WP3 progress through the participation of an AAL2 stakeholder to the RMT0379.

List of performed communication activities:

Activity	Date	Comment
Press Release - AAL2 Project Kick-off	2018	Consortium members and SESAR JU distribution lists
World ATM Congress - Madrid	2018, 2019	HON+ DAV presented
Information Leaflet - General Project Info	2018	More than 500 leaflets printed
AAL Website update with AAL2 general info	2018	
SESAR Innovation Days	2019	AAL2 leaflets was distributed
LATO, Landing and Take Off Focus group of EUROCONTROL	2018, 2019	HON + DAV presented
IGWG, International GBAS Working Group	2018, 2019	HON presented
EBACE – European Business Aviation Conference and Exhibition	2018, 2019	EBAA and DAV presented
F2F meeting with IAA	2019	HON and Ryanair
ATM Seminar	2019	
EASA RMT 379 - Cologne	2019	Dassault presented
ICAO NSP group - Montreal	2019	Eurocontrol presented
AWPG sub-group of Flight Operations Panel - Brussels	2019	Eurocontrol presented
SIAE/PARIS AIR SHOW	2019	DAV presented SESAR AAL2 project and made demo of EFVS Flaconeye
European GBAS alliance	2019	Airbus participated
AAL2 workshop with GSA	2019	WP3 workshop with GSA in Prague

European Research and Innovation days (EC)	2019	Dassault presented SESAR AAL2 project and made demo of EFVS Flaconeye
ICAO "Flight Ops" Panel	2019	Eurocontrol presented
AAL2 Workshop with ARC	2019	ARC invited to AAL2 F2F meeting
European Space Week	2019	AAL2 poster
Eurocontrol Airport Conference	2020	DAV & skeyes had a stand to present EFVS demo and ADR exp approval
Note: Targeted events planned beyond February 2020 were cancelled due to COVID-19 crisis (World ATM Congress, IGWG 2020). Video illustrating WP3 activities will be published in Autumn 2020. Presentation materials were shared with SJU via Stellar.		

6.2 Target Audience Identification

The AAL2 communication activities provided visibility around the SESAR2020 Programme's support for several promising aircraft landing technologies and the benefits foreseen for the aviation community and the wider population, strengthening the "Seeing is believing" message.

There was a wide targeted audience of AAL2 project across the airspace industry including:

- Institutional decision makers (LBA, IAA, BAF)
- Airspace users (pilots, controllers, technical),
- Organisational (ICAO, EASA, EUROCONTROL, EC, EUROCAE),
- Industry partners (Airframe and Avionics, ATC Systems),
- ANSP,
- Broader European R&D community

Partner´s web sites and communications capabilities were used.

Solution	Audience
GBAS	Institutional decision makers, hubs, larger and medium sized airports, Airspace users, ANSPs, Regulatory bodies

EFVS	Small/ medium sized aerodrome operators and bizav or regional air operators affected by adverse weather conditions, ANSPs, AWO community, Network Manager, EASA and NAAs

6.3 High Level Messages

AAL2 project consists from 12 partners and 2 solutions with specific stakeholders and objectives. To be consistent in communication, the project's key message was defined and based on the list of targeted audience that was created.

The project´s high level message was disseminated:

1. Provide Important Benefits: Improved accessibility will alleviate airport and airspace traffic, in congested, low-visibility conditions, and provide better connectivity throughout the European regions, as well as associated environmental benefits. This can be validated by demonstrating the feasibility of several advanced landing procedures at all types of airports, from all types of Airspace Users, based on augmented technologies (GBAS, SBAS and EFVS).

2. Complement Current Limited Systems

The project paved the way for the uptake of the demonstrated technologies, which are needed to overcome limitations of the current Instrument Landing System (ILS) equipment, which is costly to install and maintain, in particular at regional airports or large multi-runway hubs. It demonstrated solutions adapted to each operational environment, from small regional airports to main hubs, including business aviation, regional aviation and mainline.

3. Contribute to ATM Modernisation by Speeding-up Deployment:

During the AAL2 project, the supporting technologies/operations under development/certification are demonstrated and validated in conjunction with new airport adaptations realized in the frame of that AAL2 project.

7 References

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

[1] ICAO Annex 10, Volume 1, "Aeronautical Telecommunications – Radio Navigation Aids".

[2] ARP 4761, "Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment".

[3] EUROCAE ED-109, "Software Integrity Assurance Considerations For Communication, Navigation, Surveillance And Air Traffic Management (CNS/ATM) Systems".

[4] EUROCAE ED-114A Minimum Operational Performance Specification (MOPS) for Global Navigation Satellite Ground Based Augmentation System (GBAS) Ground Equipment to Support Category I Operations, Change 1, October 2017.

[5] ICAO DOC 8071, Volume 2 "Manual on Testing of Radio Navigation Aids – Testing of Satellite-based Radio Navigation Systems".

[6] ICAO DOC 8168 "Procedures for Air Navigation Services - Aircraft Operations".

[7] ICAO DOC 9365 "Manual of All-Weather Operations".

