Final Demonstration Report (B2)

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Abstract

This is the Demonstration Report on the Augmented Approaches to Land project, AAL. This Large Scale Demonstration project has shown 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. The demonstrated technologies were GBAS – Ground Based Augmentation System, RF Legs - Radius to Fix legs, SBAS – Satellite Based Augmentation System, SVGS – Synthetic Vision Guidance System, and EFVS – Enhanced Flight Vision System technologies. Project targeted also airspace users without their own Flight Operation Centre providing EFP&AI (Enhanced Flight Planning & Advanced Information). Over 360 successful demonstration flights were performed comprising revenue flights as well as flight test aircraft. Flights took place at small/medium airports (Bergerac, Perigueux, Groningen, Ostrava, Brno, Karlovy Vary and Bremen) and large airports (Frankfurt, Zurich). Using

data collected during demonstration campaign, the accuracy as well as feasibility of advanced procedures (from pilots and ATC perspective) were evaluated. In addition to that, noise measurement evaluation for the RNP to xLS procedures performed in Frankfurt, as well as EFVS testing in the Fog Chamber, Full Flight Simulator and real flights. All trials were supported by several benefit simulations and benefit studies focusing on environmental impact, cost benefits or airport accessibility and capacity aspects. Thanks to the synergy of various stakeholders present in the project consortium this deliverable provides a holistic view on the wide range of technologies and their capabilities with the goal to help speed up their deployment. It can be said, above all, that the demonstration flights in this AAL project brought a positive impact to acceptance of this new technology by the market. This will stimulate an increased deployment in the market, through which it will enjoy much faster the actual realization of the benefits, and thus support the ultimate goal of SESAR ATM modernization.

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This deliverable consists of SJU foreground.

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Executive Summary

This is the Demonstration Report for the SESAR Large Scale Demonstration LSD.02.02 Augmented Approaches to Land (AAL) project.

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 savings, and increasing the traffic throughput at airports. Through those large scale demonstrations, and the participation of all possible stakeholders, the AAL 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 ultimate goal of ATM modernization.

This project addressed the full 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 trial flights in such variety of operational conditions that the obtained results will be appealing, relevant, and applicable for the majority of the European airports.

The demonstrated technologies were GBAS (Ground Based Augmentation System), SBAS (Satellite Based Augmentation System), RNP with RF Leg, SVGS (Synthetic Vision Guidance System) and EFVS (Enhanced Flight Vision System). In addition, the AAL project targeted also airspace users without their own Flight Operation Centre providing EFP&AI (Enhanced Flight Planning & Advanced Information).

All the demonstrations within have been prepared, exercises, and validated for their benefits by the LSD.02.02 AAL Project members. Those comprised ANSPs (ANS CR, DFS, DSNA and Skyguide), airspace users (EBAA, Lufthansa, NetJets, SWISS), airframe manufacturers (Airbus, Dassault Aviation), avionics suppliers (Elbit Systems, Honeywell), airport operators (Fraport, Zurich Airport) and procedures design focused members (DLR).

Spread over the years 2015 and 2016, the targeted total number of trial flights was over 200. Total of 360+ demonstration flights were performed by a wide variety of aircraft and at well selected set of airports spread all over Germany, France, Switzerland, the Netherlands and the Czech Republic.

Throughout the execution of this project, the overall perception of the benefits of the demonstrated technologies has changed. These SESAR technologies will indeed support a growth in operational availability of airports and make approaches and landings possible where today restrictions may apply.

WP1 – GBAS/SBAS Advanced Procedures (RNP to xLS)

The RNP with RF leg advanced procedures were successfully demonstrated in major hubs, and smaller airspaces, and shown feasible from ATC, pilots' and accuracy perspectives.

Large number of demonstration approaches were conducted with different aircraft types (A320 family, A380, B747-8, F900) on revenue flights with Lufthansa and Swiss and as experimental flights by Honeywell. These include 206 RNP to GLS, 40 RNP to ILS, and 22 RNP to LPV approaches, which were analysed in detail by the respective partners. The feedback from ATC as well as pilots' show the procedures as feasible with number of lessons learned and recommendations that are summarized. GBAS was used for RNP to GLS demonstrations at all the three airports, and in Frankfurt both RNP to GLS and ILS were used.

For Frankfurt and Bremen, DFS designed and published ICAO compliant RNP 1 initial and intermediate approaches including RF leg in the initial segment with transition to ILS or GBAS final with increased glideslope of 3.2 degrees and 3 degrees. In Zurich, the project was challenging the current conservative ICAO criteria for intermediate segment requiring a straight in segment before the Final Approach Point. Skyguide designed RNP 1 initial and intermediate approach segments including RF legs in both segments, with the RF leg in the intermediate segment connected directly to the GBAS final approach with increased glideslope of 3.2 degrees.

All the approaches were performed during nominal wind and temperature as well as operational conditions. A number of corner cases tests were performed to test large vertical and lateral deviations with the business aircraft, testing a new FMS function to improve capture during larger vertical and lateral errors and improving continuous descend operations under all conditions.

Fraport installed a number of noise measurement stations, and conducted a thorough noise analysis study, confirming again noise decrease with increased glideslope and recommendations on RF leg placement due to noise.

The main project KPAs, with respect to environment noise impact (Frankfurt), fuel efficiency (length of approach path) and safety in terms of flight accuracy were successfully met.

The GBAS/SBAS procedure interoperability study, and the cost effectiveness of publishing a SBAS LPV approach overlay to a GBAS approach was evaluated and shown during interviews with DFS procedure designers and in-house expertise from DLR/Skyguide/DFS and NetJets. Also, NetJets and DLR analyzed the benefits of RNP to LPV procedures for satellite business aviation airports near major hubs, taking the example of Egelsbach, and provided recommendations.

Below is a short summary of the main results. Please refer to Section 8.1 and Appendix B for full explanation of the aspects and recommendations.

With respect to **WP1 GBAS/SBAS Advanced Procedures (RNP to xLS),** 5 KPAs were evaluated. Four of these KPAs – Safety, Environmental/Fuel efficiency, Human Performance and Accessibility were rated OK based on the achieved results.

Safety:

- The **horizontal flight accuracy** (TSE and/or FTE) results for the RNP part were in general very accurate and well within the required CTQ of **1NM, in general usually well within 0.3NM**.
- For **vertical flight accuracy**, the flights were **within the requirements** – i.e. no descend below FAP constraint minus 100ft considering temperature compensations.
- Some of the Frankfurt mainline aircraft approaches seem to be going over the CTQ limit, but there is always an explanation provided (e.g. ATC vectoring) and corresponding lessons learned in Appendix B.

Environment/Fuel Efficiency:

- **The SESAR P6.8.8 confirmed that curved approaches can be designed to reduce the amount of population impacted by noise. However, the noise emission levels for curved approaches versus straight in continuous descent approaches** measured in the last RF leg prior the RNP to xLS transition resulted in higher sound emission at the aircraft (up to 2dB), due to differences in flap and power settings during turns and the transition.
- To maximize the benefits of these curved procedures by facilitating continuous descent operations below 7000 feet above the ground, a set of lessons learned and recommendations are proposed, such as procedure design recommendations, better management of procedure sequencing on FMS, , as well as new aircraft functions for automatic RNP to xLS transition.
- Concerning **noise exposure level** (at the monitoring terminal on the ground) the benefits of increased glideslope showed **0.75 dB decrease** in noise on the ground.
- Potential benefits were observed during simulations for **the fuel and CO2 emission** using the new RNP procedures with increased glideslope in both test cases (Zurich, Bremen). Savings are primarily given by the difference between the lengths of the legacy conventional/RNAV to ILS and the new curved RNP procedures which were designed to be shorter in the investigated airports. ***Results range between 14 – 57% of saved fuel and CO2***. *Note 1: Simulation results only, based on the difference between the legacy and the new procedure flight tracks, without the consideration of potential ATC vectoring activity. Note 2: Outside of the simulations, a basic analysis (non-scientific study) of the real data was performed for revenue aircraft in Frankfurt and indicated positive results in the sense that for some of the aircraft there is even lower fuel burnt on the new procedures. However, statistical significance of this basic evaluation is only very limited.*

Human Performance:

- The RNP to xLS procedures together with increased glideslope to 3.2 degrees were in general **perceived as feasible from both pilot and ATC perspective** which was shown with over 268 of successful demonstration flights. *Note 1: However, the integration of RNP to xLS procedure in a complex environment needs further work. Note 2: Procedures with an increased glide slope of 3.2-degrees were demonstrated on A320 family and F900 aircraft types.*
- Number of **lessons learned, recommendations on trainings for pilots, ATC and procedure designers** is summarized in Section 8.1.

Accessibility:

- The SBAS/GBAS interoperability study from a procedure design perspective shows that the **additional effort and cost** for implementing jointly GLS together with LPV approach types **is manageable and affordable**.

Fuel efficiency of specific arrival through complex TMA in satellite airport:

- The case study of Egelsbach close to Frankfurt Main shows that using the future concept of Visual RNAV would enable to propose an expeditious and realistic flight path from above Frankfurt Main down to Egelsbach final approach, which stays completely in airspace Charlie, and **shows a potential fuel efficiency benefit of -30%** (from the top of descent at FL300 to the landing into EDFE) when this visual operation can be performed.

Conclusions and recommendations were prepared also for training of ATC and crew, charting as well as standardization.

WP2 – SVGS Advanced Procedures

The SVGS technology was successfully demonstrated in European environment on a number of ILS as well as LPV approaches, and shown feasible from pilots' as well as ATC and technical perspectives.

The goal of these demonstrations is to further speed up deployment of these procedures within Europe as well as outside. In total 74 approaches were flown with Honeywell experimental F900EX, 23 in Ostrava (LKMT), 40 in Brno (LKTB) and 11 in Karlovy Vary (LKKV), all successful. In total 45 ILS 200'-50'DH and 29 LPV 250'-50'VTH approaches were performed. Some approaches were flown with autopilot coupled and some were flown manually. Honeywell Falcon 900 experimental aircraft was equipped with SVGS and with all required features to demonstrate benefits of SVGS operations to touchdown and rollout concept of operations. Using data collected during demonstration campaign, good accuracy as well as feasibility of SVGS advanced procedures from pilots' perspective were confirmed. Data also confirmed that GNSS based systems are not susceptible to the terrain distortion and navigation is smoother (comparing ILS and LPV approaches). Regarding the perceived level of feasibility, the pilots flying the SVGS approach reported low workload scores during the approach and landing phase. The subjective data collected during the demonstration confirmed the feasibility of the SVGS approach.

During the project, Honeywell has worked with the Czech Aviation Authority (CAA) and ANS CR to receive approvals for the SVGS trials, as well as to receive a special waiver to fly in low visibility conditions. The waiver was granted based on Safety assessment provided to the regulator. ANS CR assessed the safety for airport operations and supplied overall documentation for approval to the CAA and supported the trials. Work was also conducted with the FAA, mainly with respect to discussions on SVGS on LPV, assumptions on the constellation fault modes, as well as other requirements that would be applicable. The work is still ongoing.

In order to support the demonstrations by evaluating the SVGS benefits, three benefits studies/assessments were performed. Environmental Benefits Assessment considered three potential impacts of Low Visibility Conditions (LVC) for a flight - delay, diversion and cancellation. Study showed that the combination of SVGS and EFVS helps to significantly increase the number of on-time arrivals in LVC compared to ILS, resulting also with fuel savings and less CO_2 emissions. Airport Eligibility Assessment confirmed that percentage of airports in the Czech Republic and Slovakia with instrument 3D approaches that are eligible to SVGS operation is 100%. Crew Qualification Cost Assessment showed significant potential savings for SVGS compared to ILS CAT II.

Below is a short summary of the main results. Please refer to Section 8.2 and Appendix C for full explanation of the aspects and recommendations.

With respect to **WP2 SVGS Advanced Procedures,** 5 KPAs were evaluated. All of these KPAs – Safety, Environmental/Fuel efficiency, Human Performance, Airport Capacity and Cost-effectiveness were rated OK based on the achieved results.

Safety:

- The **horizontal flight accuracy** (TSE) results were well within the CTQ value of ±1 dot. The deviation for the lateral direction was **always within ±0.4 dot**.
- For **vertical flight accuracy**, the flights were **within the requirements of** ±1 dot for the vertical direction within **usually within ±0.4 dot and maximum within ±0.7 dot**. Larger deviations were usually caused by various environmental conditions (wind, etc.) and were usually manually flown.
- With respect to the **landing performance**, all landings were well within defined CTQ value, i.e. **inside the touchdown zone of particular runway (the first third of the runway).**

Environment/Fuel Efficiency:

- **Reduction of number of diversions and delay**: Results based on analysis and simulations using data from five airports with predominant regional and business traffic, showed that the combination of SVGS and EFVS helps to **increase the number of on-time arrivals in LVC (4.84% of time) compared to ILS by at least 33%, and saves 127 kg of the fuel and 401 kg of CO2 emission per flight in LVC.**

Airport Capacity:

- Within the airport Eligibility Assessment, it was concluded that the number of airports in the Czech Republic and Slovakia with **instrument 3D approaches** that are **eligible to SVGS operation is 100%**.

Human Performance:

- The demonstration **confirmed the feasibility of the SVGS approach** as evidenced by the modified Cooper-Harper ratings from pilot perspective. The CTQ value, which was set to 95% of approaches are feasible based on feedback form pilots, was met.

Cost-effectiveness:

- Crew qualification cost can be reduced by the SVGS utilization since CAT II training is not foreseen when using SVGS (it is envisioned that some initial SVGS training would be required). Assuming 10 years of SVGS usage, total cost for CAT II training is $25,000 and for SVGS $12,000. **This represents 52% cost savings ($13,000)** which is well above the CTQ (20%).

WP3 – EFVS Advanced Procedures

For the EFVS, a study conducted jointly with DSNA and consolidated by a flight test demonstrated the adequacy of the aerodrome/ ATM procedure proposed for low visibility, even for small/ AFIS airports. 60 runs performed in the F8X full flight simulator by FLYING GROUP, DASSAULT and AIRBUS pilots in normal and abnormal conditions demonstrated the overall robustness of the EFVS to land concept of operation, even in the most critical situations. 6 approaches flown by DASSAULT aviation falcon 7X experimental aircraft in visibility conditions as low as RVR 300m demonstrated the benefits of the EFVS to land concept and confirmed that the operation is both feasible without any excessive difficulty and safe. Fog Chamber activities and flight test data confirm that EFVS performance prediction is achievable. The EFVS performances prediction method had been evaluated with SESAR flight test sample which is however too small to fully validate the prediction table. In addition to trials, a broad weather analysis and an IFR procedure review have confirmed the potential benefit of the EFVS to land concept of operation, and determined to what extent this concept could increase the access to secondary airports in low visibility conditions, and consequently decreased congestion at nearby main hubs. At this time, EFVS demo flights in low visibility are continuing over Europe to cover more conditions till end of October. Aerodrome/ ATM low visibility procedure that was shared with EASA (and FAA) will be presented to ANTWERP airport the 26th of October 2016.

Below is the summary of main results. Please refer to Section 8.3 and Appendix D for full explanation of the aspects and recommendations.

With respect to **WP3 EFVS Advanced Procedures,** 4 KPAs were evaluated. All of these KPAs – Safety, Environmental/Fuel efficiency, Human Performance and Airport Capacity were rated OK based on the achieved results.

Safety:

- **Crew workload reduction.** Results indicated the procedure is feasible even with abnormal cases and in manual. The global workload is within CTQs limits which corresponds to 70% on a Lickert adapted scale used for the tests. To alleviate workload that may remain high in manual, autopilot and autothrottle use are recommended for this low visibility operation.
- The **horizontal flight accuracy** (TSE) was well within the CTQ value of ±1 dot.
- For **vertical flight accuracy** (TSE) was well within the CTQ value of ±1 dot.
- With respect to the **successful touchdown**, all landing were safe and terminated in touchdown zone.

Environment/Fuel Efficiency:

- **Reduction of number of diversions and go around**. Considering a 2016 EFVS state of art sensor and the 2014 weather statistics in Europe, an EFVS to land concept down to RVR 300m would have permit to save 60% of the RVR < 800m or ceiling < 200ft situations that would have resulted in GO AROUND or diversion otherwise. From a concept standpoint, a full weather conditions system capable would have permit to erase 85% of the RVR<800m situations, demonstrating the big potential for such a concept in the future. In addition, SESAR AAL demonstrated that the prediction of performance is achievable for homogeneous fog with a quite good confidence level of 30%, contributing to limit the number of GO AROUND or diversion.

Airport Accessibility:

- Regarding the capacity of secondary aerodrome to accommodate EFVS to land operations in RVR lower than 550m, SESAR study conducted jointly with DSNA have proposed adequate aerodrome/ ATM recommendations that have been well received by EASA. From a deployment perspective, SESAR has demonstrated that these recommendations could be envisaged without any installation modification or significant procedure changes at the three regional/ secondary airports (Bergerac/LFBE, Bordeaux/LFBD and Périgueux/LFBX), as well as at Antwerp/EBAW airport.
- Within the airport Eligibility Assessment, it was shown that 89% of the French airports dedicated to civil aviation and having at least one IFR approach procedure are eligible EFVS to land, and this number will significantly growth in the coming years with the deployment of the PBN. More than 1/3 of the airports eligible EFVS to land are managed by AFIS.
- For the small/medium airport visibility capacity enhancement, the latest generation of IR-visual based EFVS using several sensors and advanced fusion algorithm provides optimized signal to noise ratio and enhanced performance. As an example, enhanced RVR provided by such an advanced system is at least 420m for RVR of 300m in homogeneous FOG conditions. Performance increase is expected in the coming years as new market-ready technologies will come on line.

Human Performance:

- Perceived level of feasibility of EFVS to land from pilots' perspective was successfully evaluated with RVR300m. All the abnormal cases were timely detected by the crew and resulting in an appropriate decision to go-around. No negative impact on safety and human factors was observed. Clear briefing of the operation and Training with potential deficiencies of the system is recommended. SESAR AAL exercises confirmed that the Dual HUD and CVS solutions proposed by DASSAULT were considered as valuable features for this operation by demonstrating an effective crew decision making and a far better Situation awareness than with EVS only.

WP4 – Enhanced Flight Planning

For the enhanced flight planning system positive feedback was received from pilots' and other aviation experts evaluating the tool during AAL project.

The flight planning system (EFP&AI) utilizes detailed aircraft performance data combined with the current atmospheric forecast. These inputs assure very precise calculations of flight time and fuel consumption on every flight plan created. Successful WP4 demonstrations helped to show how flight planning system brings complex tools for worldwide flight planning and to provide simple and intuitive control and to make the work of users easier and more efficient. Criteria determined in the Demonstration Plan were successfully met and positive feedback was obtained by participants during evaluations. This big variety of experts involved in the demonstrations together with realistic environment ensured significance and very good quality of demonstrations results.

Below is a short summary of the main results. Please refer to Section 8.4 and Appendix E for full explanation of the aspects and recommendations.

With respect to **WP4 Enhanced Flight Planning,** 1 KPAs were evaluated. Human performance with respect to perceived level of feasibility from Pilot's perspective was rated OK.

<u>Human Performance:</u>

- Evaluation of the perceived level of feasibility of EFP&AI technology from pilots' perspective, showed positive feedback, using Osgood's semantic methodology and Likert-type scale.

1 Introduction

This section provides the basic information for this document. Firstly the purpose will be described in Section 1.1. Then intended readership followed by a structure of the document will be mentioned in Sections 1.2 and 1.3. Finally Glossary of terms, acronyms and terminology will be included in Sections 1.4 and 1.5.

1.1 Purpose of the document

This document provides the Demonstration Report for LSD.02.02 AAL Project targeting the contribution to OFA 01.01.01 “LVPs using GBAS”, OFA 02.01.01 “Optimised 2D 3D routes”, OFA 01.01.02 ”Pilot Enhanced vision” and OFA AIM “Aeronautical Information Management”. It describes the results of demonstration exercises, defined in SESAR LSD.02.02 Demonstration Plan 2nd Review (A2) [27], and how the exercises have been conducted.

The scope of this project was targeted at demonstrating 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. Some trials were executed at large and medium airports where Ground Based Augmentation Systems are available, other trials were performed at small and medium sized airports benefitting from Satellite Based Augmentation Systems and augmented aircraft capabilities.

A variety of technologies, aircraft platforms, airlines, airport operators, air navigation service providers, and flight procedure designers supported the trial flights and were used in such way to cover two important flight segments; namely the transition from approach to landing, and then the landing itself.

Figure 1: RNP to GLS (red curve)

Figure 2: Landing at low visibility

For the first part of the project scope, the flight segment that brings the transition from approach to landing, the project relied on RNP to GLS technology (Figure 1) with some additional approaches on ILS and LPV. This technology combines the best of two types of technologies, namely an accurate and flexible 3D navigation technology, RNP, with the best out of the available landing aids (ILS, LPV or GLS). The operational benefits of the seamless transition are very clear, while additional benefits can be identified among the used landing aids. The project demonstrated benefits with respect to shorter path, decreased noise, lower fuel consumption and better accuracy of flight path.

For the second part of the project scope, the landing segment, the project addressed SVGS and EFVS technology. These are two complementary concepts aiming at improving the access in particular to small/medium airports in low visibility conditions. When landing at a small/medium airport, the flight crew needs to transition from instrument flight rules, where the Pilot Flying is looking Head Down at the primary flight display or Head-UP at a Head-Up display, to the visual flight rules, where he/she is looking out the window to locate the runway visually. When a landing minimum is published at the airport, the flight crew must have visually acquired the runway at the prescribed Decision Height to land at this airport, or proceed with a go around and eventually divert to another airport. The aim of SVGS is to extend the IFR segment by reducing the Decision Height by 50ft, by providing the flight crew with a Head Down 3D depiction of terrain, specific symbols enabling to improve aircraft position relative to the runway and improved navigation. The aim of EFVS is to extend the visual range by enabling the pilot to see through the clouds or fog, using the sensor image on Head-Up Display, thus reducing the probability of aborted landing. SVGS provides in particular a better assurance that the EFVS sensor will enable identification of the required enhanced visual cues as the aircraft is 50ft closer to the ground.

This project demonstrated through live trials involving all concerned actors the environmental benefits of RNP to xLS and the possibility of SVGS as well as EFVS to land operations to touchdown and rollout operations: increased accessibility to secondary/small airports, reduction in the number of go-around and diversions to alternate runways.

The last part of the project scope (EFP&AI) targeted airspace users without their own FOC (Flight Operation Centre). A tablet based tool enabling remote access to flight planning information, among the others to NOTAM and Weather information, was used. This demonstrated the ability of such solutions to support the future dynamic network operations, also at small and medium sized, even uncontrolled airports. The tool enables access to the existing flight planning interfaces (NMOC – Network Manager Operations Centre). Connection to a NOP (Network Operational Plan) prototype was not in scope of the project.

In the following paragraphs details information on technologies used is provided where further explanation is needed.

GBAS/SBAS Advanced Procedures

The demonstration exercises took place at the airports of Frankfurt, Bremen and Zurich which are equipped with a GBAS ground station. The involved parties, in addition to the airport operators of course, were Lufthansa and SWISS airlines as well as DFS and Skyguide, supported by DLR, Airbus and Honeywell. DFS supported by Airbus ProSky (subcontractor to Airbus) designed RNP to GLS procedures for the airports of Bremen and Frankfurt. In order to demonstrate the comparability of the procedures, RNP to ILS procedures for Frankfurt airport were designed as well, Skyguide designed an RNP to GLS procedure for Zurich airport. The RNP to GLS procedures were flown by Lufthansa and SWISS aircraft equipped with GLS on revenue flights by selected aircrews and with weather conditions permitting. Honeywell also performed RNP to GLS flight trials with its F900 Experimental aircraft. Over the course of the demonstration activity, 277 RNP approaches were flown (100 with business aircraft and 177 with mainline aircraft). 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. 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.

In addition to the RNP to GLS demonstrations, DLR and NetJets conducted a cost benefit analysis on the design of RNP to LPV (SBAS) on the same track and profile as an existing RNP to GLS. This would enable business aircraft, which are often equipped with SBAS but not with GBAS, to fly the same tracks as the RNP to GLS approaches at major airports, but to a LPV minima. This would be beneficial for the seamless integration of business aircraft with airliners at major airports, e.g. Zurich and Frankfurt. Honeywell supported the study, providing inputs on feasibility from business aircraft perspective. Flyability of such procedures was tested using a simulator.

The flexibility of RNP to xLS is expected to provide large benefits at small to medium airports near major hubs, which are mainly used by business aviation. With a RNP procedure including RF legs prior the FAP (Final Approach Point), procedures to those satellite airports can avoid the congested parts of the airspace used by the near-by large airport, while still optimizing the descent profile. However, in many cases this would require an RF leg to intercept the Final Approach Segment of more than the A-RNP 45° maximum course change, and maybe also increased descent angles than the usual 3°. The benefits of those advanced procedures were investigated by DLR, supported by NetJets, and Honeywell using the case study of Egelsbach close to Frankfurt Main.

SVGS Advanced Procedures

The SVGS for Lower than Standard Minima Approach and Landing operational concept presented in EUROCAE ED-179B/RTCA DO-315B is built on the FAA Special Authorization CAT I approach concept authorized in FAA Order 8400.13D. The SA CAT I concept consists in ILS approach with RVR 1400 ft and decision height 150 ft limits with using of CAT II aircraft and crew qualification as well as HUD installation on-board. The SVGS concept adopts the same operational concept, but removes the need for CAT II equipment and crew qualification and HUD installation. The required guidance cues are then provided by the on-board system with the required level of integrity guaranteed by the on-board monitors. At 150 ft above THRE (threshold elevation), the pilot transits to the outside view to reach required visual references to finish the landing manoeuvre in visual segment or perform missed approach.

The revision of RTCA DO-315C (currently under the elaboration) proposes extension of this operational concept also for LPV type of approaches. When authorized, FAA Order 8400.13D will need to be revised.

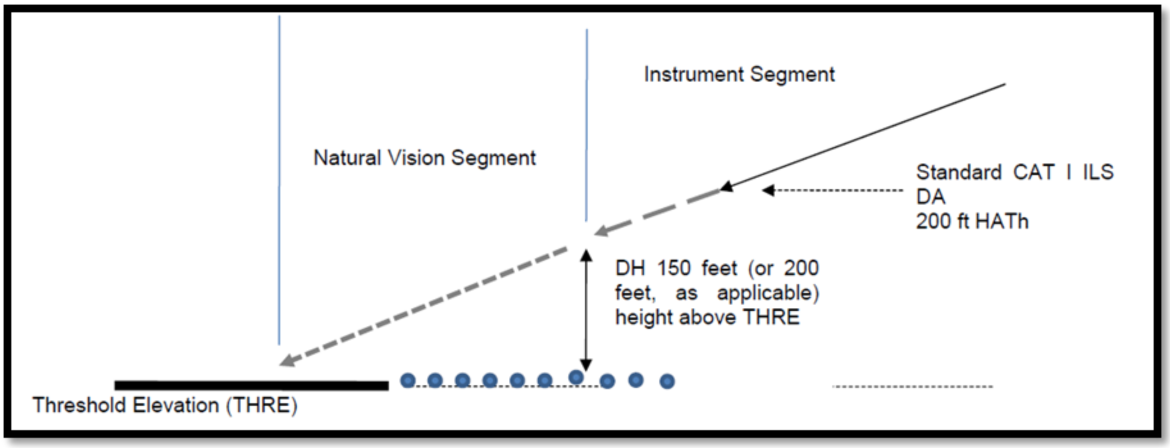


Figure 3: - SVS for Lower than Standard Minima Approach and Landing [source EUROCAE ED-179B]

EFVS Advanced Procedures

The new concept of EFVS to land was recently standardized by the workgroup SC-213 of RTCA and is currently being introduced in US regulations by the Federal Aviation Administration (FAA). This new concept permits HUD symbolism and EFVS sensor image to be relied on from DA/DH through touchdown and rollout. In other words, EFVS can be used in lieu of natural vision to control the aircraft in the visual segment of the approach and on the ground at landing until a safe taxi speed is reached. Of course some specific airborne systems requirements and also some specific operational requirements have been defined for EFVS operations to touchdown and rollout.

The existing EFVS operational gains concept (certified on F7X since July 2010):

- Gain on RVR to begin the mission and then to initiate the approach: RVR gain of 1/3 (EU rules).
- Transition from EFVS to natural vision no later than 100 ft above Threshold Elevation.

The EFVS to land concept:

- In poor visibility condition with RVR not less than 1000ft (300m), to enable to descend below published minimum (DA/DH or MDA) on certain approaches (Straight-in Approaches with approved vertical guidance and vertical minimal – ILS approaches; APV approaches with LPV minima; APV approaches with LNAV/VNAV minima) by use of an approved EFVS to continuously identify the required visual reference down to touchdown and roll-out.

The schematics in Figure 4 and Figure 5 illustrate the EFVS to land concept as compared to EFVS down to 100 ft concept.

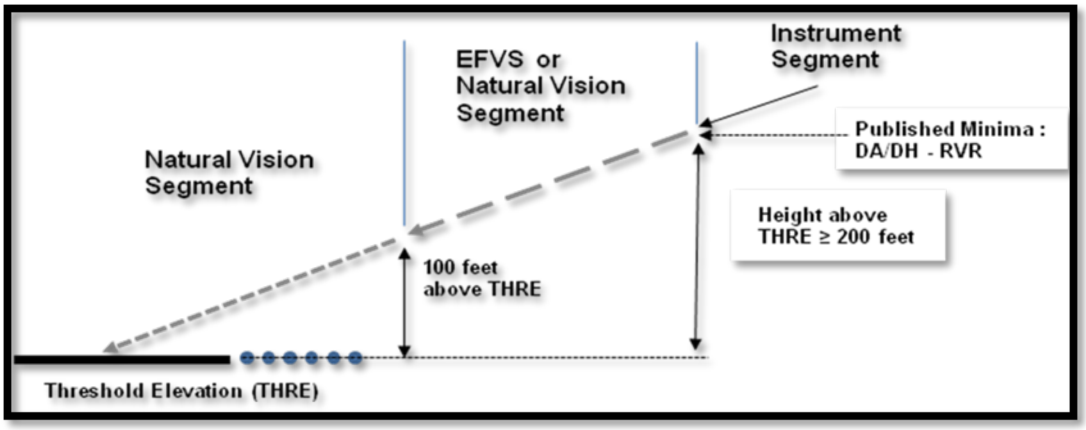


Figure 4: Existing EFVS operation/EFVS down to 100ft [source EUROCAE ED-179B]

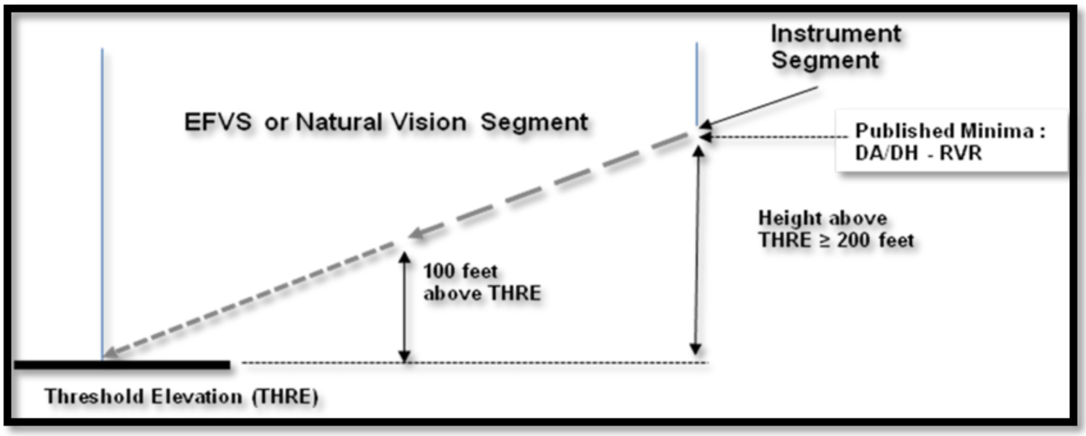


Figure 5: New EFVS concept/EFVS to land operation [source EUROCAE ED-179B]

The benefits brought by this new concept of EFVS operations are substantial:

- Simplified crew procedures when using EFVS resulting in a decrease in crew workload and increase in safety margins.
- Better probability of success when approaching in reduced visibility conditions, so decrease in go-around rate and diversions due to the fact that a predictive assessment of EFVS performance is required and checked against actual weather conditions.

The expected EFVS performance was provided in a table with the following types of inputs:

- Weather conditions:
  - Fog/Mist/Rain/Snow;
  - RVR provided by ATC.
- Time of the day:
  - Night;
  - Dusk;
  - Day;
  - Dawn.
- Type of approach lights (Incandescent/LED).

The output of this table was the “predicted EFVS_RVR”: the predicted Enhanced Flight Visibility, which represent the equivalent RVR brought by the EFVS system. This “predicted EFVS_RVR” is provided by EFVS simulation tool and was available to start the EFVS demonstration (the production of this predicted EFVS table is out of the scope of the tasks of the project).

Enhanced Flight Planning & Advanced Information

Most of the AUs without FOC use third party providers or AUs crew members act as a FOC. Such providers increase AUs expenses and decrease their competitiveness. Crew members are often busy with other activities in the pre-flight stage. Using application with full functionalities and actual data allows them to easy manage all FOC related activities, reduce costs for third party service providers, and save crew time.

1.2 Intended readership

This document is intended for audience interested in the benefits demonstration of the following technologies: GBAS – Ground Based Augmentation System, SBAS – Satellite Based Augmentation System, SVGS – Synthetic Vision Guidance System, EFVS – Enhanced Flight Vision System), EFP&AI - Enhanced Flight Planning & Advanced Information.

The readership also includes SESAR projects 5.6.3, 6.8.8, 9.29, 5.6.3, 9.10, 16.6.3 and WP11.1 as well as parties within OFA 01.01.01, OFA 01.01.02, OFA 02.01.01 and OFA AIM.

This document is also intended to regulators, standardization bodies (ICAO, LATO, EUROCAE WG-28, RTCA SC-213 / EUROCAE WG-79), Eurocontrol, ANSPs, airports, airspace users, avionics suppliers and airframe manufacturers.

1.3 Structure of the document

This document is structured into eight main sections. Section 1 provides 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 2 reminds the scope of the demonstrations. Project management is described by the Section 3. This section presents the project organization, work breakdown structure, list of deliverables and risk management. Section 4 gives an overview of execution of demonstration exercises including exercises preparation and execution. In Section 5 the summary of demonstration exercises results is presented comprising also analysis of exercises results, summary of assumptions and description of the confidence in results. Detailed exercises reports are described in Section 6 and summary of communication plan is detailed in the Section 7. Section 8 then contains conclusions and recommendations. Appendix A summarizes the KPA results. Appendix B – Appendix E then details analysis and studies performed in order to evaluate and make an assessment on the Demonstration Objectives. Appendix G - Appendix I include the approach charts used for demonstration flights and for benefit assessment simulations. Evidence of the communication activities can be found in Appendix J.

It is to be noted that this Demonstration Report consists of the following 6 separate documents (the main document + 5 documents with appendices) due to its size.

- Final Demonstration Report B2 (the main document)
    - Appendix B and G to Final Demonstration Report B2 (WP1 results + WP1 approach charts)
    - Appendix C and H to Final Demonstration Report B2 (WP2 results + WP2 approach charts)
    - Appendix D and I to Final Demonstration Report B2 (WP3 results + WP3 approach charts)
    - Appendix E to Final Demonstration Report B2 (WP4 results)
    - Appendix F to Final Demonstration Report B2 (Experimental Forms)

Also, to ‘Appendix D and I to Final Demonstration Report B2’ 4 attachments to this appendix are included (in the file *“Appendix D and I to Final Demonstration Report B2_attachments.zip*”):

- Appendix D and I to Final Demonstration Report B2_Aerodrome_Test.pdf (‘*SESAR Project - AAL EFVS OPERATION WITH OPERATIONAL CREDIT Impact on ATM-Aerodrome; Experimentation/ Demo flight in Bordeaux/ Bergerac and Périgueux aerodromes*’)

- Appendix D and I to Final Demonstration Report B2_DGT153396.pdf ('*DGT153396: SESAR Project - AAL EFVS OPERATION WITH OPERATIONAL CREDIT; Impact on ATM-Aerodrome*')
- Appendix D and I to Final Demonstration Report B2_ReducedRVR_Study.pdf ('*Analysis of reduced Runway Visual Range and low Ceiling regarding operational minima for European aerodromes usually frequented by Falcon aircrafts - Potential benefit for EFVS concepts*')
- Appendix D and I to Final Demonstration Report B2_SimReport.pdf ('*DEV 110182: Test Report - F8X EVS TO LAND Simulator Evaluation Report*')

It is to be noted that 3 attachments to 'Appendix D and I to Final Demonstration Report B2' (WP3) are classified as confidential and therefore are not included in the deliverable.

1.4 Glossary of terms

This paragraph is gathering definitions necessary to understand the concept of relevant technologies and ensure vocabulary used in this document which is shared by everyone within SESAR. Main definitions are provided in Appendix A of Demonstration Plan [27]. Detailed definitions are provided in the following documents:

- 9.12.D02 [6] (GBAS)
- 6.8.5.D04 [8] (RNP to GLS)
- Koenig [9] (Increased Glideslopes)
- European Satellite Service Provider [11] (SBAS)
- 9.27.D05 [7] (SVGS)
- ED-179B [10] (EFVS)
- D11.1.2-1 [16] (Enhanced Flight Planning & Advanced Information)

1.5 Acronyms and Terminology

Term	Definition
A/C	Aircraft
AAL	Augmented Approaches to Land
AC	Advisory Circulars (FAA)
ACI	Airports Council International
ACJ	Airbus Corporate Jet
ACD	Airworthiness Compliance Document
AFIS	Aerodrome Flight Information Service
AFM	Aircraft Flight Manual
AGL	Above Ground Level
AIM	Aeronautical Information Management
AIP	Aeronautical Information Publication (ICAO)
AIS	Aeronautical Information Services
ANS	Air Navigation Services
ANS CR	Air Navigation Services of the Czech Republic
ANSP	Air Navigation Services Provider
APP	Approach Control
APP/TWR	Approach/Tower
APV	Approach Procedures with Vertical Guidance
A-RNP	Advanced RNP
ASL	Above Sea Level

Term	Definition
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
ATSEP	Air Traffic Safety Electronics Personnel
AUO	Airspace User Operations
AUs	Airspace Users
BA	Business Aviation
C	Contributor
CAA	Civil Aviation Authority
CAT	Category
C-ATM	"Co-operative Air Traffic Management" Project
CAVOK	Ceiling And Visibility OK
CC	Consortium Coordinator
CDA	Continuous Descend Approach
CNS	Communication Navigation Surveillance
CTR	Control Tower
CTQ	Critical to Quality
CVS	Combined Vision System
DA	Decision Altitude
DAS	Dassault Aviation
DB	Database
DFS	Deutsche Flugsicherung (German ANSP)
DH	Decision Height
DIN	“Deutsche Industrie Norm“: German Industry Standard
DLR	Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center)
DME	Distance Measuring Equipment
DOD	Detailed Operational Description
DSNA	Direction des Services de la Navigation Aerienne (French ANSP)
EASA	European Aviation Safety Agency
E-ATMS	European Air Traffic Management System
EBAA	European Business Aviation Association
EBACE	European Business Aviation Conference & Exhibition
EC	Commission Regulation
EDDF	Frankfurt Airport, Germany (ICAO code)
EDDW	Bremen Airport, Germany (ICAO code)
EDFE	Frankfurt-Egelsbach Airport, Germany (ICAO code)
EFP&AI	Enhanced Flight Planning & Advanced Information
EFVS	Enhanced Flight Vision System
EGNOS	European Geostationary Navigation Overlay Service
EHGG	Groningen Airport Eelde, the Netherlands (ICAO code)
E-OCVM	European Operational Concept Validation Methodology
ESARR	Eurocontrol Safety Regulatory Requirements
EU	European Union
EUROCAE	European Organisation for Civil Aviation Equipment
EUROCONTOL	European Organisation for the Safety of Air Navigation

Term	Definition
EXE	Exercise
F2F	Face-to-Face Meeting
FAA	Federal Aviation Administration
FAF	Final Approach Fix
FAP	Final Approach Point
FAS	Final Approach Segment
FCOM	Flight Crew Operating Manual
FCTM	Flight Crew Training Manual
FD	Flight Director
FFS	Full Flight Simulation
FL	Flight Level
FMS	Flight Management System
FOC	Flight Operation Centre
FPV	Flight Path Vector
FSI	FlightSafety International
FTE	Flight Technical Error
G-PAPI	Geometric Precision Approach Path Indicator
GA	General Aviation
GBAS	Ground Based Augmentation System
GLS	GNSS Landing System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GS	Ground Station
GSL	Glideslope
HAGL	Height above Ground Level
HF	Human Factors
HON	Honeywell
HUD	Head-Up Display
IAC	Instrument Approach Chart
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
IFP	Instrument Flight Procedure
IFR	Instrument Flight Rules
I-GWG	International GBAS Working Group (EUROCONTROL)
IF	Intended Function
ILS	Instrument Landing System
ISA	International Standard Atmosphere
JU	Joint Undertaking
KOM	Kick-off Meeting
KPA	Key Performance Area
KPI	Key Performance Indicator
L	Leader
LATO	Landing and Take-off Group (EUROCONTROL)
LASmax	AS-weighted maximum sound pressure level
LFBD	Bordeaux Airport, France (ICAO code)
LFBE	Bergerac Airport, France (ICAO code)

Term	Definition
LFBX	Perigueux -Bassillac Airport, France (ICAO code)
LKKV	Karlovy Vary Airport, Czech Republic (ICAO code)
LKMT	Ostrava Airport, Czech Republic (ICAO code)
LKTB	Brno Airport, Czech Republic (ICAO code)
LNAV	Lateral Navigation
LPV	Localizer Performance with Vertical Guidance
LSD	Large Scale Demonstrations
LSZH	Zurich Airport, Switzerland (ICAO code)
LTP	Landing Threshold Point
LVP	Low Visibility Procedures
MASPS	Minimum Aviation System Performance Standard
MCH	Modified Cooper-Harper Scale/Rating
MET	Meteorological Data
MMEL	Master Minimum Equipment List
MOPS	Minimum Operational Performance Standards
MP	"Messpunkt": Noise Monitoring Terminal
MVA	Minimum Vectoring Altitude
NASA TLX	NASA Task Load Index
NE	North-East
NJ	NetJets
NM	Nautical Mile
NMOC	Network Manager Operations Centre
NMT	Noise Monitoring Terminals
NOP	Network Operational Plan
NPA	Non-Precision Approach
NPRM	Notice for Proposed Rulemaking
NSA	National Supervisory Authority
NSE	Navigational Sensor Error
NSP	Navigation Systems Panel (ICAO)
NW	North-West
OBJ	Objective
OFA	Operational Focus Area
ORE	Operational Risk Evaluation
PANS-OPS	Procedure for Air Navigation Services - Aircraft Operations
PAPI	Precision Approach Path Indicator
PBN	Performance Based Navigation
PF	Pilot Flying
PM	Pilot Monitoring
PMP	Program Management Plan
PPC	Project Point of Contact
PSSA	Preliminary System Safety Assessment
QNH	Q-code (barometric pressure adjusted to sea level)
R	Reviewer
RA	Radio Altitude
RA	TCAS Resolution Advisory
RAI	Runway Approach Indicator

Term	Definition
R&D	Research & Development
RAAS	Runway Awareness and Alerting System
RF	Radius to Fix
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP APCH	Required Navigation Performance Approach
RNP AR	Required Navigation Performance Authorization Required
RPAS	Remotely Piloted Aircraft Systems
RTCA	Radio Technical Commission for Aeronautics
RTS	Real Time simulations
RVR	Runway Visual Range
RWY	Runway
SA	Special Approval
SA	Safety Assessment
SBAS	Space Based Augmentation System
SB	Service Bulletin
SC	Special Committee (RTCA)
SCN	Scenario
SEAC	SESAR European Airports Consortium
SEL	Single exposure level
SEMP	System Engineering Management Plan
SESAR	Single European Sky ATM Research
SESAR Programme	The programme which defines the Research and Development activities and
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SOP	Standard Operational Procedures
SVGS	Synthetic Vision Guidance System
SVS	Synthetic Vision System
SW/HW	Software/Hardware
SWISS	SWISS International Air Lines
SWL	Sub-Work Package Leader
SWP	Sub-Work Package
TCAS	Traffic Collision Avoidance System
TF	Track to Fix
TIU	Test Interface Unit
TL	Task Leader
TLX	Task Load Index
TMA	Terminal Manoeuvring Area
TSE	Total System Error
TWR	Aerodrome Control
VLD	View Limiting Device
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
VTH	Visual Transition Height

Term	Definition
WAC	World Aerospace Congress
WG	Working Group
WOC	Wing Operation Centre
WP	Work Package
WPM	Work Package Manager
xLS	Instrument/Microwave/GNSS Landing System

2 Context of the Demonstrations

In order to relieve the pressure on major European airports during periods of high demand (or low capacity), Business Aviation needs to secure access into small and regional airports in all weather conditions. Airborne augmented reality, through enhanced vision and synthetic vision systems, is an affordable solution for airlines making it possible to operate to and from airports that are not equipped with advanced landing aids. Usually those are the small and medium sized airports. For those airports, this technology will thus enhance their operational accessibility in adverse weather conditions without having to rely on expensive investments. Furthermore, small airports are often closely located to large airports next to metropolitan areas. The flexibility of augmented Global Navigation Satellite System (GNSS) based approach procedures holds promising ways to reduce both the impact on the environment and the burden of mixed aircraft category operations through complex Terminal Manoeuvring Areas (TMAs).