[8] ICAO DOC 9613 "Performance Based Navigation (PBN) manual".

[9] ICAO 9573-AN/937: "Manual of Area Navigation (RNAV) Operations".

[10] ICAO DOC 9613 "Manual on Required Navigation Performance (RNP)".

[11] ICAO EUR Doc 013 "European Guidance Material On All Weather Operations At Aerodromes", Edition 5, September 2016.

[12] NfL II-51/08, Notification concerning the requirements for type-certification of GBAS ground facilities as aeronautical radionavigation stations.

[13] ED-78A Guidelines for Approval of the Provision and Use of Air Traffic Services Supported by Data Communications.[3]

[14] EUROCAE ED-179 — Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems, 2008.

[15] EASA NPA 216/2008, 2018 (in progress under RMT0379). All Weather Operation regulation.

[16] EASA CS 25 -1302-: Certification Specification for large aeroplane -Installed Systems and Equipment for Use by the Flight Crew-

[17] 14-CFR § 91.176 Straight-in landing operations below DA/DH or MDA using an enhanced flight vision system (EFVS) under IFR, Dec 2016.

[18]FAA Advisory circular AC 90-106A Enhanced Flight Vision Systems, 2017.

[19]FAA Advisory Circular AC 20-167A Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment, 2016.

[20]DGT 153396 (DSNA/DASSAULT): SESAR AAL project. EFVS operation with operational credit. Impact on ATM-aerodromes.

[21]ICAO – Guidance on the Balanced Approach to Aircraft Noise Management, Doc 9829

[22]ECAC – Report on Standard Method of Computing Noise Contours around Civil Airports, ECAC.CEAC Doc 29.

[23]ISO – Acoustics – Procedure for describing aircraft noise heard on the ground, ISO 3891.

[24]DLR, Numerical Simulation of Aerodynamic Noise with DLR's aeroacoustic code PIANO, 2008.

[25]DLR, Evaluation of Simulator and Flight Tested Noise Abatement Approach Procedures, 2008.

[26]DLR, Noise prediction toolbox used by the DLR aircraft noise working group, 2013.

[27]SESAR 2020 Communication Guidelines 06.00.00 [19/01/2017].

[28]783112, AAL2 Grant Agreement, [22/12/2017].

[29]ATM Master Plan, data set 17b, 28/01/2018.

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

[31]SESAR 06_08_05-D11, GBAS CAT III OSED update for V3, “GBAS CAT II-III Functional Descriptions Update Report-update for V3”, 0.01.01, 30/06/2015.

[32]SESAR 15.03.06-D20-002, GBAS GAST D ConOps Final, 00.01.00, 18/07/2012.

[33]SESAR 9_09-D24, RNP to xLS Operational Concept Document – final, 00.01.00, 19/09/2014.

[34]SESAR P06 08 08 D07, Enhanced Arrival Procedures Enabled by GBAS - OSED Consolidation, 00.01.01.

[35]Precision approaches using GBAS CAT II/III based on GPS L1, Contextual note - SESAR solution description form for deployment planning, Release 4 SESAR Solution #55

[36]Precision approaches using GBAS CAT II/III based on GPS L1, SESAR Solution Regulatory Overview - final, 12/11/2015.

[37]GBAS CAT III OSED update for V3, “GBAS CAT II-III Functional Descriptions Update Report-update for V3”, 0.01.01, SESAR 06.08.05 – D47, 30/06/2015.

[38]OFA 01.01.01 GBAS CAT III L1 Safety Assessment Report, 00.01.00, SESAR 15.03.06-D22, 28/01/2015.

[39]GBAS GAST D ConOps Final, 00.01.00, 15.03.06-D20-002, 18/07/2012.

[40]Ground Architecture and Airport Installation, 00.01.00, SESAR 15.03.06-D04, 21/03/2013.

[41]GBAS CAT II/III Operational Validation Input for Business Aircraft, Flight Test and Simulations, 00.01.00, SESAR 9.12, 03/03/2015.

[42]Enhanced terminal operations with RNP transition to ILS/GLS, Contextual note – SESAR Solution description form for deployment planning, Release 5 SESAR Solution ID #09.

[43]Enhanced terminal operations with automatic RNP transition to ILS/GLS, SESAR Solution Regulatory Overview, 01.00.00, 3/11/2016.

[44]Enhanced Arrival Procedures Enabled by GBAS - SPR – Consolidation (RNP Transition to xLS), 00.01.02, 06.08.08 – D04, 14/11/2016.

[45]Enhanced Arrival Procedures Enabled by GBAS - INTEROP – Consolidation, 00.01.02, 06.08.08 – D05, 14/11/2016.

[46]RNP to xLS Operational Concept Document – final, 00.01.00, 9.09 - D24, 19/09/2014.

[47]Enhanced Arrival Procedures Enabled by GBAS - OSED Consolidation, 00.01.01, 06.08.08 - D07, 21/09/2016.

[48]RNP to xLS Architecture – final, 00.01.00, 9.09 - D26, 08/10/2014.