The SESAR large scale demonstration provided an opportunity to demonstrate benefits for the aviation community with respect to lowering minima, environment as well as fuel cost savings and increased throughput at airports. The supporting technologies have been developed or are in final stages of validation (GBAS – Ground Based Augmentation System, RNP with RF Leg, SBAS – Satellite Based Augmentation System, SVGS – Synthetic Vision Guidance System, EFVS – Enhanced Flight Vision System) but actual procedures or advanced procedures at airports are not yet published. The project will speed up the deployment and actual realization of the benefits, and thus support the ultimate goal of ATM modernization.

The strength of this project was to provide a global approach to enabling low visibility procedures for landing, both in terms of technology and operations, and to demonstrate a way forward to deployment.

The project targeted the following operational goals:

- Operational Goal 1: New procedures and regulation associated with SESAR technology can improve the access of business aviation as well as mainline users to all types of European airports, in particular in low visibility conditions. The types of airports include small/medium size without landing aids found at larger airports, as well as larger airports with such additional landing aids.
- Operational Goal 2: Adequate procedure design leveraging augmentation system and SESAR Approach and Landing concepts can reduce the impact on the environment at all airports and reduce the complexity of operating into business aviation satellite airports close to neighbouring large airports.

The main players of business aviation in Europe have joined their forces to set up the AAL (Augmented Approaches to Land) consortium:

- NetJets, the main Business Aviation operator,
- The European Business Aviation Association,
- Dassault Aviation, the main business aviation aircraft manufacturer
- Honeywell, the main business aviation avionics manufacturer.

Together with further partners representing Airspace Users (Lufthansa, SWISS), Air Navigation Service Providers - ANSPs (ANS CR, DFS, DSNA and Skyguide), Airport Operators (Fraport, Zurich Airport), mainline and corporate jet manufacturer (Airbus), Avionics Suppliers (Honeywell, Elbit Systems) and Procedure Designers (DLR) they created a strong consortium with all the capabilities needed to demonstrate the presented goals.

Lot 2 addresses improvements at small/medium size airports, but is not necessarily limited to these and thus also demonstrates the benefits for other size of airports.

Flights took place at small/medium airports (Bergerac, Perigueux, Groningen, Ostrava, Brno/Karlovy Vary and Bremen) and large airports (Frankfurt, Zurich).

In support of Operational Goal 1, DSNA (French ANSP) supported the demonstration of EFVS to land at French airports (Bergerac, Perigueux) and Dutch airport (Groningen), pioneering the use of this technology to improve the access to small and medium airports during low visibility conditions. It demonstrated the performance of the concept with business aircraft to show the validity and benefits of EFVS to land operations to touchdown and rollout for both business and general aviation.

The procedures designed by ANS CR (Czech ANSP) for Ostrava and Brno/Karlovy Vary airports made the best use of Synthetic Vision and SBAS using the flexibility and specific constraints of a Medium size airport. Successful trials at Ostrava and Brno/Karlovy Vary (backup) airports may have a positive influence on ANS CR plans to introduce such procedures also at other airports within the Czech Republic for all possible runway ends. It should be emphasized that the procedures designed for business jets will also benefit the light regional jets. Regional jets featuring a Synthetic Vision System will be in operation before the end of the decade.

Similarly, procedures to be designed by DFS (German ANSP) for Bremen and Frankfurt airports, and Skyguide (Swiss ANSP) for Zurich, made the best use of RNP to xLS transitions (GLS for Bremen and Zurich, GLS and ILS for Frankfurt), as well as increased glidepaths. By accommodating a lighter aircraft in a flow of mainliners, as both categories demonstrated that they can support advanced approach operations, the Augmentation System based operations at these airports will pave the way to improved aircraft operations in general, including regional aircraft.

Involvement of large airports was required to demonstrate Operational Goal 2 in particular. With Fraport, DFS and Lufthansa, the consortium included the operational trio (airport operator, the ANSP and the main airline operating at the airport) at Frankfurt to ensure that the intended advanced operations can be supported by all key stakeholders, business as well as mainline aircraft, and that they bring expected benefits with respect to environment (noise abatement by avoiding populated areas, fuel consumption, lower emissions), cost, as well as throughput (into large airports as well as into neighbouring business aviation satellite airports). A benefit study assessed the advanced procedure potential for improvements at Egelsbach which is the satellite airport close to Frankfurt-Main airport. Zurich Airport, Skyguide and SWISS constituted an equivalent trio for Zurich. Having such a city pair (Zurich, Frankfurt) with their major airlines in the project provided more flight opportunities.

The LSD.02.02 AAL Project intended to show added value for all involved actors (aircraft operators, Air Traffic Control, ANSPs and airports) in Business and General Aviation at small/medium as well as large airports, and for Air Transport users at medium and large airports.

It was a strong objective of the consortium to look beyond the pure demonstration of SESAR technologies and to ensure that the procedures designed in this project can be used as an example for a larger deployment at small/medium airports as well as hubs. To that end, dissemination actions were taken to foster crystallization around the SESAR procedures demonstrated during the trial.

2.1 Scope of the demonstration and complementarity with the SESAR Programme

Demonstration Exercise ID and Title	**EXE-02.02-D-100: GBAS/SBAS Advanced Procedures Feasibility and Benefits Demonstration**
Leading organization	Honeywell
Demonstration exercise objectives	GBAS/SBAS Advanced Procedures feasibility/benefits demonstration
High-level description of the Concept of Operations	SESAR ConOps Step 1 [22], SESAR ConOps Step 2 [17]
Applicable Operational Context	Approach, Final Approach

Expected results per KPA	**KPA Safety:** The project will demonstrate the safety with respect to the accuracy, in both vertical as well as horizontal performance with respect to the demonstrated approaches. In particular, the project will assess the safe transition from RNP path (including RF Leg) to GLS final approach segment. **KPA Environment / Fuel Efficiency:** RNP to xLS procedures are flexible and enable to resolve customized challenges of each airport. For some airports there is a need for shorter flight path of new procedures which brings fuel savings as well as less CO2 emitted during the approach. For other airports the demand can be a flexible flight trajectory (which can be longer than the legacy one) in order to reduce noise in particular highly populated areas. This project aims to demonstrate both types of benefits – fuel savings and less CO2 emissions with the new procedures in Bremen and Zurich and noise abatement benefit in Frankfurt. Increase of the glideslope brings additional benefit with respect to the noise abatement. **KPA Human Performance:** Human performance KPA is linked mainly to the perceived level of feasibility for this exercise. The assessment will be provided based on feedback from pilots and ATC.
Number of flight trials	277
Demonstration Technique	Flight Trial, Real Time Simulations, Study
Related projects in the SESAR Programme	SESAR 6.8.8 “Enhanced Arrival Procedures to reduce occupancy time using GBAS” SESAR 9.9 “RNP Transition to xLS” SESAR 5.6.3 “QM-3 – Approach Procedure with Vertical Guidance (APV)”
OFA addressed	OFA 01.01.01 “LVPs using GBAS” OFA 02.01.01 “Optimised 2D 3D routes”

Demonstration Exercise ID and Title	**EXE-02.02-D-200: SVGS Advanced Procedures Feasibility and Benefits Demonstration**
Leading organization	Honeywell
Demonstration exercise objectives	SVGS Advanced Procedures feasibility/benefits demonstration
High-level description of the Concept of Operations	SESAR ConOps Step 1 [22], SESAR ConOps Step 2 [17]
Applicable Operational Context	Final Approach
Expected results per KPA	**KPA Safety:** In accordance with FAA AC20-138 LP/LPV and GNSS Category I approaches, presenting misleading information to the flight crew is considered to be a hazardous failure condition. The SVGS system includes the independent monitor outside of typical flight guidance monitoring to address the system safety weaknesses of the LPV approaches. The method to be used in the project consists of proposed approach type safety assessment for the intended airport as well as on-board system safety assessment reference. The project will demonstrate the safety with respect to the accuracy, in both

	vertical as well as horizontal performance with respect to the demonstrated approaches. **KPA Cost Effectiveness:** The cost effectiveness is aimed to the savings regarding the cost reduction in the maintenance cost aircraft equipage and crew training for qualification higher than CAT I. **KPA Environment / Fuel Efficiency:** The main impact of the SVGS regarding fuel efficiency and less pollutant emitted in the case of reducing number of go-arounds, diversion or holding of the aircraft due to visual limitations. The reduction of these events is variable for particular airport minimum obstacle limitation resulting in the different decision height and probability of the visual limits below CAT I requirements. However, indicators evaluated in the scope SESAR 9.28 and 9.29 Cost Benefit Assessments demonstrates the capability for reduction of the CO2 emission by 30-40 kg and NOX emission by 0.35 kg per minute of the flight which will be not affected by go-around or holding. **KPA Capacity:** The airport capacity is typically affected by application of Low Visibility Procedures (LVP) when several additional procedures are in place for safe operation during lower than CAT I visibility requirements causing reduction of the airport throughput. The utilization of the SVGS system presumes the reduction of the limitation by additional on-board capability which gives the crew the possibility to extend CAT I instrument segment and increase the probability for visual references capture. **KPA Human Performance:** Human performance KPA is linked mainly to the perceived level of feasibility for this exercise. The assessment will be provided based on feedback from pilots.
Number of flight trials	74
Demonstration Technique	Flight Trial, Study
Related projects in the SESAR Programme	SESAR 9.29 “Enhanced & Synthetic Vision”
OFA addressed	OFA 01.01.02 ”Pilot Enhanced vision”

Demonstration Exercise ID and Title	**EXE-02.02-D-300: EFVS Advanced procedures feasibility and benefits demonstration**
Leading organization	Dassault Aviation
Demonstration exercise objectives	EFVS Advanced Procedures feasibility/benefits demonstration
High-level description of the Concept of Operations	SESAR ConOps Step 1 [22], SESAR ConOps Step 2 [17]
Applicable Operational Context	Final Approach
Expected results per KPA	**KPA Safety and KPA Human Performance:** The benefits of EFVS to land concept operations regarding safety is obtained through crew workload reduction during EFVS operation compared to existing EFVS operations:

	- Simplified procedure (no transition to natural vision at 100 ft). - Better crew coordination (EFVS repeater in the Primary Field of View of the co-pilot). In addition worldwide harmonization of EFVS operations (EFVS to land is a concept supported by FAA) will enable a better knowledge of EFVS operations by the different national authorities and airports, then increase the safety of EFVS operations. **KPA Environment / Fuel Efficiency:** The benefits of EFVS to land operations regarding environment is based on the reliability of the EFVS to land operations compared to existing EFVS operations since the authorized reduction of RVR depends on the demonstrated EFVS performance, so reduced go-arounds and diversions brought by the increased reliability. **KPA Capacity:** The benefits of EFVS to land operations regarding capacity is obtained thanks to access to smaller airports in bad weather conditions, and consequently decreased congestion at nearby main hubs. The benefits of EFVS to land operations regarding cost efficiency is based on the access to small/medium airports in low visibility conditions without (or small impacts) on the airports infrastructures and procedures.
Number of flight trials	9 (10 more expected by end of October 2016)
Demonstration Technique	Flight Trial, Real Time Simulations, Study
Related projects in the SESAR Programme	SESAR 9.29 "Enhanced & Synthetic Vision" SESAR 5.6.3, "Approach Procedure with Vertical guidance" SESAR 9.10 "Approach with Vertical Guidance APV"
OFA addressed	OFA 01.01.02 "Pilot Enhanced vision"

Demonstration Exercise ID and Title	**EXE-02.02-D-400: EFP&AI Benefits Demonstration**
Leading organization	Honeywell
Demonstration exercise objectives	Enhanced Flight Planning & Advanced Information feasibility/benefits demonstration
High-level description of the Concept of Operations	SESAR ConOps Step 2 [17]
Applicable Operational Context	Long/Medium/Short Term Planning
Expected results per KPA	**KPA Human Performance:** Instant access to actual data brings higher quality of used information, thus globally enhances crew effectiveness and decision making.
Number of flight trials	N/A (will be a part of WP 1 & 2 flights)
Demonstration Technique	Flight Trial
Related projects in the SESAR Programme	SESAR WP 11.1. "Flight and Wing Operation Centres"
OFA addressed	OFA AIM "Aeronautical Information Management"

3 Programme Management

This section details the main project management principles. Section 3.1 informs about project organization, followed by the work breakdown structure in Section 3.2. Dates for formal deliverables are summarized in Section 3.3. Section 3.4 then provides information for risk management. For details about Programme Management see the Demonstration Plan [27].

3.1 Organisation

The consortium was set up an organization so as to ensure both the operational focus and the efficiency of LSD.02.02 AAL Project.

Figure 6 shows the consortium organization with Consortium coordinator (CC), Work Package Manager (WPM) and Consortium Members with respect to responsibilities, internal interactions as well as interactions with the SJU. For responsibilities detailed description of CC, WMP and Consortium Members see the Demonstration Plan [27].

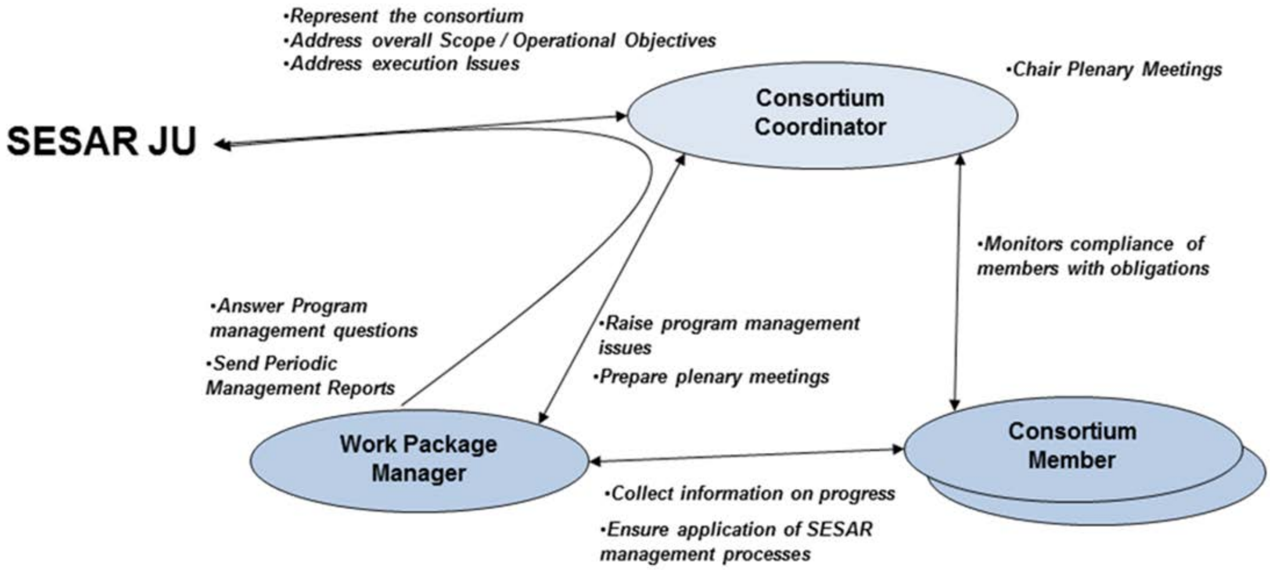


Figure 6: Consortium organization and role

The project team consisted of Airspace users (EBAA, Lufthansa, NetJets as well as SWISS), ANSPs (Czech ANSP – ANS CR, German ANSP – DFS, French ANSP – DSNA and Swiss ANSP - Skyguide), airport operators (Fraport, Zurich Airport), airframe manufacturers (Airbus, Dassault Aviation), avionics suppliers (Elbit Systems, Honeywell) and procedures designers (Airbus, DLR).

Lean organization was obtained thanks to the Work Breakdown Structure, presented in Section 3.2, consisting of four technical work packages and one coordination work package. Table 1 presents the project team description with respect to leadership of these packages, as well as persons responsible for external interfaces and communications, and explains how quality is managed.

External Interfaces and Communications role was divided into two main roles. First, the Consortium Coordinator provided the interface with the SJU as well as represented the consortium to the outer world as described in Section 3.1.1 in the Demonstration Plan [27]. The Communications Focal point ensured proper communication to external stakeholders and was supported by Consortium Coordinator as well as focal points from each of the consortium members. Each Work Package was responsible for executing the communication plan and working with the Communication Focal Point and Consortium Coordinator to ensure consistency.

Table 1: Summary of project team description

Role	Name	Involvement Percentage
Consortium Coordinator	[redacted] (NetJets)	10%
Responsible for External Interfaces and Communications	Interface with SJU, consortium representation: [redacted] (NetJets)	
	Focal Point: [redacted] (EBAA)	5%
Work Package Manager – WP 0	[redacted] (NetJets)	10%
Work Package Manager – WP 1, WP 2, WP 4	[redacted] (Honeywell)	20%
Work Package Manager – WP 3	[redacted] (Dassault Aviation)	40%
Quality Manager	Quality is managed within each Work Package. WPL and TL, and contributors are responsible for quality per quality assurance plan (Section 3.1.6 in Demo Plan) and escalation process described (Section 3.1.5 in Demo Plan [27]).	N/A

All point of contacts (management, technical, financial and public relations) for each work package were maintained by Work Package leader per Work Package, and per project by Consortium Coordinator. The spread sheet is stored on Extranet.

For details about Project Monitoring and Control, Risk Management Plan and Quality Assurance Plan see the Demonstration Plan [27].

3.2 Work Breakdown Structure

LSD.02.02 AAL Project was organized in a lean structure with five Work Packages (WP) – one coordination Work Package and four technical Work Packages. High level description is shown in the Figure 7. WP 0 (Consortium Coordination), led by the Consortium Coordinator (CC) NetJets, was connecting remaining four Work Packages in terms of high level coordination as well as in terms of the preparation and delivery of Demonstration Plan (WP 0.1) and Demonstration Report (WP 0.2), both led by Honeywell. All deliverables included inputs from all technical Work Packages (WP 1, WP 2, WP 3, and WP 4).

WP 1 (GBAS/SBAS Advanced Procedures), WP 2 (SVGS Advanced Procedures) and WP 4 (Enhanced Flight Planning & Advanced Information) were led by Work Package Manager (WPM) Honeywell. WP 3 (EFVS Advanced Procedures) was led by Work Package Manager Dassault Aviation.

WP1, WP2 and WP 3 included three Sub-Work Packages - Definition, Systems and Trials. WP 4 included two Sub-Work Packages - Systems and Trials. All four technical Work Packages were providing inputs to one common Demonstration Plan and Demonstration Report. WPMs assured proper communication between these WPs. Figure 7 shows the Sub-Work Package Leaders (SWL) underlined for each SWP.

This section is structured in the following way. First, a graphical summary of Work breakdown structure is presented followed by a table overview of the tasks and start and end dates.