[49]01 CN EFVS in HUD in LVC – Contextual note - SESAR solution description form for deployment planning, Release 7 SESAR Solution #117.

[50]LSD.02.02 - Augmented Approaches to Land – Final Demonstration Report B2, 02.00.00, 16/11/2016.

[51]SESAR 16.06.05 D 27 HP Reference Material D27.

[52]SESAR 2020 Project Handbook, edition 01.00.01, [27/04/2017].

[53]SESAR Requirements and V&V guidelines.

[54]SESAR Safety Reference Material, Edition 4.0, April 2016.

[55]SESAR ENV Assessment Process 4 (ERM methodology update), Project 16.06.03, Deliverable D27, 12/05/2016.

[56]SESAR 2020 VLD – AAL2 Demonstration Plan 01.01.00 2nd Review, December 2018.

Appendix A Demonstration Exercise EXE-VLD-V4-100 Report

This Appendix presents the detailed analysis and assessments on the objectives from EXE_VLD-V4-100.

See document "Appendix A to SESAR 2020 AAL2 DEMO Report".

Appendix B Demonstration Exercise EXE-VLD-V4-200 Report

This Appendix presents the detailed analysis and assessments on the objectives from EXE_VLD-V4-200.

See document "Appendix B to SESAR 2020 AAL2 DEMO Report".

Appendix C Safety Assessment Report (SAR)

This Appendix presents the detailed safety analysis and assessments on the objectives from EXE_VLD-V4-100 and EXE_VLD-V4-200.

See document "Appendix C and D to SESAR 2020 AAL2 DEMO Report".

Appendix D Security Assessment Report (SecAR)

This Appendix presents the detailed Security analysis and assessments on the objectives from EXE_VLD-V4-100 and EXE_VLD-V4-200.

See document "Appendix C and D to SESAR 2020 AAL2 DEMO Report".

Appendix E Human Performance Assessment Report (HPAR)

This Appendix presents the detailed Human Performance analysis and assessments on the objectives from EXE_VLD-V4-100 and EXE_VLD-V4-200.

See document "Appendix E to SESAR 2020 AAL2 DEMO Report".

Appendix F EXE-VLD-V4-100 Assessment of differences between approaches with ILS and GLS

This Appendix presents the detailed assessments of differences between approaches with ILS and GLS for objective EXE_VLD-V4-100.

See document “Appendix F, G, H and I to SESAR 2020 AAL2 DEMO Report”.

Appendix G EXE-VLD-V4-100 Cost Efficiency Study of GBAS Considering CAT II Approach Operation

This Appendix presents the detailed cost efficiency study for objective EXE_VLD-V4-100.

See document “Appendix F, G, H and I to SESAR 2020 AAL2 DEMO Report”.

Appendix H EXE-VLD-V4-100 RNP to GLS CAT I Approach Charts (EDDW)

This Appendix presents the RNP to GLS CAT I Approach charts for objective EXE_VLD-V4-100.

See document “Appendix F, G, H and I to SESAR 2020 AAL2 DEMO Report”.

Appendix I EXE-VLD-V4-100 Compliance Matrix to SESAR Solution #55

This Appendix presents the compliance matrix to SESAR Solution #55 for objective EXE_VLD-V4-100.

See document “Appendix F, G, H and I to SESAR 2020 AAL2 DEMO Report”.

Appendix J EXE-VLD-V4-200 Weather Impact Analysis on EFVS Operations

This Appendix J to the SESAR 2020 AAL2 Demonstration Report for Augmented Approaches to Land 2 project analyses the weather impact on landing operations for objective EXE-VLD-V4-200.

See document "Appendix J, K and L to SESAR 2020 AAL2 DEMO Report".

Appendix K EXE-VLD-V4-200 De-generalizing Instrument Approach Minima to Non-Instrument Runways

This Appendix K to the SESAR 2020 AAL2 Demonstration Report for Augmented Approaches to Land 2 project describes De-generalizing instrument approach minima to non-instrument runways for objective EXE-VLD-V4-200.

See document “Appendix J, K and L to SESAR 2020 AAL2 DEMO Report”.

Appendix L EXE-VLD-V4-200 Performance Prediction Analysis

This Appendix presents the detailed performance prediction analysis and assessments on the objectives from EXE_VLD-V4-200.

See document "Appendix J, K and L to SESAR 2020 AAL2 DEMO Report".

Appendix M VLD progress towards TRL-7

During planning and execution, the AAL2 project worked on demonstration of two technologies while making use of SESAR Solution #55 and Solution #117. As the scope of demonstration was not exactly matching these solutions and, in some instances, built on new enhanced capabilities not available in current Solution definition, upon agreement with SJU before DEMR delivery, and by considering criteria to establish new solution and technical achievements of the AAL2 project as well as work done before and outside SESAR project, the AAL2 provides two new SESAR Solutions. As the AAL2 project was by its scope and work performed a demonstration project focusing on VLD objectives, it will not provide typical IR project deliverables. However, it delivers at the same time two new SESAR solutions and as such was proposed to be assessed at V3. Therefore, VLD progress towards TRL 7 chapter is not relevant.