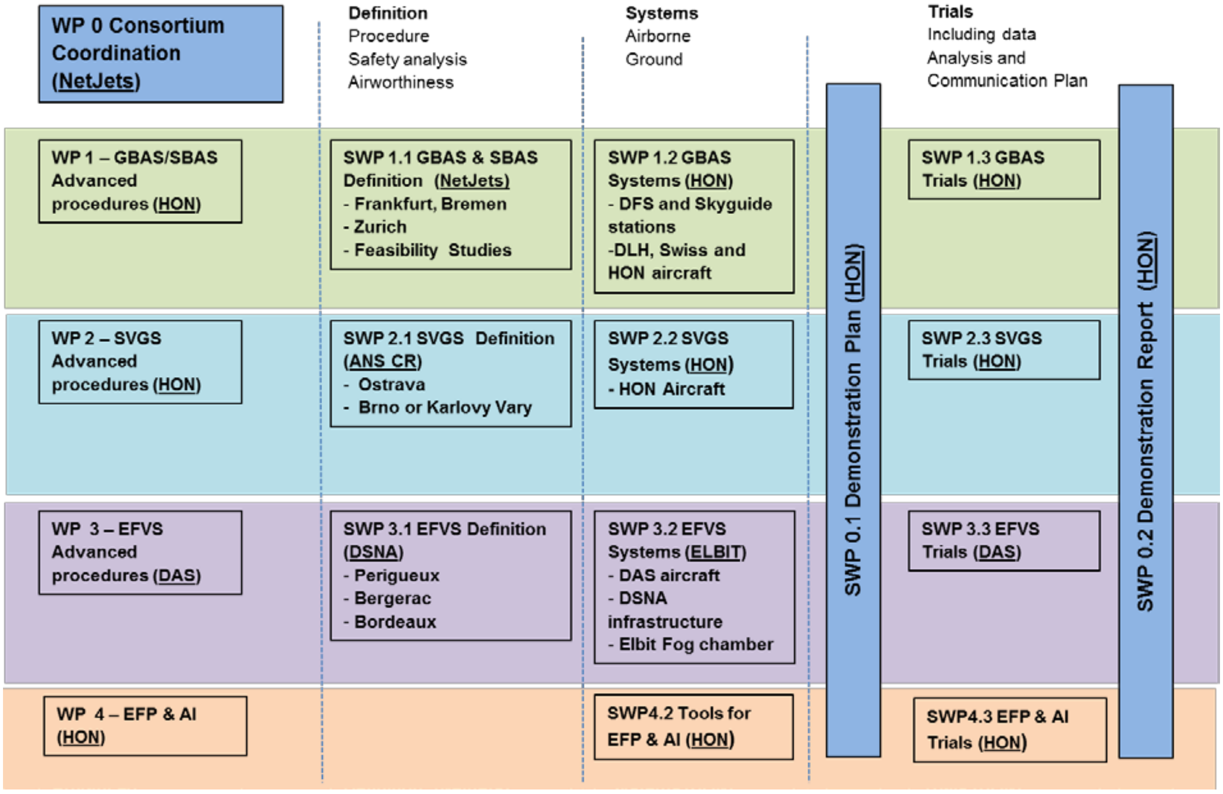


Figure 7: Work organizational breakdown structure

Table 2 describes the work breakdown structure. It gives also an overview on individual WPs and SWPs high level content and start and end dates of the activities.

Table 2: WBS

WP/SWP	Task Name	From	To	High Level Description
WP 0	Consortium Coordination	11/2014	10/2016	Coordination of the Consortium
SWP 0.1	Demonstration Plan	11/2014	09/2015	Consolidation of Demonstration Plan
SWP 0.2	Demonstration Report	01/2016	10/2016	Consolidation of Demonstration Report
WP 1	GBAS/SBAS Advance Procedures	11/2014	10/2016	Management
SWP 1.1	GBAS/SBAS Definition	02/2015	05/2016	Procedure definition, Safety assessment procedures
SWP 1.2	GBAS Systems (Air & Ground)	01/2015	02/2016	Airborne and Ground systems preparation
SWP 1.3	GBAS Trials	11/2014	10/2016	Demonstration Plan Input, Preparation of Trial, Execution, Demonstration Report Input, Communication
WP 2	SVGS Advanced Procedures	11/2014	10/2016	Management
SWP 2.1	SVGS Definition	02/2015	08/2015	Procedure definition, Safety assessment procedures
SWP 2.2	SVGS Systems	01/2015	06/2016	Airborne system preparation
SWP 2.3	SVGS Trials	11/2014	10/2016	Demonstration Plan Input, Preparation of Trial, Execution, Demonstration Report Input, Communication
WP 3	EFVS Advanced Procedures	11/2014	10/2016	Management
SWP 3.1	EFVS Definition	11/2014	01/2016	Procedure definition, Safety assessment procedures
SWP 3.2	EFVS Systems	11/2014	05/2016	Ground and Airborne systems preparation
SWP 3.3	EFVS Trials	11/2014	10/2016	Demonstration Plan Input, Preparation of Trial, Execution, Demonstration Report Input, Communication
WP 4	EFP & AI	11/2014	10/2016	Management
SWP 4.2	Tools for EFP & AI	01/2015	06/2016	Tools preparation
SWP 4.3	EFP & AI Trials	11/2014	10/2016	Demonstration Plan Input, Preparation of Trial, Execution, Demonstration Report Input, Communication

Table 3 summarizes all consortium members involvement in individual WPs/SWPs in terms of leading (L), contributing (C) or reviewing (R) of the activity.

The work breakdown structure is described in details in the Demonstration Plan [27]including the description, participating consortium members and their involvement in the activities in terms of hours estimate as well as leadership of the activity (WPM = Work Package Manager, SWL = Sub-Work Package Leader, TL = Task Leader).

Table 3: Consortium members involvement (L=Lead, C=Contribute, R=Review)

	Honeywell	DFS	ANS CR	NetJets	EBAA	Fraport	Lufthansa	DAS	DSNA	Elbit	Airbus	Zurich Air.	DLR	SWISS	Skyguide
WP 0				L	C										
SWP 0.1	L														
SWP 0.2	L														
WP 1	L														
SWP 1.1	R	C		L	R	C	C	R			C	C	C	C	C
SWP 1.2	L	C				C	C							C	C
SWP 1.3	L	C		R	C	C	C	R			C	C	C	C	C
WP 2	L														
SWP 2.1	R		L	R	R			R							
SWP 2.2	L														
SWP 2.3	L		C	R	C			R							
WP 3								L							
SWP 3.1				R	R			C	L	C					
SWP 3.2								C	C	L					
SWP 3.3				R	R			L	C	C	C				
WP 4	L														
SWP 4.2	L				R										
SWP 4.3	L				C										

3.3 Deliverables

Table 4 describes the due dates for the formal deliverables to the SJU. The description of deliverables is presented below the table.

Table 4: Due dates for the formal deliverables to the SJU

Deliverable name	Date
Demonstration Plan 1st review (A1)	15.12.2014 (DONE)
Demonstration Plan 2nd review (A2)	29.10.2015 (DONE)
Demonstration Report (B1)	06.10.2016 (DONE)
Final Demonstration Report (B2)	24.10.2016 (DONE)

Description of formal deliverables:

Demonstration Plan 1st review - Document containing initial elements necessary for better understanding of planned demonstration and its intention. The plan will be delivered by December 15th, 2014.

Demonstration Plan 2nd review - Document will be delivered before the first trial and will update the first version of the plan. It will define in particular all components essential for the design of trials such as information about the scenarios, designed procedures and introduces all elements relevant to demonstration. The plan will be delivered by October 29th, 2015.

Demonstration Report - Report will summarizes the results from the demonstration trials and will show how all intended goals were performed. The report will be delivered by October 6th, 2016.

Final Updated Demonstration Report – Report will be based on feedback from SJU from Final Project Review on October 13th, 2016 including potentially updated results. The final report will be delivered on October 24th, 2016. Risks #06 and #20 (Section 3.4) has been identified and added with respect to late trials to affect outcome of the report.

For detailed list of all reports (including internal ones) and milestones see the Demonstration Plan [27].

3.4 Risk Management

This section is intended to analyse and summarize all risks that applied to the project. Table 5 presents all risks identified, including the risks description as well as their impact or consequence on the project (all risks are already closed). The severity of the risk impact and the probability of risk occurrence are expressed in the scale of L (low), M (medium) and H (high). For each of the risks the treatment action applied during project is described and the risk owner is identified. The project succeeded in mitigating all the risks except some risks for WP3, especially risk #12. This was in advance communicated properly and partially recovered.

Table 5: List of risks (L=Low, M=Medium, H=High)

Risk #	Risk Description	Impact/ Consequence	Severity of Impact	Treatment Action Applied	Probability	Risk Owner
01 (CLOSED)	Availability of flight test aircraft.	Flight trials are delayed.	M	Good timing of all actions before trials was set and adequate time buffer was assumed. Frequent communication with Flight OPS.	M	HON
02 (CLOSED)	Additional opportunity to demonstrate benefits of SVGS outside current CAT I operational approval in VMC will be not permitted by the certification authority.	Flight trials are delayed.	L	Close cooperation with certification authority was ensured and needed approvals were obtained. Flight trials were conducted in VMC conditions as no low visibility was captured during trial periods.	H	ANS CR
03 (CLOSED)	Demanding coordination with high number of consortium members with different objectives.	Project is delayed.	M	Prepared good project plan, communication plan, assigned clear roles and objectives, planned coordination meetings.	M	NJ (CC)
04 (CLOSED)	Demanding WP management (WP1, WP 2 and WP 4) with high number of consortium members.	Project is delayed.	M	Prepared good project plan, communication plan, assigned clear roles and objectives, planned coordination meetings.	M	HON (WPM 1,2,4)

Risk #	Risk Description	Impact/ Consequence	Severity of Impact	Treatment Action Applied	Probability	Risk Owner
05 (CLOSED)	Demanding WP management (WP 3) with high number of consortium members.	Project is delayed.	M	Prepared good project plan, communication plan, assigned clear roles and objectives, planned coordination meetings.	M	DAS (WPM 3)
06 (CLOSED)	Demonstration Report completion need by 6.10.2016. Not all results from the last trials from WP 1 included in the final report. Updated Results will change the outcome of the final report or they will not be included due to time restrictions.	Not enough time to finish project.	H	Prepared good plan – trials started as early as possible, communicated well with all stakeholders. Later trials in Frankfurt (WP 1) were mitigated by thorough preparation of all possible activities before the trial to then focus all resources on finalizing the report part with respect to Frankfurt in due time and quality.	H	HON (WPM 1), DLH
07 (CLOSED)	Dependency on R&D project (SESAR 6.8.8) can cause potential delay of work in WP 1.	Project is delayed.	M	Tight cooperation with 6.8.8 project set. Risk taken into account for demo time management.	M	HON (WPM 1)
08 (CLOSED)	ANSP (DFS) need cooperate and be supported by the national aviation authority and/or EASA for creation supporting documents. This dependency can cause delay in delivery of expected outputs before trials.	Flight trials are delayed.	H	Envisaged procedures were part of the ICAO approved procedures. Good communication channel and the procedure for specific safety case was set up in advance.	H	DFS
09 (CLOSED)	ANSP (ANS CR) needs to cooperate with and be supported by the national aviation authority for creation supporting documents. This dependency can cause delay in delivery of expected outputs before trials.	Flight trials are delayed.	M	Good communication channel and the procedure for specific safety case was set up in advance.	L	ANS CR
10 (CLOSED)	Availability of procedure design tool in DFS.	Project is delayed.	L	Monitoring was applied and procedures successfully designed	M	DFS
11 (CLOSED)	Availability of Full Flight Simulator with EFVS system.	Project is delayed.	M	Good communication and coordination with FFS supplier was set and FFS was available for tests.	M	DAS

Risk #	Risk Description	Impact/ Consequence	Severity of Impact	Treatment Action Applied	Probability	Risk Owner
12 (CLOSED)	Availability of F7X MSN1 with EFVS system.	Full demo in flight (dual HUD + OPS (credit camera)) not performed. 2 Key points of ConOPS are still assessed. Airports flight are still planned.	M	Falcon single HUD was available and permitted to assess the major 2 key points in flight and to perform the validation flights on French airports.	L	DAS
13 (CLOSED)	Availability of Fog chamber.	Project is delayed.	M	Good communication and coordination was set between Elbit Divisions and fog chamber was available for the tests.	L	Elbit
14 (CLOSED)	ANSP (Skyguide) needs to cooperate with and be supported by the national aviation authority for creation supporting documents. This dependency can cause delay in delivery of expected outputs before trials.	Flight trials are delayed.	M	Good communication channel and the procedure for specific safety case was set up in advance and trials executed as planned.	L	Skyguide
15 (CLOSED)	Bordeaux, Bergerac, Perigueux airports needs to be available in the required period.	Flight trials are delayed.	M	Good communication and coordination of the DSNA with the Airports was set and aerodromes were available for the tests.	L	DSNA
16 (CLOSED)	Advanced RNP needs to be approved by EASA and local authority (ICAO documentation still not available).	In case of missing approval flight trials with revenue flights will not be possible.	H	Early and intensive communication with authority was set and required approvals were obtained.	M	Lufthansa
17 (CLOSED)	Advanced RNP needs to be approved by EASA and local authority (ICAO documentation still not available).	In case of missing approval flight trials with revenue flights will not be possible.	H	Early and intensive communication with authority was set and required approvals were obtained	M	SWISS
18 (CLOSED)	Needed amount of data not obtained in Frankfurt because of the weather conditions (noise measurements) and lack of trials in the trial period.	Scope reduced.	H	Monitoring was applied, more approaches were planned and needed number of approaches was achieved.	H	Fraport, DFS
19 (CLOSED)	Availability of aircraft simulator.	Project is delayed.	M	Monitoring was applied and aircraft simulator was obtained as needed	L	Airbus

Risk #	Risk Description	Impact/ Consequence	Severity of Impact	Treatment Action Applied	Probability	Risk Owner
20 (CLOSED)	Demonstration Report completion need by 6.10.2016. Not all results from the last trials from WP 3 included in the final report. Updated Results will change the outcome of the final report or they will not be included due to time restrictions.	Not enough time to finish project.	M	Final results will be included in the report (24.10. 2016) reviewed, although flights will continue till end of October to demonstrate the concept in dual HUD in more weather conditions and environment. Some results will be not included in the final reports.	H	DAS (WPM 3)
21 (CLOSED)	Risk of insufficient coverage of RNP to GLS approaches due to availability of equipped mainline aircraft and service at the airport.	Scope reduced	H	Planned to execute representative number of RNP to GLS approaches at Frankfurt and Bremen airports. Monitoring was applied and more approaches planned and executed.	M	DLH, DFS, HON
22 (CLOSED)	Weather conditions for EFVS flights may be difficult to find.	More flights need to be performed to obtain flights in the required conditions	M	Flights will be performed till the end of October in order to obtain a maximum number of weather conditions.	M	DAS (WP3)
23 (CLOSED)	Approval from FOCA may not also cover the planned Honeywell flights (raised by Swiss), a specific FOCA approval required for Honeywell.	Delay of flights in ZUR.	H	Approval from FOCA also covered the planned Honeywell flights, meaning there was no specific FOCA approval required for Honeywell.	L	HON (WP1)

4 Execution of Demonstration Exercises

The main focus area of the project was “Precision Arrival and Departure Procedures”. This was supported by works around RNP to xLS with increased glideslope and lowering decision minima for landings in low visibility conditions. In addition, the project also addressed the focus area “Enhanced Flight Planning and Aeronautical Information for airspace users without their own FOC”.

This project was destined to demonstrate the full 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 trial flights in such variety of operational conditions that the obtained results will be appealing, relevant, and applicable for the majority of the European airports.

The consortium that have run this project comprises all necessary business stakeholders:

- 4 Airspace Users : EBAA, Lufthansa, NetJets, SWISS;
- 4 Air Navigation Service Providers : ANS CR, DFS, DSNA, Skyguide;
- 2 Airport Operators : Fraport, Zurich Airport;
- 2 Airframe Manufacturers : Airbus, Dassault Aviation;
- 2 Avionics Supplier : Elbit Systems, Honeywell;
- 1 Procedure Designer: DLR.

The trial flights were held at a variety of European airports:

- 2 Large Hubs : Frankfurt, Zurich;
- Medium/Small sized: Bergerac, Perigueux, Groningen, Bremen, Ostrava, Brno, Karlovy Vary;
- 2 Complex airspace structures (TMA/CTR): Frankfurt, Zurich.

The project also ensured that all technical means were available 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 for:

- Airports with available GBAS stations: Frankfurt, Bremen, Zurich.
- Different type of aircraft: A380, A319, A320, A321, B747-8, F7X (experimental), F900 (experimental).
- Aircraft with EFVS avionics: Dassault Falcon 7X experimental.
- Aircraft with SVGS avionics: Honeywell Falcon 900 experimental.
- Aircraft with GBAS avionics: Honeywell Falcon 900 experimental, A380, A319, A320, A321, B747-8 (revenue flights).
- Procedure designers with relevant experience: DLR.

4.1 Exercises Preparation

Preparatory activities are covered by relevant X.1 and X.2 SWPs (see Section 3.2 for Work Breakdown Structure). Below a brief summary of activities performed is provided. For detailed description of activities see Section 6.

EXE_0202_100 (WP1)

- SWP 1.1 “GBAS/SBAS Definition”
  - This SWP provided the GBAS/SBAS definition activities and involved the airports in Germany (Frankfurt, Bremen) as well as in Switzerland (Zurich). This SWP included 2 main Tasks – Procedures definition and Safety Assessment. The Feasibility Studies Task dealing with procedure interoperability of SBAS/GBAS from procedure design

perspective as well as advanced RNP procedures to LPV into satellite airport with larger RF leg were part of this SWP as well.

- SWP 1.2 “GBAS Systems (Air & Ground)”
    - This SWP provided the Airborne and Ground systems preparation and involved the airports in Germany (Frankfurt, Bremen) as well as in Switzerland (Zurich). This SWP included 2 main Tasks – Aircraft & Receiver Modification and Ground aspects Preparation.

EXE_0202_200 (WP2)

- SWP 2.1 “SVGS Definition”
    - This SWP provided the SVGS definition activities and involved the airports in the Czech Republic (Ostrava, Brno and Karlovy Vary). This SWP included 2 main Tasks – Procedures definition and Safety Assessment.
- SWP 2.2 “SVGS Systems”
    - The SWP included preparation of all necessary airborne equipment for SVGS trials. It covered an integration of SVGS which was demonstrated into the experimental aircraft. A CVS monitoring capability was hosted on board for data recording purposes. The integration also incorporated means to measure required data supporting the SVGS part in demonstration report.

EXE_0202_300 (WP3)

- SWP 3.1 “EFVS Definition”
    - This SWP covered the definition of the Air operational procedure and small/medium airports procedures definition and also safety assessments of these procedures for the EFVS to land operations.
- SWP 3.2 “EFVS Systems”
    - This SWP covered the preparations of the means which were used during the trials (F8X Full Flight Simulator, F7X, Fog Chamber) and also the specific airports procedure definition to perform the tests safely on small/medium airports.

EXE_0202_400 (WP4)

- SWP 4.2 “Tools for EFP & AI”
    - This SWP provided the tools preparation. This SWP covered the preparation of the tools relevant to demonstrations and the training of the pilots for the EFP&AI software loaded to IPad used during demonstrations.

4.2 Exercises Execution

Spread over the year 2015 and 2016, the targeted total number of trial flights was well over 200 with achieved total 360+ demonstration flights. Those were performed by a wide variety of aircraft and at well selected set of airports spread all over Germany, France, Switzerland, the Netherlands and the Czech Republic.

With respect to RNP approaches, 100 approaches were performed by Honeywell experimental F900 business jet (including nominal RNP to GLS approaches, vectored approaches used for noise evaluation and corner cases testing approaches), 17 RNP to GLS approaches were performed by SWISS, and 160 approaches (120 RNP to GLS and 40 RNP to ILS) were performed by Lufthansa. Since these RNP procedures were published by DFS, limited number of approaches were performed by other airlines (not directly participating to the call) as an opportunity to test the new procedures as well, complementing the efforts by Lufthansa (supporting Frankfurt, Bremen and Zurich), SWISS (supporting Zurich) and Honeywell (supporting Frankfurt, Bremen and Zurich).

74 approaches were performed (live trials) on a Honeywell Falcon 900 experimental aircraft equipped with SVGS and all required features to demonstrate benefits of SVGS operations to touchdown and

rollout concept of operations. AFP& AI was tested during these trials as well as during special sessions.

For the EFVS flights, 9 approaches were flown by Dassault Aviation Falcon 7X experimental aircraft until mid-October 2016.

To summarize, the flight trials were executed using the following aircraft:

- **SWISS**: GLS equipped A320 (Figure 8) and A321.
- **Lufthansa**: GLS equipped A380 (Figure 10), B 747-8 (Figure 11) as well as A319 (Figure 9).
- **Honeywell**: GLS and SVGS equipped experimental Falcon 900 (Figure 12).
- **Dassault Aviation**: EFVS equipped experimental Falcon 7X (Figure 13).

Figure 8: SWISS A320FAM aircraft

Figure 9: Lufthansa A319 (photo by: Ingrid Friedl)

Figure 10: Lufthansa A380 (photo by: M. Lindner und Lutz Borck)

Figure 11: Lufthansa B747-8 (photo by: Jürgen Mai)

Figure 12: Honeywell's experimental F900 (photo by: Ivo Carvan ICARcz)

Figure 13: Dassault experimental Falcon 7X MSN1

Table 6 presents actual demonstration schedule.

Table 6: Exercises execution/analysis dates

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise analysis start date	Actual Exercise analysis end date
EXE-02.02-D-100	GBAS/SBAS Advanced Procedures Feasibility and Benefits Demonstration	10 / 2015	9 / 2016	11 / 2015	10 / 2016
EXE-02.02-D-200	SVGS Advanced Procedures Feasibility and Benefits Demonstration	10 / 2015	5 / 2016	11 / 2015	8 / 2016
EXE-02.02-D-300	EFVS Advanced Procedures Feasibility and Benefits Demonstration	02 / 2016	10 / 2016	03 / 2016	10 / 2016
EXE-02.02-D-400	EFP&AI Benefits Demonstration	10 / 2015	5 / 2016	11 / 2015	8 / 2016

For detailed description of execution activities see Section 6. For detailed description of scenarios flown see Demonstration Plan [27].

4.3 Deviations from the planned activities

EXE_0202_100 (WP1)

Within WP1 a minimum of 10 RNP to GLS approaches by use of SWISS revenue service flights were planned. Due to a good cooperation with all internal and external stakeholders and partners a total number of 17 successful approaches was achieved.

Within WP1, more than 100 RNP to xLS approaches by use of Lufthansa revenue service flights were planned. Due to a good cooperation with all internal and external stakeholders and partners a total number of 160 successful approaches (140 RNP to GLS and 40 RNP to ILS) was achieved. Also A320 family (A319/A320/A321) was included in addition to demonstrations of RNP to GLS on the Lufthansa side and RNP to ILS approaches were flown to demonstrate feasibility as well.

Within WP1, a minimum of 30 demonstration flights were planned for testing flights (with Honeywell business A/C F900EX). During demonstrations, total 100 successful flights (69 RNP to GLS, 22 RNP to LPV and 9 vectored GLS approaches) were achieved. This number comprise of 62 RNP to GLS flights in Zurich, Frankfurt and Bremen, 9 vectored approaches which were used as a baseline for noise evaluation in Frankfurt, and also 29 approaches used for corner cases testing (22 in USA and 7 in Bremen) – for overview see Table 25.This higher number of approaches improved a statistical significance for data evaluation with respect to accuracy measurements as well as with respect to the human factors (feasibility) assessment. Also, corner cases testing was performed in addition to the Demonstration Plan and brought important results for confirmation of feasibility of this type of procedures. In USA, 22 approaches took part in the corner cases testing (8 of 22 trials were nominal RNP to GLS used for corner cases evaluation) and 7 corner cases testing approaches were performed also in Bremen. Corner cases testing included trials with intentional horizontal offset (0.5 and 0.3 NM) as well as with intentional vertical (baro) offset. Another important input to the corner cases testing was a new Honeywell FMS function that will significantly improve RNP to GLS Localizer/Glideslope capture. This new blending function provides a real-time correction of vertical errors induced by uncompensated non-standard atmospheric conditions (e.g. high/low temperatures) and also FMS lateral navigation errors induced by non-GPS position sensors (applicable to RNP to ILS only). For details see Appendix B (Section B.1.3).

Table 7: EXE_0202_100: Overview of testing flights (with Honeywell business A/C F900EX)

	TOTAL	nominal RNP to GLS	vectors	corner cases
LSZH	**28**	28	0	0
EDDF	**27**	18	9	0
EDDW	**23**	16	0	7 (GLS)
USA	**22**	0	0	22* (LPV)
TOTAL	100	62	9	29

**NOTE: 8 of 22 trials were nominal RNP approaches used for corner cases evaluation comparison.*

EXE_0202_200 (WP2)

Flights in Brno (LKTB) and Karlovy Vary (LKKV) were planned as opportunities, when one or the other was intended to be chosen to fly LPV approaches. Eventually, the demonstrations included both airports for the flights and moreover, both – ILS and LPV procedures – were flown on these airports. Therefore demonstrations showed results based on bigger variety of airports for LPV procedure as well as for ILS procedure scenarios.

Within WP2, at least 30 demonstration flights were expected. During demonstrations in total 74 successful flights have been achieved. This improved a statistical significance for data evaluation with respect to accuracy measurements as well as with respect to the human factors (feasibility) assessment.

EXE_0202_300 (WP3)

Within WP3, 50 trials were expected to be performed in flight (Dassault F7X). As of early October 2016, 9 approaches were achieved, but flights in real low visibility conditions are going on and 5 to 10 more are expected before the end of the project (end of October 2016). The analysis of these additional flights will be performed by Dassault, but will not be part of this Report due to time constraints.

- 3 of the trials were dedicated to the consolidation of the aerodrome / ATM low visibility procedure. These flights have demonstrated the adequacy of procedures to regional and small airports, including those with AFIS.
- 6 of the trials have been performed to partially validate the EFVS to land concept of operation in fog conditions with RVR as low as 300m. This validation was partial and limited because the DUAL HUD which is part of the full EFVS to land concept was not fully ready in the proper time for demo due to development delay encountered during the latest stage of validation of this complex system. Nonetheless, evaluation conducted in single HUD, associated to FFS runs performed in DUAL HUD configuration permitted to validate the major key points of the EFVS to land concept of operation.

- DUAL HUD is now available and flights have resumed with the objective to assess the concept in more low visibility conditions and more environments.

All the data gathered in flight were used for prediction performance validation.

Within WP3, 40 conditions were initially planned to be simulated inside the fog chamber. It was finally possible to simulate 12 scenario combining the lighting level with different types of fog and lights. These scenario permitted to obtain preliminary conclusions for part of the weather conditions of interest. Confirmation of those conclusion and extension to other conditions will require fog chamber modifications and further analysis before continuing the tests.

Within WP3, 15 conditions resulting from flight tests were expected to be played-back inside the Fog chamber. Finally one flight condition had been replayed with good correlation between flight test results and Fog Chamber play-back results.

Beyond WP3 initial objectives:

The aerodrome / ATM impact activity was widely shared with other than AAL stakeholders:

- The results were discussed with EASA in the frame of the ongoing rulemaking task RMT0379. All the work done jointly with the DSNA is considered as the major input to support the drafting of aerodrome EFVS related GM/AMC materials.
- The results will be presented by DASSAULT and the DSNA to ANTWERP airport 26th of October 2016. FLYING GROUP and EASA will attend. This should consolidate the work done with French authorities.
- The results were presented and officially disseminated to the FAA regulation and certification offices.

Regarding performance prediction activity, DASSAULT compared computed EFVS performance with real flight test data. This activity highlighted the effect of the SVR to RVR ratio which is a major concern in the determination of the EFVS performance prediction.

Regarding the Full flight Simulator activity, the list of special events and safety failure cases considered for the demo was shared with EASA certification authorities.

EXE_0202_400 (WP4)

Initially it was planned, that WP4 demonstrations will be part of WP2 demonstrations. In order to increase the variety of evaluation participants involved in the demonstrations and therefore increase the significance and representativeness of the results, several changes to the initial plan were made:

- WP4 demonstrations were also executed during some WP1 demonstrations (testing flights) in order to involve more testing pilots.
- Special sessions were arranged (replacing scenario SCN_0202_402) in order to involve also commercial pilots with different level of flying experience and of different age in order to increase the variety of participants involved. Moreover, on these sessions the commercial mainline aircraft pilots as well as commercial business jets pilots were participating.
- Flight ops dispatcher was involved in the questionnaire special session too.

As mentioned above, scenario SCN_0202_402 (In-aircraft information update) was changed to scenario of special sessions. Expected data were obtained.

5 Exercises Results

This section provides the summary of exercises results in Section 5.1 followed by the description of chosen metrics and indicators in Section 5.2. Section 5.3 summarizes the assumptions and Section 5.4 details the results per KPA. Section 5.5 outlines the impact of results on the safety, capacity and human factors and Section 5.6 describes the assessment methodology. Results impacting the regulation and standardization initiatives are summarized in Section 5.7. Section 5.8 then provides analysis of exercises results. Finally Section 5.9 outlines the confidence in these results.

5.1 Summary of Exercises Results

Table 8 summarizes the results of the all Demonstration Exercises. It shows the summary of results compared to the success criteria identified within the Demonstration Plan per demonstration objective. The analysis covered all the Demonstration Objectives embedded in all Demonstration Exercises as per the corresponding Demonstration Plan and is detailed in Section 6.

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 with some exceptions (exercise results partially achieve success criteria),
- NOK: Demonstration objective does not achieve the expectations (exercise results do not achieve success criteria).

Table 8: Summary of Demonstration Exercises Results

EXE-02.02-D-XXX	Demonstration Objective ID	Demonstration Objective	Success Criterion	Demo Objective Status
100	OBJ_0202_011	To demonstrate the feasibility of curved approaches with RNP to xLS.	Curved approach with RNP to xLS procedure is feasible based on the feedback from ATC and pilots.	**OK*1)**
100	OBJ_0202_012	To demonstrate the feasibility of GLS approaches with increased glideslopes of 3.2 deg.	GLS approach with increased glideslope (3.2 deg) procedure is feasible based on the feedback from ATC and pilots.	**OK**
200	OBJ_0202_013	To demonstrate feasibility of SVGS DH-50ft on ILS 200’.	SVGS DH-50ft on ILS 200’ procedure is feasible based on the feedback from pilots.	**OK**
200	OBJ_0202_014	To demonstrate feasibility of SVGS VTH-50ft on LPV 250’.	SVGS VTH-50ft on LPV 250’ procedure is feasible based on the feedback from pilots.	**OK**
300	OBJ_0202_015	To demonstrate feasibility of EFVS approaches.	EFVS approach procedure is feasible based on the feedback from pilots.	**OK**
400	OBJ_0202_016	To demonstrate benefits of EFP&AI (e.g. relevant information successfully obtained in user-friendly format).	EFP&AI is usable based on the feedback from Pilots.	**OK**
100, 200, 300	OBJ_0202_021	To demonstrate accuracy of advanced procedures.	TSE for advanced procedure approaches is within the relevant CTQ value.	**OK*2)**

EXE-02.02-D-XXX	Demonstration Objective ID	Demonstration Objective	Success Criterion	Demo Objective Status
300	OBJ_0202_022	The operational concept of "EFVS to land" is safe and the operational credit obtained with EFVS is significant compared to exiting EFVS concepts.	Approaches successfully flown on FFS and Flight Tests.	**OK**
300	OBJ_0202_023	Reliability of EFVS to land operations in various weather conditions.	Predicted Enhanced Flight vision is consistent with flight test results and fog chamber tests results.	**OK**
100	OBJ_0202_024	To investigate the environmental impact of some advanced procedures in terms of local noise (at RNP to xLS transition and under increased glideslope).	Noise measurements during approaches with some advanced procedures show a change in the noise by relevant CTQ value.	**OK**
100	OBJ_0202_025	To demonstrate fuel efficiency benefits of some advanced procedures.	Fuel consumption evaluation for some advanced approaches show a reduction on the fuel consumption by relevant CTQ value.	**OK**
100	OBJ_0202_026	To demonstrate environmental benefits of some advanced procedures in terms of CO_2 emitted.	CO2 emission evaluation for some advanced approaches shows a reduction on CO2 emission by relevant CTQ value.	**OK**
200, 300	OBJ_0202_027	Estimate reduction of number of diversion, delay or go-around.	Evaluation shows decreased number of diversion, delay or go-around by relevant CTQ.	**OK**
100	OBJ_0202_028	To evaluate the quality of flight track compared to designed (theoretical optimum) RNP to xLS approach.	Evaluation of the quality of flight track compared to designed (theoretical optimum) RNP to xLS approach provided.	**OK**
200	OBJ_0202_029	To estimate cost-effectiveness benefits of advanced procedures, such as cost savings for the crew qualification.	Evaluation shows decreased cost for the crew qualification.	**OK**
300	OBJ_0202_030	Definition of the impacts on the small/medium airport infrastructure and procedures to enable EVS operations in low visibility conditions.	Procedures and possible requirement for specific infrastructure to do EFVS to land Operations on small/medium airports are defined.	**OK**
200, 300	OBJ_0202_031	To demonstrate airport eligibility for advanced procedures.	Airport eligibility evaluation for advanced approaches show reachability to relevant CTQ value.	**OK**
100	OBJ_0202_041	Evaluation of the cost of publishing a SBAS LPV approach overlaid to a GBAS GLS approach.	Affordable cost implementation of SBAS approach in relation to the cost of GBAS implementation.	**OK**

EXE-02.02-D-XXX	Demonstration Objective ID	Demonstration Objective	Success Criterion	Demo Objective Status
100	OBJ_0202_042	Having advanced RNP procedures to LPV (increased glideslope with the intercept RF Leg > 45deg), to describe how such an advanced procedure could facilitate independent RNP arrivals into business aviation satellite airports through complex TMAs.	Fuel efficiency compared to present operation with a case study accessing Egelsbach through Frankfurt complex TMA.	POK*3)

*1) *NOTE: The RNP procedures were rated as feasible by both ATC and pilots. However, there were number of lessons learned and recommendations for future noted by both groups that are captured in Section 8.1.*

*2) *NOTE: For WP1 only: Some of the Frankfurt mainline aircraft approaches seem to be going over the CTQ limit, but there is always an explanation provided (e.g. ATC vectoring) in Appendix B.*

*3) *NOTE: Fuel efficiency slightly negative with IFR procedure RNP to LPV due to airspace and airport configuration of EDDF/EDFE. However, positive fuel efficiency results with the concept of Visual RNAV. For more details see Section 6.1.3.2.7.*

5.2 Choice of metrics and indicators

5.2.1 EXE_0202_100

For EXE_0202_100 relevant KPI/metric and CTQs for all KPA are summarized in the Table 9.

Table 9: KPA, KPI/metric and CTQs for EXE_0202_100

KPA	KPI	Methodology	EDDF	EDDW	LSZH	Metric	CTQ definition	CTQ value
Safety	Horizontal flight accuracy (RNP to xLS)	Flights	x	x	x	Evaluation of horizontal TSE for xLS approaches on the RF leg and transition to the final approach segment.	Horizontal TSE for xLS approaches is within CTQ limit.	within 1NM
	Vertical flight accuracy (RNP to xLS)		x	x	x	Evaluation of vertical path for xLS approaches on RF leg and the vertical transition to the final approach segment.	Vertical path for xLS approaches is within CTQ limit.	No descend below FAP constraint – 100ft (considering temperature compensations)*
Environment/ Fuel efficiency	Noise measured on ground (RNP to xLS)	Flights	x			Evaluation of difference in noise emission (at source) for straight-in wings level approach (legacy) and RNP RF leg (aircraft with bank angle) approach.	Change in noise distribution measured for a RF Leg	positive or negative for the local area

KPA	KPI	Methodology	EDDF	EDDW	LSZH	Metric	CTQ definition	CTQ value
	Noise measured on ground (IG xLS)	Flights	x			Evaluation of difference in noise immission (exposure level) for approach with glideslope 3 deg (legacy) and for approach with glideslope 3.2 deg.	Decreased noise immission (exposure level) for approach with glideslope 3.2 deg (compared to 3.0 deg)	by at least 0.5 dB
	Fuel burned per approach (RNP to xLS)	RTS		x	x	Evaluation of difference in fuel consumption for legacy approach and RNP to xLS approach.	Decreased fuel consumption for RNP to xLS approach (compared to legacy approach).	by at least 5%
	CO2 emission per approach (RNP to xLS)	RTS		x	x	Evaluation of difference in CO2 emission for legacy approach and RNP to xLS approach.	Decreased CO2 emission for RNP to xLS approach (compared to legacy approach).	by at least 5%
	Quality of flight tracks in the horizontal (RNP to xLS)	Flights	x	x	x	Evaluation of the quality of flight tracks in the horizontal compared to designed (theoretical optimum) approach.	Flight tracks in horizontal evaluated.	YES
	Quality of flight tracks in the vertical (RNP to xLS)	Flights	x	x	x	Evaluation of the quality of flight tracks in the vertical compared to designed (theoretical optimum) approach.	Flight tracks in vertical evaluated.	YES
Human Performance	Perceived level of feasibility – ATC (RNP to xLS)	Flights + Questionnaires	x	x	x	Questionnaire to be completed by ATC for RNP to xLS approaches flown.	RNP to xLS approaches are feasible based on feedback form ATC.	YES >95% appr. successful
	Perceived level of feasibility – ATC (IG xLS)		x	x	x	Questionnaire to be completed by ATC for approaches with increased glideslope flown.	Approaches with increased glideslope are feasible based on feedback form ATC.	YES >95% appr. successful
	Perceived level of feasibility – pilots (RNP to xLS)		x	x	x	Questionnaire to be completed by pilots for RNP to xLS approaches flown.	RNP to xLS approaches are feasible based on feedback form pilots.	YES >95% appr. successful

KPA	KPI	Methodology	EDDF	EDDW	LSZH	Metric	CTQ definition	CTQ value
	Perceived level of feasibility – pilots (IG xLS)		x	x	x	Questionnaire to be completed by pilots for approaches with increased glideslope flown.	Approaches with increased glideslope are feasible based on feedback form pilots.	YES >95% appr. successful
Accessibility	Cost effectiveness (SBAS/GBAS)	Interview (Study)	N/A			Cost of publishing a SBAS LPV approach overlaid to a GBAS GLS approach.	Affordable cost implementation of SBAS approach in relation to the cost of GBAS implementation.	YES (qualitative outputs of analysis)
Environment/ Fuel efficiency	Fuel consumption within specific TMA (RNP)	Analysis (Study)	N/A			Evaluation of the difference in terms of fuel consumption between new RNP to LPV procedure with current practice.	Decreased fuel consumption within specific TMA (compared to legacy procedures).	less fuel burn within specific TMA

** The planned vertical path is at or above the FAP alt constraint (considering temperature compensation or not), and the total system error should be less than 100ft in vertical.*

Regarding the methodology used to secure a comprehensive analysis of the data that were collected during flight trials, measured data were evaluated and statistically analysed. Various statistical methodologies and techniques were used for pairwise comparisons of captured data of each targeted area and procedures. For data capturing the tools described below were used.

Flight path accuracy performance (vertical and horizontal):

In order to measure the aircraft precise position was measured by the geodetic dual-frequency receiver. Such a system has one part aboard the aircraft connected to the antenna and the other part on the ground connected to an antenna with an accurately known position. Knowing the precise aircraft position, the total system error (TSE) in horizontal can be computed as the deviation from intended flight path. Regarding the vertical direction, the vertical profile was analysed.

Approach fuel burned:

Fuel consumption was evaluated by using simulator (due to insufficient real weight flight data accuracy). Simulations were performed with standardized conditions.

Estimated CO2 emission:

The CO2 emission was evaluated by using simulator (due to insufficient real weight flight data accuracy).

Noise measured on ground:

In order to evaluate noise impact on the ground during the approach the noise measurement stations installed in the Frankfurt airport proximity were used.

Perceived level of feasibility:

In order to evaluate the feasibility of demonstrated procedure ATC as well as pilots were asked to fill the questionnaire. Obtained data were statistically evaluated and analysed.

5.2.2 EXE_0202_200

For EXE_0202_200 relevant KPI/metric and CTQs for all KPA are summarized in the Table 10.

Table 10: KPA, KPI/metric and CTQs for EXE_0202_200

KPA	KPI	Methodology	Metric	CTQ definition	CTQ value
Safety	Horizontal Flight accuracy (SVGS)	Flights	Evaluation of horizontal TSE for SVGS approaches.	Horizontal TSE for SVGS approaches is within CTQ limit.	within 1 dot
	Vertical Flight accuracy (SVGS)		Evaluation of vertical TSE for SVGS approaches.	Vertical TSE for SVGS approaches is within CTQ limit.	within 1 dot
	Successful touchdown (SVGS)	Flights	Measure of the touchdown footprint for SVGS approaches.	Touchdown footprint for SVGS approaches is within CTQ limit.	in touchdown zone*
Environment/ Fuel efficiency	Reduction of number of diversion and delay (SVGS)	Study	Evaluation of the percentage of successful landing on destination airport in LVC.	Increase the percentage of landing on destination airport in LVC.	N/A (not quantifiable in absolute, depends on each operator activity)
Airport Capacity	Airport procedure and installation eligibility (SVGS)	Study	Evaluation of the percentage of eligible airports for SVGS operations.	The number of airports in the Czech Republic and Slovakia with instrument 3D approaches that are eligible to SVGS operation is better than CTQ.	at least 80%
Human Performance	Perceived level of feasibility – pilots (SVGS)	Flights + Questionnaires	Questionnaire to be completed by pilots for SVGS approaches flown.	SVGS approaches are feasible based on feedback form pilots.	YES >95% appr. successful
Cost-effectiveness	Cost savings (SVGS)	Study	Estimate of the cost savings for the crew qualification.	Decreased cost for the crew qualification.	by at least 20%

** Touchdown zone is defined as the first third of the runway.*

Note: Reduction of number of diversion and delay provides benefits from several aspects. Benefits are mainly connected with Airport Capacity KPA. According to the B.04.01.D41 [35], the main influencing factors (sources of capacity gain) relate to separation, sequencing, runway occupancy time and buffers applied for departure and arrival traffic respectively. Also as explained in B.04.01.D41 [35], the SESAR Airport Capacity framework focuses on the most challenging (or constrained) environments, i.e. similar to the approach adopted for Airspace Capacity. For Airport Capacity this means targeting on the basis of busy hours at certain reference airports, i.e. the capacity declaration at "Best-in-Class" (BIC) airports. AAL project contributes to this KPA by improving the access in particular to small/medium airports (and therefore increase the global airport network capacity), especially in low visibility conditions. This means that part of the traffic heading to the small/medium airports will no longer need to be redirected or diverted to large and constrained airports situated nearby. Also, this means that the part of the traffic heading to the hub airports may be redirected to small/regional situated nearby. Also, this contributes to the KPA Resilience, which covers the ability to withstand and recover from planned and unplanned events and conditions which cause a loss of nominal capacity (e.g. weather such as thunderstorm, strong wind, freezing, low visibility conditions; or infrastructure degradation such as technical failures, strikes, accidents, runway maintenance and special events) as defined in B.04.01.D41 [35].

Note 2: As explained in B.04.01.D41 [35] various aspects are relevant to SESAR Cost-Effectiveness KPA and those aspects are captured and handled through means other than validation targets, e.g. Cost Benefit Analyses (CBA) that consider also the indirect impacts on benefits and costs for Airspace Users. B.04.01.D41 [35] also states that in this context, indirect ATM impacts on airspace user costs are costs and benefits resulting from changes in flight efficiency, temporal aspects (predictability and punctuality), and flexibility, etc.; they effectively represent the monetisation of changes in those respective KPA outcomes and thus, the monetary implications of changes to those KPAs are considered within the CBA rather than as separate areas for SESAR target setting. AAL project focuses mainly on the demonstration of benefits from the Airspace Users point of view, where cost perspective of the technology is an important focus point with several second order benefits (as there is an influence and interaction between KPAs). The is important to mention that showing the benefits to the Airspace Users is an essential part of demonstrations in order to encourage and support the deployment of the technology and therefore to contribute to the future SESAR deployment phase.

With the respect to the demonstration goals, the various statistical methodologies and techniques were used for quantitative as well as qualitative data evaluation:

Flight path tracking accuracy (vertical and horizontal):

In order to measure the aircraft precise position were measured by the geodetic dual-frequency receiver. Such a system has one part aboard the aircraft connected to the antenna and the other part on the ground connected to an antenna with an accurately known position. Knowing the precise aircraft position, the total system error (TSE) in horizontal as well as vertical direction can be computed as the deviation from intended flight path.

Perceived level of feasibility:

The variable workload and feasibility assessment questionnaires were used for workload level assessment.

Reduction of number of diversion and delay:

The aircraft technical specification and the references to SESAR 9.29.D03 Cost Benefit Analysis [19] was used for number of diversion and delay assessments.

Cost savings:

Expert evaluation was used for cost savings for the crew qualification assessments.

5.2.3 EXE_0202_300

For EXE_0202_300 relevant KPI/metric and CTQs for all KPA are summarized in the Table 11.

Table 11: KPA, KPI/metric and CTQs for EXE_0202_300

KPA	KPI	Methodology	Metric	CTQ definition	CTQ value
Safety	Crew workload reduction (EFVS)	Simulation + Flights	Evaluation of the crew capacity to perform EFVS operation (acquisition of visual references, stabilized approach).	The global workload is within CTQs limits	major difficulties (level 7/10 Cooper Harper)
	Horizontal Flight accuracy (EFVS)		Evaluation of horizontal TSE for EFVS approaches.	Horizontal TSE for EFVS approaches is within CTQ limit	within 1 dot
	Vertical Flight accuracy (EFVS)		Evaluation of vertical TSE for EFVS approaches.	Vertical TSE for EFVS approaches is within CTQ limit	within 1 dot

KPA	KPI	Methodology	Metric	CTQ definition	CTQ value
	Successful touchdown (EFVS)		Measure of the touchdown footprint for EFVS approaches.	Touchdown footprint for EFVS approaches is within CTQ limit	in touchdown zone*
Environment/ Fuel efficiency	Reduction of number of diversion and GO AROUND (EFVS)	Study	Evaluation of the percentage of successful landing on expected destination airport.	Increase the number of landing on expected DEST airport	N/A (not quantifiable in absolute, depends on each operator activity)
Airport Capacity	Airport procedure and installation eligibility (EFVS)	Study	Evaluation of the percentage of eligible airports for EFVS operations.	The number of controlled (AFIS or ATC) French airports with instrument 3D approaches that are eligible to EFVS to land operation is better than CTQ	at least 80%
	Small/medium airport visibility capacity enhancement (EFVS)	Simulation + Fog Chamber	Evaluation of the effective eRVR compared to actual RVR.	The effective eRVR is greater than actual RVR	eRVR is at least 420m (for RVR of 300m in day FOG conditions)
Human Performance	Perceived level of feasibility – pilots (EFVS)	Flights	Evaluation of pilot's perceived difficulty to do EFVS operation. Evaluation of pilot's perceived accuracy during EFVS to land operation. Use of questionnaires to be completed by PF and PM.	The EFVS to land approach is feasible (based on feedback form pilots) without any excessive difficulty and with adequate accuracy for at least CTQ	YES >90% appr. successful

** Touchdown zone is defined as the first third of the runway.*

Note: Reduction of number of diversion and delay provides benefits from several aspects. Benefits are mainly connected with Airport Capacity KPA. According to the B.04.01.D41 [35], the main influencing factors (sources of capacity gain) relate to separation, sequencing, runway occupancy time and buffers applied for departure and arrival traffic respectively. Also as explained in B.04.01.D41 [35], the SESAR Airport Capacity framework focuses on the most challenging (or constrained) environments, i.e. similar to the approach adopted for Airspace Capacity. For Airport Capacity this means targeting on the basis of busy hours at certain reference airports, i.e. the capacity declaration at "Best-in-Class" (BIC) airports. AAL project contributes to this KPA by improving the access in particular to small/medium airports (and therefore increase the airport capacity), especially in low visibility conditions. This means that part of the traffic heading to the small/medium airports will no longer need to be redirected or diverted to large and constrained airports situated nearby. Also, this means that the part of the traffic heading to the hub airports may be redirected to small/regional situated nearby. Also, this contributes to the KPA Resilience, which covers the ability to withstand and recover from planned and unplanned events and conditions which cause a loss of nominal capacity (e.g. weather such as thunderstorm, strong wind, freezing, low visibility conditions; or infrastructure degradation such as technical failures, strikes, accidents, runway maintenance and special events) as defined in B.04.01.D41 [35].

Note 2: As explained in B.04.01.D41 [35] various aspects are relevant to SESAR Cost-Effectiveness KPA and those aspects are captured and handled through means other than validation targets, e.g.

Cost Benefit Analyses (CBA) that consider also the indirect impacts on benefits and costs for Airspace Users. B.04.01.D41 [35] also states that in this context, indirect ATM impacts on airspace user costs are costs and benefits resulting from changes in flight efficiency, temporal aspects (predictability and punctuality), and flexibility, etc.; they effectively represent the monetisation of changes in those respective KPA outcomes and thus, the monetary implications of changes to those KPAs are considered within the CBA rather than as separate areas for SESAR target setting. AAL project focuses mainly on the demonstration of benefits from the Airspace Users point of view, where cost perspective of the technology is an important focus point with several second order benefits (as there is an influence and interaction between KPAs). The is important to mention that showing the benefits to the Airspace Users is an essential part of demonstrations in order to encourage and support the deployment of the technology and therefore to contribute to the future SESAR deployment phase.

Crew workload reduction:

Human Factors process as requested in CS 25.1302 was applied to perform Full Flight Simulators Tests and Flight tests.

Capacity of the crew to handle failures:

Safety failure process as requested in CS 25.1309 was applied to perform Full Flight Simulators Tests and Flight tests.

Successful approach:

Each approach performed in low visibility was tagged Succeed or Fail. When fail, the reason why the approach has failed would be identified. It will help to define what specific training is necessary to perform the operation.

Touch Down distance from Runway axis and threshold:

Touchdown features were recorded (Distance of Touch Down, distance from the axis, vertical Speed at Touch Down) and compared to Touch Down features with natural vision operations Objective was to show that these features are similar when landing with or without EFVS.

Real Enhanced Flight Visibility versus predicative Enhanced Flight Visibility:

The Flight tests and fog chamber tests enabled to identify the real Enhanced Flight Visibility, which were compared to the predicative Enhance Flight Visibility.

Impacts on small/medium airports:

The tests in small/medium airports enabled to identify the minimum list of infrastructure and procedure necessary to perform EFVS to land operation.

5.2.4 EXE_0202_400

For EXE_0202_400 relevant KPI/metric and CTQs for all KPA are summarized in the Table 12.

Table 12: KPA, KPI/metric and CTQs for EXE_0202_400

KPA	KPI	Methodology	Metric	CTQ definition	CTQ value
Human Performance	Perceived level of feasibility – pilots (EFP&AI)	Questionnaires	Questionnaire to be completed by pilots for EFP&AI (5 point Likert Scale).	Acceptable assessment of evaluated usability aspects.	No major issues identified

Perceived level of feasibility:

In order to evaluate the benefits and feasibility of EFP&AI application, pilots were asked to fill the questionnaire. Obtained data were statistically evaluated and analysed.

5.3 Summary of Assumptions

Below, the issues to be reported according to the assumptions defined in the Demo Plan are defined.

EXE_0202_100

No issues to be reported.

The project was coordinating with SESAR Project 6.8.8. Good communication with this project was set thanks to many companies participating to both projects. Fraport took care of updating AAL participants. Also, EUROCONTOL representatives (participating in 6.8.8 and 15.3.7) were invited to review the AAL project results and participate on the WP1 monthly review meetings.

According to the project plan the WP 1 GBAS flight trials were supposed to finish by mid of 2016. As anticipated (see Risk #06 in the Risk Register), some flight trials continued until end of August in order to collect all required data for all KPA/KPIs. Preparation of majority of possible activities before the trial then enabled to focus all resources on finalizing the report part, with respect to late trials, in due time and quality.

Demonstration Flight Assumptions were the following:

- No adverse weather conditions;
- No special events creating traffic peaks beyond usual traffic level for the targeting season, day and time of the trials;
- No traffic restrictions due to NOTAM, temporary personnel shortage, temporary systems unavailability or military operations.

EXE_0202_200

No issues to be reported.

Test aircraft was available with the required SVGS installation on-board in the proper time for demonstration.

Appropriate safety measures were applied for the demonstrations for both VMC and LVC conditions. The Czech CAA has provided an approval to fly in lower visibility conditions, based on assessment documentation and coordination with ANS CR. Even though the first demonstration period was planned for November 2015 with high chances to fly in actual LVC, the weather conditions were good and thus it was not possible to perform any LVC approaches. Nevertheless, the VMC condition approaches serve very well for the needed objectives.

Thanks to good coordination with the project partners it was possible to collect data without interruptions during demonstrations in Ostrava, Brno and Karlovy Vary airports.

EXE_0202_300

Due to delays in the latest stage of the development of the dual HUD / EFVS innovative system, initial timeframe reserved for SESAR flight demo had to be supplemented with extra time slots. These new slots matching the full HUD/EFVS requested configuration and compatible with the aircraft planning were less favourable to the research of low visibility conditions.

Despite this difficult context, the main key points of the EFVS to land concept of operation were successfully assessed in single HUD. Flight demo in full configuration will be achieved by end of October 2016.

Modifications and validation activities of the Fog Chamber had taken more time than initially planned at the beginning of SESAR-AAL which is the reason why Fog Chamber was not available for validating the EFVS performance prediction. However, simulations and flight test play-back gave optimistic results and confirmed the potential of the Fog Chamber for EFVS performance validation.

Thanks to a good coordination with project partners, Falcon 8X Full flight simulator was available and permitted to perform the tests as expected.

The availability of the airports for the period of the tests was ensured by a tight coordination between DASSAULT flight test department and aerodromes / ATM local authorities.

EXE_0202_400

No issues to be reported.

5.4 Results per KPA

List of Key Performance Areas (KPA) and Key Performance Indicators (KPI) involved, CTQ values used, related Demonstration objectives and results are given separately for each Demonstration exercise in Table 13, Table 14, Table 15 and Table 16. Details about evaluation and results can be found in Section 6.

Table 13: KPA, KPI/metric, Demo Objective, CTQs and results for EXE_0202_100

KPA	KPI	Related OBJ_0202_XXX	CTQ definition	CTQ value	Status/ Result
Safety	Horizontal flight accuracy (RNP to xLS)	021	Horizontal TSE for xLS approaches is within CTQ limit.	within 1NM	OK*2)
	Vertical flight accuracy (RNP to xLS)	021	Vertical path for xLS approaches is within CTQ limit.	No descend below FAP constraint – 100ft (considering temperature compensations)**	OK*2)
Environment / Fuel efficiency	Noise measured on ground (RNP to xLS)	024	Change in noise distribution measured for a RF Leg	positive or negative for the local area	OK
	Noise measured on ground (IG xLS)	024	Decreased noise immission (exposure level) for approach with glideslope 3.2 deg (compared to 3.0 deg)	by at least 0.5 dB	OK*3)
	Fuel burned per approach (RNP to xLS)	025	Decreased fuel consumption for RNP to xLS approach (compared to legacy approach).	by at least 5%	OK
	CO2 emission per approach (RNP to xLS)	026	Decreased CO2 emission for RNP to xLS approach (compared to legacy approach).	by at least 5%	OK
	Quality of flight tracks in the horizontal (RNP to xLS)	028	Flight tracks in horizontal evaluated.	YES	OK
	Quality of flight tracks in the vertical (RNP to xLS)	028	Flight tracks in vertical evaluated.	YES	OK
Human Performance	Perceived level of feasibility – ATC (RNP to xLS)	011	RNP to xLS approaches are feasible based on feedback form ATC.	YES >95% appr. successful	OK*1)
	Perceived level of feasibility – ATC (IG xLS)	012	Approaches with increased glideslope are feasible based on feedback form ATC.	YES >95% appr. successful	OK

KPA	KPI	Related OBJ 02 02_XXX	CTQ definition	CTQ value	Status/ Result
	Perceived level of feasibility – pilots (RNP to xLS)	011	RNP to xLS approaches are feasible based on feedback form pilots.	YES >95% appr. successful	OK*1)
	Perceived level of feasibility – pilots (IG xLS)	012	Approaches with increased glideslope are feasible based on feedback form pilots.	YES >95% appr. successful	OK
Accessibility	Cost effectiveness (SBAS/GBAS)	041	Affordable cost implementation of SBAS approach in relation to the cost of GBAS implementation.	YES (qualitative outputs of analysis)	OK
Environment / Fuel efficiency	Fuel efficiency of specific arrival through complex TMA in satellite airport (RNP to LPV)	042	Decreased fuel consumption within complex TMA (compared to legacy operation).	less fuel burn within specific TMA	POK*4)

**1) NOTE: The RNP procedures were rated as feasible by both ATC and pilots. However, there were number of lessons learned and recommendations for future noted by both groups that are captured in Section 8.1.*

**2) NOTE: For WP1 only: Some of the Frankfurt mainline aircraft approaches seem to be going over the CTQ limit, but there is always an explanation provided (e.g. ATC vectoring) and corresponding lessons learned in Appendix B.*

**3) NOTE:*
Emission: Sound pressure level emitted by a source, here aircraft, in 1m distance.
Immission: Sound exposure level at a receiver, here noise monitoring terminal. Referred to in the document as "exposure level".

**4) NOTE: Fuel efficiency slightly negative with IFR procedure RNP to LPV due to airspace and airport configuration of EDDF/EDFE. However, positive fuel efficiency results with the concept of Visual RNAV. For more details see Section 6.1.3.2.7.*

*** The planned vertical path is at or above the FAP alt constraint (considering temperature compensation or not), and the total system error should be less than 100 ft in vertical.*

Table 14: KPA, KPI/metric, Demo Objective, CTQs and results for EXE_0202_200

KPA	KPI	Related OBJ 02 02_XXX	CTQ definition	CTQ value	Status/ Results
Safety	Horizontal Flight accuracy (SVGS)	021	Horizontal TSE for SVGS approaches is within CTQ limit.	within 1 dot	OK
	Vertical Flight accuracy (SVGS)	021	Vertical TSE for SVGS approaches is within CTQ limit.	within 1 dot	OK

KPA	KPI	Related OBJ_02 02_XXX	CTQ definition	CTQ value	Status/ Results
	Successful touchdown (SVGS)	021	Touchdown footprint for SVGS approaches is within CTQ limit.	in touchdown zone*	OK
Environment/ Fuel efficiency	Reduction of number of diversion and delay (SVGS)	027	Increase the percentage of landing on destination airport in LVC.	N/A (not quantifiable in absolute, depends on each operator activity)	OK
Airport Capacity	Airport procedure and installation eligibility (SVGS)	031	The number of airports in the Czech Republic and Slovakia with instrument 3D approaches that are eligible to SVGS operation is better than CTQ.	at least 80%	OK
Human Performance	Perceived level of feasibility – pilots (SVGS)	013 014	SVGS approaches are feasible based on feedback form pilots.	YES >95% appr. successful	OK
Cost-effectiveness	Cost savings (SVGS)	029	Decreased cost for the crew qualification.	by at least 20%	OK

** Touchdown zone is defined as the first third of the runway.*

Table 15: KPA, KPI/metric, Demo Objective, CTQs and results for EXE_0202_300

KPA	KPI	Related OBJ_02 02_XXX	CTQ definition	CTQ value	Status/ Results
Safety	Crew workload reduction (EFVS)	022 023	The global workload is within CTQs limits	major difficulties (level 7/10 Cooper Harper)	OK
	Horizontal Flight accuracy (EFVS)	021	Horizontal TSE for EFVS approaches is within CTQ limit	within 1 dot	OK
	Vertical Flight accuracy (EFVS)	021	Vertical TSE for EFVS approaches is within CTQ limit	within 1 dot	OK
	Successful touchdown (EFVS)	021	Touchdown footprint for EFVS approaches is within CTQ limit	in touchdown zone*	OK
Environment / Fuel efficiency	Reduction of number of diversion and GO AROUND (EFVS)	027	Increase the number of landing on expected DEST airport	N/A (not quantifiable in absolute, depends on each operator activity)	OK

KPA	KPI	Related OBJ_02 02_XXX	CTQ definition	CTQ value	Status/ Results
Airport Capacity	Airport procedure and installation eligibility (EFVS)	031	The number of controlled (AFIS or ATC) French airports with instrument 3D approaches that are eligible to EFVS to land operation is better than CTQ	at least 80%	OK
	Small/medium airport visibility capacity enhancement (EFVS)	030	The effective eRVR is greater than actual RVR	eRVR is at least 420m (for RVR of 300m in day FOG conditions)	OK
Human Performance	Perceived level of feasibility – pilots (EFVS)	015	The EFVS to land approach is feasible (based on feedback form pilots) without any excessive difficulty and with adequate accuracy for at least CTQ	YES >90% appr. successful	OK

** Touchdown zone is defined as the first third of the runway.*

Table 16: KPA, KPI/metric, Demo Objective, CTQs and results for EXE_0202_400

KPA	KPI	Related OBJ_02 02_XXX	CTQ definition	CTQ value	Status/ Results
Human Performanc e	Perceived level of feasibility – pilots (EFP&AI)	016	Acceptable assessment of evaluated usability aspects.	No major issues identified	OK

5.5 Impact on Safety, Capacity and Human Factors

EXE_0202_100 (WP1)

In total 277 approaches were performed within WP1. 100 approaches were performed by Honeywell experimental F900 business jet (including nominal RNP to GLS approaches, vectored approaches used for noise evaluation and corner cases testing approaches), 17 RNP to GLS approaches were performed by SWISS, and 160 approaches (120 RNP to GLS and 40 RNP to ILS) were performed by Lufthansa. Several assessments analysing the impact on safety, capacity and human factors were provided. Please refer to Section 8.1 for detailed description of assessments outcomes regarding these topics.

EXE_0202_200 (WP2)

In total 74 approaches were flown with Honeywell experimental F900EX on ILS 200’ and LPV 250’. Observed accuracy performance (horizontal and vertical TSE) was well within the CTQ value of ±1 dot. Thus no negative impact on safety was observed. The perceived level of feasibility from the pilots’ perspective was evaluated for SVGS procedures performed with ILS (200’) and LPV (250’). The results indicated an acceptable level of workload in all measured aspects experienced by pilots within ILS and within LVP approaches. No specific issues were identified by participants regarding the workload relative to the SVGS approach. Therefore no negative impact on safety and human factors was observed. Benefit study was performed in order to evaluate the impact on the capacity. Assessment results showed positive impact on the airport capacity during LVC.

EXE_0202_300 (WP3)

In total, 60 runs were performed in F8X FFS in normal and abnormal conditions, and 6 approaches were flown with DASSAULT experimental Falcon 7X in low visibility conditions. The principle of flying the aircraft by following guidance and by using the EVS image for verification of trajectory has been validated. None of the crew was tempted to maneuver the aircraft with the help of the image instead of following the guidance. Observed accuracy performance (horizontal and vertical TSE) was well within the CTQ value of ±1 dot and all landing were safe and terminated in touchdown zone. All the abnormal cases were timely detected by the crew and resulting in an appropriate decision to go-around. Thus no negative impact on safety was observed. The perceived level of feasibility from the pilots' perspective was evaluated for EFVS to land procedures with RVR300m. the three "go around gate" principle was validated and the results indicated the procedure is feasible even with abnormal cases and in manual. To alleviate workload that may be high in manual, autopilot and autothrottle use are recommended for this low visibility operation. Dual HUD and CVS were considered as valuable features for this operation and demonstrated an efficient crew decision making and a far better Situation awareness than with EVS only. Therefore no negative impact on safety and human factors was observed. Clear briefing of the operation and Training with potential deficiencies of the system is recommended.

More detailed are provided in 6.4.2.2. Benefit study was performed in order to evaluate the impact on the capacity. Assessment results showed positive impact on the airport capacity during LVC.

EXE_0202_400 (WP4)

In this WP the benefits (e.g. relevant information successfully obtained in user-friendly format) were evaluated for EFP&AI application. Big variety of participants was involved in the demonstrations in realistic environment. During evaluation of the perceived level of feasibility of EFP&AI technology from pilots' perspective, no major issues with respect to human factors were identified. There is no impact on safety nor capacity.

5.6 Description of assessment methodology

This section describes the assessment methodology for the feasibility – human factors evaluation (Section 5.6.1), accuracy evaluation (Section 5.6.2), benefits evaluation by simulations (Section 5.6.3) and benefits evaluation by studies (Section 5.6.4).

5.6.1 Feasibility (HF) Assessment (Demo Flights + Questionnaires) Methodology

For the feasibility assessment of the advanced procedures from the pilots' perspective 4 methodologies for obtained data evaluation were used – Likert-type Scale, NASA-TLX, Modified Cooper Harper Scale and Osgood's Semantic Differential Methodology (see description below). The methodologies used for the feasibility assessment follow Human Performance assessment process as described in SESAR Human Performance Reference Material-Guidance [33].

Likert-type scale

A Likert scale is a psychometric scale commonly involved in research employing questionnaires. When responding to a Likert questionnaire item, respondents specify their level of agreement or disagreement on a symmetric agree – disagree scale for a series of statements. Likert scaling is a bipolar scaling method measuring either positive or negative response to a statement thus, the range captures the intensity of their feelings or level of agreement for a given item. Sometimes an even-point scale is used, where the middle option of "Neither agree nor disagree" is not available. This is sometimes called a "forced choice" method, since the neutral option is removed.

NASA-TLX

The NASA Task Load Index (TLX) is a multidimensional subjective workload-rating method. In NASA TLX, workload is defined as the “cost incurred by human operators to achieve a specific level of performance.” The subjective experience of workload is defined as an integration of subjective responses (emotional, cognitive, and physical) and evaluation of behaviours. The behaviours and subjective responses, in turn, are driven by perceptions of task demand. Task demands can be objectively quantified in terms of magnitude and importance. An experimentally based process of elimination led to the identification of six dimensions for the subjective experience of workload: mental demand, physical demand, temporal demand, perceived performance, effort, and frustration level.

NASA-TLX is designed to obtain workload estimates from one or more operators while they are performing a task or immediately afterwards. NASA-TLX allows users to perform subjective workload assessments on operator(s) working with various human-machine systems. NASA-TLX derives an overall workload score based on an average of ratings on six subscales.

These subscales include Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration. It can be used to assess workload in various human-machine environments such as aircraft cockpits, command, control, and communication workstations; supervisory and process control environments; simulations and laboratory tests.

The main advantages of the NASA TLX are that is it a flexible, quick and easy method of estimating workload based on multi-dimensional approach and nevertheless is well-established and widely accepted in the research community.

Modified Cooper Harper Scale

The modified Cooper Harper scale is a uni-dimensional measure that uses a decision tree to elicit operator mental workload. The Cooper Harper Scales is a decision tree rating scale that was originally developed as an aircraft handling measurement tool. The scales were used to attain subjective pilot ratings of the controllability of aircrafts. The output of the scale is based upon the controllability of the aircraft and also the level of input required by the pilot to maintain suitable control. The modified Cooper Harper Scale is based upon the assumption that there is a direct relationship between the level of difficulty of aircraft controllability and pilot workload. Administered post-trial, the MCH involves the participant simply following the decision tree, answering questions regarding the specific task and system under analysis, in order to elicit an appropriate workload rating.

The main advantages are that it is very easy and quick to use, requiring no additional equipment. It is unobtrusive, easily administered and easily transferable. Furthermore, the data obtained when using uni-dimensional tools is easier to analyse than when using multi-dimensional tools.

Osgood’s Semantic Differential Methodology

Semantic Differential is a measurement technique and linguistic tool designed to measure attitudes towards a topic, event, object, activity, or concept, revealing the deeper meanings that are attached to an individual experience. It was introduced in 1957 by Osgood, Suci and Tannenbaum [37] and it is one of the most appropriate techniques to assess the intensity and direction of the meaning of concepts, opinions, and attitudes. Semantic differential method uses a set of bipolar scales. In their simplest form, each of the bipolar scales that make up a semantic differential consists of an antonym pair, which are usually two adjectives (e.g., bad – good; unpleasant – pleasant). The opposites in each bipolar scale are linked in most cases by a continuum of seven or nine points and demand from respondents to indicate how they see the concept. This form of measurement, in which the direction and the intention of meaning is controlled and allocated with bipolar scales, is what is known as semantic differentiation. A unique benefit of the semantic differential is that it offers respondents the opportunity to express their opinions about the concept more fully, that is, ranging from the negative polar to the positive polar.

5.6.2 Accuracy Assessment (Demo Flights) Methodology

In the accuracy assessment the horizontal and the vertical flight path accuracy was evaluated for flown approaches. Dual frequency receiver was used as a truthing system for test flights with the Honeywell experimental business A/C F900. Having one receiver on the ground (installed dedicated one, or publicly accessible one) and another receiver on-board, the obtained post-processed position is of centimetre level accuracy (less than 10cm on a baseline of 10 NM). Total System Error (TSE), which was evaluated by using measured data during testing demonstration flights, is defined as the difference between the aircraft true position and the desired one. TSE could be therefore computed by using the truthing system. Flown vertical path (evaluated within WP1) was also evaluated using a truthing system. For the revenue flights (WP1), GPS measurements were used as there is no possibility to install dual frequency receivers on-board for all involved A/Cs and therefore Flight Technical Error (FTE) was evaluated for revenue flights. Nevertheless, measurements for revenue flights provided sufficient level of accuracy and representativeness for the CTQs. In order to provide a check of results and therefore to ensure the integrity of the results, ANSP (Skyguide) provided ADS-B/radar measurements (for testing as well as revenue flights within WP1 in Zurich).

5.6.3 Benefits Assessment (Simulations) Methodology

For the benefits assessment involving the WP1 (RNP to GLS) benefits simulations (for more details see Appendix B – Section B.4) of the advanced procedures, the recommended SESAR methodology [34] for flights simulations and data evaluation was in general used. Differences between SESAR methodology and the methodology used for simulated data evaluation are identified and explained below.

- Fuel consumption evaluation considers the fuel consumption of the A/C from the common point (IAF or other point agreed by WP1 team) to THR. It includes the fuel consumption during the last phase of the flight/approach (approximately 12NM before THR), where HF/pilot behaviour may have influence on the fuel consumption (flaps position set-up, gear up/down) as this is important phase of the approach for the evaluation. WP1 team defined the configuration schedule for the simulations.
- Simulation conditions: wind = 0kts, Temp = ISA only (conditions were defined by the WP1 team).
- Only one initial weight of aircraft – at the starting point was used (conditions were defined by WP1 team).
- Only one profile (constrained optimum) was used as the simulated vertical profile of the flight, keeping the altitude and the speed constrains (conditions were defined by WP1 team).
- During the same descent/approach it was needed use speed brakes (non-optimal descent due to high altitude at IAF and short distance from IAF to FAF).

5.6.4 Benefits Assessment (Studies) Methodology

Several studies were performed within this project to show a variety of the benefits of involved technologies. Some studies have provided only qualitative outputs of the analysis (justification of such approach is added for the respective parameter). Study evaluating the fuel consumption within specific TMA (RNP) – see Appendix B (Section B.4.2), was directly comparing a real (measured) legacy approach with new simulated one. Airport eligibility analysis for SVGS and EFVS (see Appendix C (Section C.3.2) and Appendix D (Section D.2.2) were based on the evaluation of the percentage of eligible airports for SVGS and EFVS to land operations using the available airports databases. Cost savings for SVGS (see Appendix C – Section C.3.3) analysis was then based on the experts' estimate of the cost savings for the crew qualification.

Within WP2 and WP3, two independent benefit studies with respect to SVGS and EFVS were performed. Analysis evaluating the reduction of diversions/delays/go-arounds for SVGS and EFVS (see Appendix C – Section C.3.1 and Appendix D – Section D.2.1) were based on the evaluation of available airports weather statistics and airport operating hours/traffic statistics. These two independent studies partially used similar methodology. However, as some inputs and several essential details differed in the considered studies, we observe difference in the results.

Figure 14 depicts how WP2 and WP3 diversions/delays/go-arounds studies differ and how they complement each other. In general, it can be stated that WP3 study focused on very detailed weather analysis using the large-scale airport weather database and evaluated benefits in terms of operating hours. Whilst WP2 study concentrated on the quantification of benefits in terms of the number of flights impacted by flight diversion, delay and cancellation (by using relevant airports traffic statistics) and also on the environmental aspects evaluating saved fuel and CO_2 emissions, all primarily for the combination of SVGS and EFVS (i.e. showing the benefits coming from the combination of both technologies). WP3 study looked on the-state-of-art as well as on the future possibilities (e.g. having an ideal no-fail sensor). WP2 study, on the other hand, tended to be very conservative with respect to the assumptions and thus we can foresee better results in reality than those presented in the results of the study. WP2 study kept the same database, methodology and models as previously used in SESAR 9.29 CBA [19]. On the other hand, WP3 study incorporated newer and much wider airport weather database compared to WP2 study. Concluding, each study brings its unique contribution to the project and considering their complementarity, we obtain a wide view on the focus area.

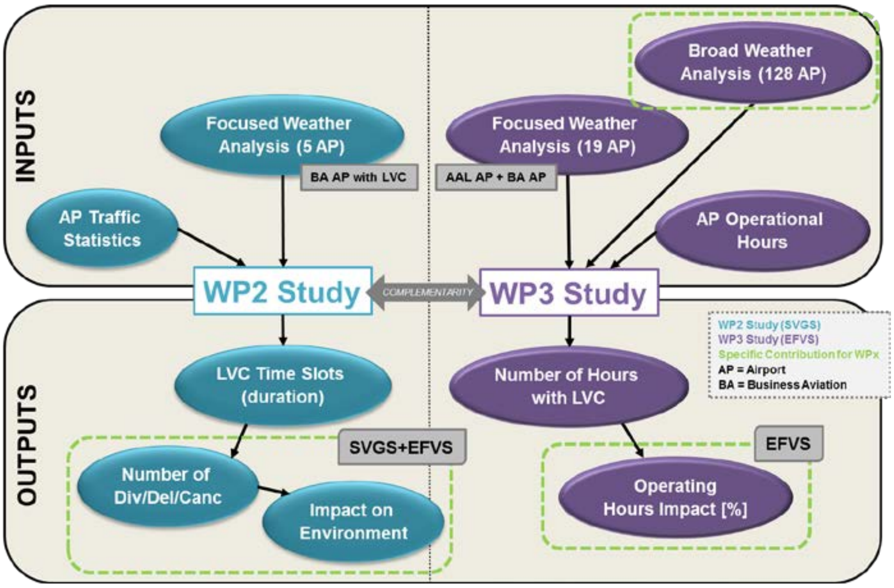


Figure 14: WP2 & WP3 diversions/delays/go-arounds study complementarity

5.7 Results impacting regulation and standardisation initiatives

EXE_0202_100 (WP1)

Impact on the regulations and standards and the importance of the results is due to the significant amount of data collected during demonstrations and due to the methodologies used during data processing and evaluation. Regarding the procedures in Frankfurt and Bremen, results (including both, flight data as well as the noise measurements) are very important for regulatory bodies for confirmation of feasibility and potential improvements of this type of procedures. Regarding the procedures in Zurich, demonstrations will provide important inputs for regulatory bodies to enable the approval for this kind of procedures in the future.

EXE_0202_200 (WP2)

Procedure design for SVGS demonstrations had not to be changed as all required procedures were published and no special charts were necessary for experimental flights, as a guidance from ANS CR. Proposal of charting was implemented into documentation of the project (but not published in the Czech AIP) as not seen necessary. Safety assessment was finished early-September 2015 and test flights were approved by the Czech CAA, also for low visibility procedures. No hazards were seen from ATC perspective, as expected. Overall it may be concluded that demonstrations were successful and showed benefits of SVGS technology and also feasibility from operational perspective in a real environment. Demonstration flights results together with real operational experience with SVGS described above may provide a valuable contribution to the future support of a preparation of a formal application for a European certification of this system. WP2 activity may also contribute to the future work of RTCA SC213 / EUROCAE WG79.

EXE_0202_300 (WP3)

Each of the results of SESAR AAL WP3 have been or will be shared with EASA and FAA certification authorities in the frame of the DASSAULT regular certification activities and through DASSAULT participation to rulemaking task RMT0379 dedicated to low vis operations including EFVS. As of today, aerodrome / ATM impact activity has been shared and discussed with the RMT0379 Operational and aerodrome team. The material produced in SESAR is considered as a major input for the drafting of the aerodrome GM/AMC related to EFVS to land operation. Beyond EASA regulation, aerodrome / ATM impact results will be a valuable contribution to the future homologation of some aerodromes desiring to start deployment of EFVS to land operation. The tight collaboration between DASSAULT and EASA will continue beyond SESAR.

EXE_0202_400 (WP4)

There are no results impacting regulatory and standardisation activities for WP4.

5.8 Analysis of Exercises Results

Exercises results are analysed separately for each exercise – see the summary below and Section 6.

EXE_0202_100 (WP1)

Total 277 approaches were performed within WP1 by Lufthansa and SWISS (revenue flights) and Honeywell (testing flights) in Zurich, Frankfurt and Bremen.

Table 17: EXE_0202_100: WP1 Flights (used for analysis) Overview

Airport	Procedure	IAF	DLH	SWISS	HON
LSZH	GLS X RWY 14	AMIKI	0	6	16
		RILAX	22	11	12
	GLS Y RWY 14	AMIKI	N/A	N/A	N/A
		RILAX	N/A	N/A	N/A
LSZH RNP to GLS TOTAL:			22	17	28
EDDF	GLS X RWY 07R	CHA	8	N/A	5
		RID	0	N/A	0
		IBLUS	4	N/A	0
	GLS X RWY 25L	CHA	14	N/A	0
		DF411	34	N/A	4
	GLS X RWY 25R	CHA	2	N/A	3
		DF411	14	N/A	6
		MTR	0	N/A	0
EDDF RNP to GLS TOTAL:			76	0	18
EDDW	GLS Y RWY 09	GIBMA	0	N/A	4
		EKROV	0	N/A	1
		ARGUV	0	N/A	0
		PIXUR	6	N/A	3
		BMN	0	N/A	0
	GLS Y RWY 27	GIBMA	0	N/A	3
		EKROV	0	N/A	0
		VERED	16	N/A	1
		PIXUR	0	N/A	4
		BMN	0	N/A	0
EDDW RNP to GLS TOTAL:			22	0	16
RNP to GLS [LSZH,EDDF,EDDW] TOTAL:			120	17	62
RNP to ILS [EDDF] TOTAL:			40	0	0
Vectored (noise) [EDDF] TOTAL:			0	0	9
RNP Corner Cases [EDDW, USA] TOTAL:			0	0	7+22
TOTAL:			160	17	100
TOTAL: 277					

Table 17 provides an overview of the approaches. Several types of approaches were included in the demonstrations:

- **RNP to GLS approaches**: flying newly designed RNP to GLS procedures in LSZH, EDDF and EDDW
- **RNP to ILS approaches**: flying newly designed RNP to ILS procedures in EDDF
- **Vectored approaches**: some approaches in EDDF were intentionally vectored (not RNP to GLS) and used in the noise measurement evaluation
- **Corner cases**: special RNP approaches performed in EDDW and USA testing A/C behaviour with intentional horizontal and vertical offset

Several assessments supported by simulations and benefit studies were performed and are included in Section 6.1 and Appendix B, namely:

- RNP to GLS Accuracy Assessment
- RNP to GLS Noise Assessment (for Frankfurt)
- RNP to GLS Flight Tracks Assessment (including corner cases testing)
- RNP to GLS Feasibility Assessment (pilots' and ATC perspective)
- RNP to GLS Fuel and CO2 Benefit Assessment (RTS)
- Procedure interoperability SBAS/GBAS Study from Procedure Design Perspective
- Definition of Procedures into Selected BA Airport near Major Hub (Egelsbach) with Advanced RNP to LPV Assessment

EXE_0202_200 (WP2)

Total 74 approaches were performed within WP2 by Honeywell (testing flights) in Brno, Ostrava and Karlovy Vary. Table 18 provides an overview of the approaches. Several types of approaches were included in the demonstrations:

- **ILS 200'-50'HD**: SVGS approaches with ILS 200', with autopilot coupled or manually flown
- **LPV 250'-50'VTH**: SVGS approaches with LPV 250', with autopilot coupled or manually flown

Table 18: EXE_0202_200: WP2 Flights Overview

AP/Proc.	ILS 200'-50'HD	LPV 250'-50'VTH	TOTAL
LKTB	17	23	40
LKKV	5	6	11
LKMT	23	0	23
TOTAL	45	29	74

Several assessments supported by benefit studies were performed and are included in Section 6.2 and Appendix C, namely:

- SVGS Accuracy Assessment
- SVGS Feasibility Assessment (pilots' perspective)
- SVGS Diversion/Delay/Go-Around and Environmental Impact Assessment (Study)
- Airport Eligibility for SVGS Assessment (Study)
- Crew Qualification Cost for SVGS Assessment (Study)

EXE_0202_300 (WP3)

Total 9 approaches were performed within WP3 by Dassault (testing flights) in France and the Netherlands - Bergerac, Perigueux and Groningen. Also about 60 runs on Full Flight Simulator were performed. Table 19 provides an overview of the demonstrations.

Table 19: EXE_0202_200: Total number of flight and FFS runs trials

	EHGG	LFBE	LFBX	European aerodrome with low Vis conditions	Total
DAS (in Flight)	6	2	1	*10 by end of October 2016*	9 *(19)*
FLYING GROUP (FFS)					24
AIRBUS (in FFS)					24
DASSAULT OPS (in FFS)					19
TOTAL					76 *(86)*

Several assessments supported by benefit studies were performed and are included in Section 6.3 and Appendix C, namely:

- EFVS Accuracy Assessment
- EFVS Safety Assessment
- EFVS Reliability Assessment
- SVGS Airport Capacity Assessment
- SVGS Feasibility Assessment (pilots' perspective)
- SVGS Diversion/Delay/Go-Around Assessment (Study)
- Airport Eligibility for EFVS Assessment (Study)

EXE_0202_400 (WP4)

WP4 demonstrations were executed together with WP1 and WP2 trials and also during special sessions. EFP&AI Feasibility Assessment was performed and is included in Section 6.4 and Appendix E.

5.8.1 Unexpected Behaviours/Results

Unexpected behaviours/results are evaluated separately for each exercise.

EXE_0202_100 (WP1)

There were a few cases of unexpected behaviour mainly noted by DLH crews during Frankfurt approaches (e.g. case of airspace breach described in Appendix B – Section B.1.3). They led to lessons learned, proper mitigation methods (e.g. further pilot trainings) were applied and these were corrected during the course of the project. This was very valuable as the project was able to provide comprehensive lessons learned, and recommendations.

EXE_0202_200 (WP2)

There are no unexpected behaviours/results for WP2.

EXE_0202_300 (WP3)

The difference between SVR and RVR significantly affects the EFVS performance prediction and a specific study should be conducted and a specific study should be conducted.

In FFS in day low visibility conditions, the rendering of the lights was not found as bright as it is in reality. It impairs the pilot's acquisition of real lights through the HUD with EVS as part of the EVS to land concept. For this reason, visual acquisition aspect must be assessed in flight.

EXE_0202_400 (WP4)

There are no unexpected behaviours/results for WP4.

5.9 Confidence in Results of Demonstration Exercises

This section provides the description of quality (Section 5.9.1) and significance (Section 5.9.2) of Demonstration Exercise results.

5.9.1 Quality of Demonstration Exercises Results

Quality of demonstration exercises results is evaluated separately for each exercise.

EXE_0202_100 (WP1)

Demonstration flights were performed in various environment including the airports in Europe comprising major hubs as well as regional airports (Frankfurt - EDDF, Bremen - EDDW, Zurich - LSZH). Flight test data analysis itself were performed in a very detailed way. In order to check the sanity of the results, often more than one approach to perform the analysis was used. This enabled to critically assess the analysis results.

Demonstration flights campaign was supported by pilots in the loop simulations and human factors assessments on the feasibility of procedures and operations, real time simulations evaluating the environmental impacts (such as fuel consumption and CO2 emission) and several benefit studies and benefit assessments.

EXE_0202_200 (WP2)

Demonstration flights were successfully performed in a real environment including 3 European regional airports (LKMT, LKTB, LKKV). Testing approaches including the HF questionnaire evaluation also involved several testing pilots in order to get a good representativeness of the results. Flight test data analysis itself was performed in a detailed way in order to enable critical assessments of the analysis results (accuracy assessment, feasibility assessment).

Demonstration flights campaign was supported by several benefits studies and benefits assessments. Overall, flight trials in a real operational environment together with benefits studies brought very good quality and representativeness of the results of the SVGS technology demonstrations.

EXE_0202_300 (WP3)

An aerodrome impact study involving many experts from various domains and local aerodrome authorities (LFBD, LFBE, LFBX), demonstration flights in low visibility and in real operational environment, FFS runs in limit conditions, benefit studies on 128 European aerodromes frequented by bizjet and a performance prediction validation study were achieved.

These five coherent and complementary activities federated by SESAR and with EASA in the loop have permit to push forward EFVS to land operation in the perspective of its deployment.

EXE_0202_400 (WP4)

In order to ensure good quality and representativeness of the results, variety of evaluation participants involved in the demonstrations was considered. The group that went through the demonstration and questionnaires sessions involved testing and commercial pilots of mainline as well as of business aircraft with different level of flying experience and of different age. Flight ops dispatcher was involved as well. Therefore a good quality and representativeness of the results for the EFP&AI technology demonstrations was ensured.

5.9.2 Significance of Demonstration Exercises Results

Significance of demonstration exercises results is evaluated separately for each exercise.

EXE_0202_100 (WP1)

Procedures using ILS are usable by nearly all commercial aircraft, GBAS is about to follow as an upcoming technology. The exploration of the PBN element RF in combination with these final approach guidance systems is valuable, as it can improve approach procedures regarding noise and fuel efficiency.

Large amount of trials (277) by different aircraft types, operators at different airports in different countries ensures good operational and statistical significance. This exercise has a very good level of representativeness also due to the possibility of demonstrations on the revenue flights (177 flights). Correct behaviour was verified by simulators. Also corner cases were tested with experimental aircraft (testing flights).

Total number of flight trials within this exercise is 277. Table 20Table 27 provides details of A/C type and operator.

Table 20: EXE_0202_100: Total number of flight trials, A/C type and operator

Operator	A/C type		Number of successful RNP to GLS flight trials
Honeywell	Falcon 900EX	experimental	100*
Lufthansa	A380	revenue flights	27
	B 747-8	revenue flights	17
	A320 family	revenue flights	116**
SWISS	A320	revenue flights	14
	A321	revenue flights	3

**NOTE: 78 RNP to GLS, 22 RNP to LPV.*

***NOTE: 76 RNP to GLS with A319, 40 RNP to ILS with A319/320/321.*

EXE_0202_200 (WP2)

Demonstration flights were performed in real operational environment in the EU ensuring good operational significance. Such demonstrations could give a stepping stone for publishing of similar procedures in the Czech Republic, and possibly showing way forward to other European ANSPs.

Total number of successful flight trials performed within this exercise is 74, providing very good statistical significance. Table 21 provides details about the number of approaches per airport and per flown procedure.

In summary, significant number of flight trials in a real operational environment brought very good statistical and operational significance of the results of the SVGS technology demonstrations.

Table 21: EXE_0202_200: Total number of flight trials

AP/Proc.	ILS 200'-50'HD	LPV 250'-50'VTH	TOTAL
LKTB	17	23	**40**
LKKV	5	6	**11**
LKMT	23	0	**23**
TOTAL	**45**	**29**	**74**

EXE_0202_300 (WP3)

Impacts on aerodrome / ATM identified jointly with DSNA and shared with EASA and FAA were consolidated by a flight demo (3 approaches) achieved at both secondary (LFBE) and small AFIS (LFBX) aerodrome in real operational environment. Impacts on aerodrome / ATM will be presented to Antwerp aerodrome on 26th of October 2016.

60 runs were performed at 8 different airports in FFS8X dual HUD by FLYING GROUP, AIRBUS and DASSAULT crews, in normal and abnormal conditions, and for large set of situations such as RVR as low as 300m. Test cases were shared with EASA. Feasibility of the operation was supported by human factor questionnaires resulting from a CS 25 1302 methodology and using a Lickert adapted scale.

A study of the impact of the EFVS to land operation on the capacity was carried out. It is based on the analysis of weather data for 128 European aerodromes frequently used by Bizjets. 19 aerodromes were also analyzed in detail. An IFR procedure review was also done for France to precise the proportion of aerodrome that would be capable to accommodate the EFVS to land operation.

EFVS performance prediction validation study based on 12 fog scenario replayed in fog chamber was conducted. It was supplemented by a comparison with 2 flights in low visibility conditions.

6 approaches in RVR300m with F7X single HUD were performed in real operational environment.

In summary, significant number of FFS trials addressing limit cases, and flight in a real operational environment brought very good operational significance of the results of the EFVS to land operation demonstrations. For flights, 10 more approaches are expected to be performed in more aerodrome environment and in more real low vis conditions by end of October 2016. This will enable to validate some specific points that cannot be checked in FFS. Some of approaches will be performed in dual HUD.

Table 22: EXE_0202_200: Total number of flight and FFS runs trials

	EHGG	LFBE	LFBX	European aerodrome with low Vis conditions	Total
DAS (in Flight)	6	2	1	*10 by end of October 2016*	9 *(19)*
FLYING GROUP (FFS)					24
AIRBUS (in FFS)					24
DASSAULT OPS (in FFS)					19
TOTAL					*76 (86)*

EXE_0202_400 (WP4)

Pilots' evaluation of the EFP & AI application was performed together with RNP to GLS and SVGS flight trials in real environment and operation. Moreover, special sessions were arranged. The group that went through the demonstration and questionnaires sessions involved testing and commercial pilots of mainline as well as of business aircraft, with different level of flying experience, and of different age. Flight ops dispatcher was involved as well. There were 7 questionnaires' respondents in total, what together with a big variety of people involved in the demonstrations ensured good significance of demonstrations results.

5.10 Conclusions and recommendations

Conclusions and recommendations are stated separately for each exercise.

EXE_0202_100 (WP1)

See Section 8.1.

EXE_0202_200 (WP2)

See Section 8.2.

EXE_0202_300 (WP3)

See Section 8.3.

EXE_0202_400 (WP4)

See Section 8.4.

6 Demonstration Exercises reports

6.1 Demonstration Exercise EXE_0202_100 Report

GBAS/SBAS Advanced procedures feasibility and benefits demonstration. This exercise was executed within WP 1.

6.1.1 Exercise Scope

Demonstration Exercise EXE_0202_100 Plan is detailed in Demonstration Plan [27] in Section 5.1.

Technology maturity level will be addressed separately for individual solutions/concept elements in this paragraph. According to the integrated roadmap [36], the enabler CTE-N07a "GBAS Cat I based on Single-Constellation / Single-Frequency GNSS (GPS L1)" within Pre-step1 (AO-0502 — Improved Operations in Low Visibility Conditions) has targeted the IOC on 31.12.2012. The enabler CTE-N07b "GBAS Cat II/III based on Single-Constellation / Single-Frequency GNSS (GPS L1)" within Step1 (AO-0505a — Improve Low Visibility Operation using GBAS Cat II/III based on GPS L1) targeted end of V3 on 31.12.2016. Step 2&3 (AO-0505b — Improve Low Visibility Operation using GBAS Cat II/III based on dual GNSS) is then focused on GBAS movement towards multi-constellation/multi-frequency concept (CTE-N07c "GBAS Cat II/III based on Multi-Constellation / Multi-Frequency (MCMF) GNSS (GPS + GALILEO / L1 + L5)") with targeted end of V3 on 31.12.2022. According to the integrated roadmap [36], the Operational Improvement Step AOM-0605 "Enhanced Terminal Operations with RNP transition to ILS/GLS/LPV" is currently on V2 maturity, targeting IOC 31.12.2020. Also, the Operational Improvement Step AO-0320 "Enhanced Arrival procedures using Increased Glide Slope" is currently on V2 maturity, targeting IOC 31.12.2023.

According to information provided in OSED [18] the Ground Based Augmentation System (GBAS), in addition to ILS, LPV and MLS, is able to provide lateral and vertical guidance within the Final Approach Segment of an Instrumental Precision Approach Procedure. The Current GBAS stations being implemented worldwide are able to provide a level of performances, at least, equal to CAT I. Within the Framework of SESAR GBAS CAT II/III prototypes are being developed.

Although the current standards enable GBAS to provide Terminal Area Procedures and positioning service, the available GBAS CAT I stations provide services only for aligned straight-in final approaches procedures. The straight–in final approach procedure represents the typical operation method for final approach procedures at most airports all around the world. Typically it is used an ILS or "ILS look-alike" technology. These kinds of procedures are designed so that the aircraft can use the intermediate segment to be aligned with the FAS course. Typically it is designed a 2 NM segment before the FAP in order to get the aircraft stabilized before the FAS. The ILS look-alike concept provides Operational benefits, crew training cost reduction and takes advantages of xLS crew skills for the benefit of safety. This concept applied to GLS in the cockpit allows taking advantages coming from the ILS similarities such as displays, tuning, warnings etc.

The last PBN manual allows the RF leg function to be used in initial and intermediate approach segments and potentially in the final phase of the missed approach. The RF leg feature is already included within the RNP AR Navigation Specification, even to be used in the final segment, but the ideas developed within this project would allow avoiding the demanding RNP AR certification and approval process maintaining or improving the current standard safety levels.

The implementation of the RNP with transition to xLS provides clear benefits for the involved actors (ANSP, Airlines) comprising from the optimization of operational flight safety and the reduction of operating cost to the reduction of the environmental impact.

It is relevant to highlight that very similar concepts can be developed with a GBAS CAT II/III enabler.

GBAS/SBAS Advanced procedures are strongly linked to the Operational Focus Area OFA 01.01.01 "LVPs using GBAS" and related to Operational Improvement AO-0505-B "Improved Low Visibility Runway Operations Using GNSS/GBAS" (STEP 2).

RNP1 with RF-legs procedures to GLS/LPV with an increased glideslope will enable the flexibility to redesign arrival procedures taking more into consideration environmental issues such as noise abatement or fuel efficiency. We propose to study the benefits of those ecological approaches into large airports as well as into business aviation satellite airports.

It is to be noted that RNP1 with RF leg complies with A-RNP, they are the same from the procedure designer's perspective.

One of the objectives was to design of the relevant GBAS / RNP to xLS approaches procedures for Frankfurt airport, Bremen as well as Zurich airport. The main KPAs included:

- Environmental impact (noise), measured by noise measurement stations of Fraport at Frankfurt.
- Fuel efficiency (length of approach path) in Bremen and Zurich airport.
- Safety in terms of flight path accuracy (flight path lateral / vertical accuracy).

The project measured fuel, noise and accuracy benefits comparing present practices with proposed advanced procedures at two large airports: Frankfurt and Zurich and at one medium airport: Bremen. RNP to xLS procedures are flexible and enable to resolve customized challenges of each airport. For some airports there is a need for shorter flight path of new procedures which brings fuel savings as well as less CO2 emitted during the approach. For other airports the demand can be a flexible flight trajectory (which can be longer than the legacy one) in order to reduce noise in particular highly populated areas. This project aimed to demonstrate both types of benefits – fuel savings and less CO2 emissions with the new procedures in Bremen and Zurich and noise abatement benefit in Frankfurt. Increase of the glideslope brings additional benefit with respect to the noise abatement. The goal was also to validate that a GBAS-based approach will meet the relevant safety requirements and reduce the impact of aircraft noise on the communities surrounding the airport while keeping the airport's capacity at the same level as for conventional (ILS) approaches.

A benefit study analysed traffic flows at those locations and make use of the advanced procedure design flexibility to enhance accessibility into business aviation satellite airports, while minimising the disturbance at its neighbouring large airport. The example of Egelsbach in the Frankfurt area was studied.

The project also focused on procedure interoperability. Precision approach procedures were supported by GBAS and SBAS enablers, with different targeted operations. However, the 3D flight path of the Advanced RNP procedure to GLS or LPV was identical, and Airspace Users need to remain the owner of the operation they intend to execute. A benefit study analysed from a GLS/LPV procedure design perspective the delta between both developments, with the objective to minimise the costs of publishing those precision approach procedure with GLS and LPV lines of minima. Relevant parts of documents provided by SESAR 6.8.8 (6.8.8.D14 INTEROP [23], 6.8.8.D08 VALP-V2 [24] and 6.8.8.D10 VALP-V3 [25]) and by SESAR 5.6.3 (5.6.3.D38 V3 SPR [26]) were taken into consideration for Demonstration Plan and Report.

6.1.2 Conduct of Demonstration

This section details the preparatory activities (Section 6.1.2.1), the execution activities (Section 6.1.2.2) and description of deviations from the planned activities (Section 6.1.2.3).

6.1.2.1 Exercise Preparation

Preparatory activities were covered by the SWP 1.1 "GBAS/SBAS Definition" and SWP 1.2 "GBAS Systems (Air & Ground)".

SWP 1.1 "GBAS/SBAS Definition" provided the GBAS/SBAS definition activities and involved the airports in Germany (Frankfurt, Bremen) as well as in Switzerland (Zurich). This SWP included 2 main Tasks – Procedures definition and Safety Assessment. The Feasibility Studies Task dealing with procedure interoperability of SBAS/GBAS from procedure design perspective as well as advanced RNP procedures to LPV with larger RF leg was part of this SWP too.

SWP 1.2 "GBAS Systems (Air & Ground)" provided the Airborne and Ground systems preparation and involved the airports in Germany (Frankfurt, Bremen) as well as in Switzerland (Zurich). This SWP included 2 main Tasks – Aircraft & Receiver Modification and Ground aspects Preparation.

The following paragraphs detail the achievements within these SWPs per task and per contribution of each partner separately.

SWP 1.1 GBAS/SBAS Definition

T 1.1.1 Procedures Definition [Germany]

DFS [TL]

Based on an existing ground infrastructure the procedures for Bremen and Frankfurt were developed to evaluate the possible benefits of RF-legs in initial segments and shorter final approaches with steeper descent angles. The existing airspace concept was taken into account and all important parts of the procedures were designed to be as far as possible within airspace class C. The remaining parts were constructed within airspace class E and a specific note on all charts have enhanced awareness of this situation.

Specific attention was paid to the fact that because of shorter final the flight altitudes are well below the now existing procedures. So the obstacle evaluation was an important part during procedure design to optimize the nominal flight path.

All necessary measures have been taken to prepare the basic files for chart production. FAS DB as well as Waypoint lists with all necessary coordinates have been developed. Also a tabular description of the IFP (instrument flight procedure) with the recommended coding was created to ease the process of database-preparation.

All procedures were approved by regulator.

For the GLS-final with 3.2° in Bremen the issue with the PAPI, set to 3.0° presently, could not be solved until begin of trials and the live-trials were executed without PAPI. If new procedure is to be implemented, it is necessary to assure that an existing PAPI and the new final approach descent path match. Otherwise, at least in Germany, there will be a legal problem to invent this new procedure.

Airbus

With respect to the support of Frankfurt and Bremen RNP1 with RF-legs to ILS/GLS approaches development (including operational assessment using Airbus aircraft simulator), 3 simulator session were performed on EDDW by Airbus, 5 on EDDF and 2 on LSZH. Finally a Full Flight Simulator session was performed with SWISS and Lufthansa pilots on all airports to share experience acquired by Airbus. Evaluation of procedure design was based on charts. Conclusion was provided to DFS to support ATM procedure safety assessment.

Regarding the development of SOP for flight crew, the first tests, Airbus existing SOPs (in FCOM) and recommendations in FCTM address this type of procedures followed. No new SOP was required. Nevertheless, the appropriate way of activating the "APPR" push button described in the SOP was underlined.

T 1.1.2 Procedures Definition [Switzerland]

Skyguide [TL]

The procedure design has been done in accordance with ICAO Doc 8168 PANS-OPS, except for RF leg intercept. In case of RF leg intercept to the FAP of the GLS X approach some design assumption had to be made as the ICAO criteria for such an intercept do not exist yet. Since the flight track lies above the Minimum Vectoring Altitude (MVA), obstacle clearance is not an issue there.

The designs of each approach are documented in an instrument flight procedure (IFP) report, including also the relevant data of the FAS data block. The IFP reports have received approval from the Federal Office of Civil Aviation.

Instrument Approach Charts (IAC) have been developed as well as coding tables and coordinate lists and were handed over to Lufthansa and Swiss for the FMS coding.

Flight validation took place in June and August 2015 with a Beechcraft 350 of the Flight Calibration Service using Rockwell Collins avionics.

Honeywell

Navigation Database was updated with the newly designed GLS X RWY 14 procedure for Zurich. It was loaded on the F900 Integration bench for validation and performance testing. The procedure was validated with respect to the defined approach plate. Waypoints, speed/altitude constraints, leg types, computed descent angles, and computed leg length were successfully verified. In order to also check the vertical and lateral performance under different conditions, 30+ approaches were dynamically flown using both AMIKI and RILAX transitions (see Figure 15). With respect to the localizer capture (tested with no position error), the initial testing does not suggest issues even if the approach button is pushed early - in such case, RF leg from IF may not be flown exactly but it is not expected to exceed RNP 1. Recommendations to use the Airbus FCOM for ILS/GLS precision approaches agreed between partners (see [21]).

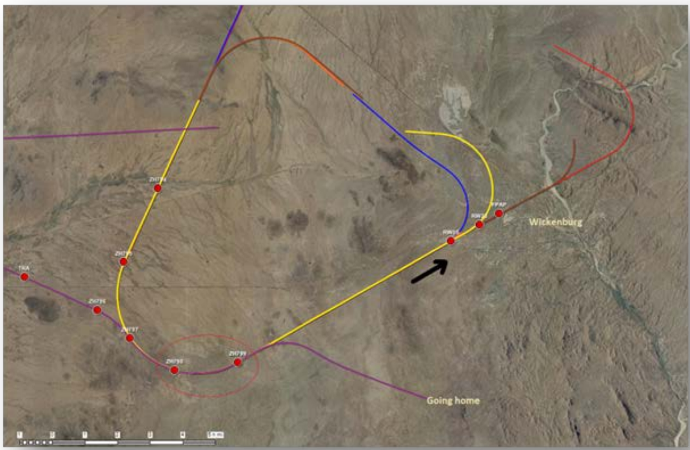


Figure 15: Ground track - Testing flights for Zurich Procedure GLS X RWY14 in Wickenburg

When an RF leg is connected directly to the FAP, the GS capture can be compromised even when flying level to the FAP. The Flight Control mode logic has to capture the LOC portion before the GS can capture. With an RF leg preceding the FAP, the LOC capture is delayed until the aircraft is aligned just a short distance before the FAP. On a straight-in approach, the LOC mode is free to capture long before the FAP.

In cold conditions, the operational method of leaving the altitude selector at the FAP altitude will work even for RF to FAP as the GS capture point occurs after passing the FAP. However in hot temperatures, the GS capture point comes prior to the FAP and may occur before the LOC has captured thus preventing the GS from capturing. This will occur even when flying level at the FAP altitude on the RF leg.

Honeywell analysis and flight testing show that for continuous descents with the altitude selector dialled down to the MDA, the experimental Zurich GLS RWY 14 with an RF to FAP could present GS capture problems. The temperature thresholds for capture without temp comp active were analysed to be -2 deg Celsius and 36 deg Celsius (field temperature) for this case. On the cold end of the temperature range, setting the altitude selector at the FAP altitude will force a level off and assure GS capture. Thus the standard operating procedure of setting the altitude selector at the FAP altitude works as a mitigation. This method does not work in hot conditions as described above, as the LOC captures after the aircraft is above the GS capture zone. Thus handling hot temperatures is of the main interest and will be discussed below.

Honeywell also analysed and flight tested lateral offsets of 0.3, 0.5, and 1.0 nm. The results show that lateral offsets bigger than 0.5 nm will result in a failure to capture the LOC. Thus the RNP 1.0 allowance is too liberal for assured LOC capture. However, the real lateral flight navigation error is next to negligible for aircraft equipped with GPS. The flight technical error in LNAV is also generally only a fraction of even the 0.3 nm RNP. Thus in practicality, the lateral capture is not an issue. It is expected that all aircraft equipped to fly RF legs also have a GPS navigation solution.[1]

It is important to highlight crew training for manual transition correcting the VNAV managed mode with selected vertical mode. The manual interaction is not needed with advanced aircraft functionality, such as use of the function described below.

Honeywell has implemented and tested a new FMS function that will significantly improve RNP to xLS Localizer/Glideslope capture. The technology provides real-time correction of vertical errors induced by uncompensated non-standard atmospheric conditions (e.g. high/low temperatures), and real-time correction FMS lateral navigation errors induced by non-GPS position sensors (applicable to RNP to ILS only). Operational benefits include consistent and precise final approach captures, reduction of crew workload and reduction of missed approaches. Detailed results can be found in Appendix B (Section B.1.3).

T 1.1.3 Safety Assessment

Airbus [TL]

Airbus tested and validated the proposed procedures and provided procedure designers and airlines with simulator report summaries to support their safety assessment.

DFS

All IFP were developed in accordance with ICAO DOC 8168 and ICAO DOC 9613 (A-RNP or RNP-1, RF-functionality required) and are fully ICAO-compliant. Therefore the standard processes for safety assessments within DFS are valid and cover all procedure segments.

Skyguide

ICAO Annex 11 places an obligation on States to ensure the Safety of Air Traffic Services via the adoption of Safety Management Systems. Eurocontrol Safety Regulatory Requirements (ESARRs) have been developed by the Safety Regulation Commission in order to translate this obligation into a set of concrete requirements to be fulfilled across Europe. In particular, ESARR4 concerns the use of Safety Assessments in Air Traffic Management (ATM) when introducing and/or planning changes to the ATM System. Skyguide's Safety Assessment process affects changes to the ATM System and supporting services lying within its managerial control. For operational trials, safety activities shall address all aspects of the trials.

A safety assessment workshop has taken place with participation of Skyguide system safety experts, CNS experts, ATCO's, a PANS-OPS expert, a pilot and an engineer from SWISS flight OPS engineering and a representative from Zurich airport. The operational trials have been discussed and potential failures/malfunctions that may arise from the change have been identified. Three failures/malfunctions have been found. For each of them, the potential effects, and the severity have been defined together with an estimation of the likelihood of producing these effects.

[1] ***Note for cold temperatures:***
In cold weather conditions, the FAP altitude constraint can be compensated manually or by the FMS if equipped with a temp comp function. By raising the FAP altitude, the FMS VNAV baro decent path aligns better with the precision descent path.
An alternative new experimental FMS function (tested in this project and explained above) works by smoothly transitioning the VNAV baro path guidance to the precision glideslope prior to arriving at the FAP.
Operationally, cold temperature effects on the baro VNAV path can be mitigated by setting the altitude selector at the FAP altitude. This will prevent the aircraft from descending further in VNAV and cause a small level off after FAP to capture the precision descent path.

The expert judgments and opinions of the participants were utilized to identify hazards for the implementation of the operational trials and to propose mitigation strategies. No hazards have been identified related to the trial flights, as enough mitigation are in place. Therefore, it has been considered, that the trial phase will not have any negative safety impact on ATCO work and it has been concluded that the proposed trials are acceptably safe for implementation.

The safety assessment is documented in a report called Initial Safety Analysis of ATM System Changes for the change 2015-0012 SESAR AAL.

DLH

The ORE (Operational Risk Evaluation) was written to cover the possible risks for the line operation during the flight trials. The ORE was reviewed by DLH safety department without any restrictions indicated.

SWISS

SWISS pilots and engineers attended the Skyguide Safety Assessment in order to support and give inputs from an airspace user point of view. Furthermore a SWISS internal Operational Risk Evaluation has been performed in order to evaluate potential risks associated with the trial procedures and to define possible mitigation measures.

T 1.1.4 Feasibility studies

NetJets [TL], DLR

Activities within this task were split into two phases. Phase 1 (January - July 2015) included the procedure interoperability SBAS/GBAS study from procedure design perspective –results are included in Appendix B (Section B.4.1). Phase 2 (August 2015 – April 2016) focused on definition of procedures into selected business aviation airport near major hub (Egelsbach) with Advanced RNP procedures to LPV and a Visual RNAV proposition - results are included in Appendix B (Section B.4.2).

SWP 1.2 GBAS Systems (Air & Ground)

T 1.2.1 Aircraft & Receiver Modification

Honeywell [TL]

The software changes of the GBAS receiver which have been needed were assessed and as these are minor changes they were performed as part of the aircraft integration testing.

The installation consisted of a VIDL/G receiver, with a prototype upgrade to GBAS CAT II/III, integrated with the autopilot. The FMS NDB was updated with the FAS data for the expected approaches. The SPAN-SE Novatel receiver was used as a truthing system.

The RS232 data output, as well as ARINC 429 outputs from the VIDL/G receiver were recorded using a laptop. Required ASCB data were recorded using the TIU (Test Interface Unit). Novatel receiver outputs were recorded using the TIU as well. See Figure 16.

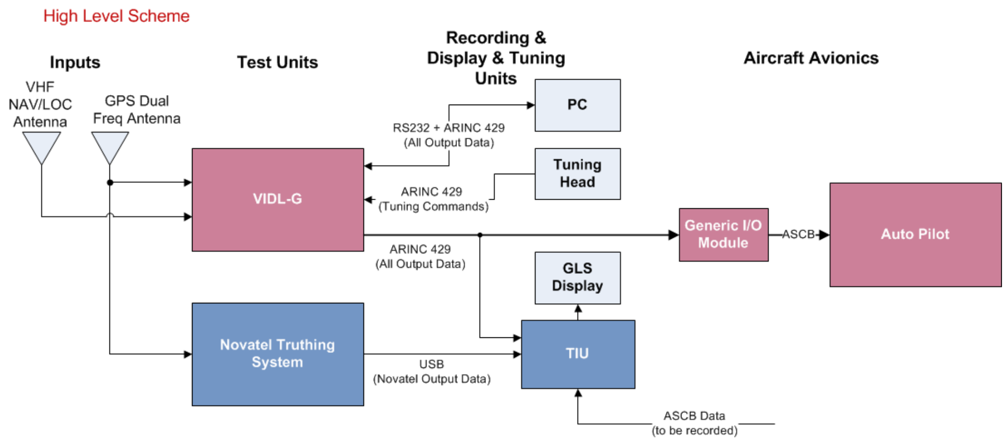


Figure 16: Honeywell High Level Integration Scheme

DLH

3 A319 aircraft have been equipped with GLS. The SBs (Service Bulletin) were delivered by Airbus as well as the needed kits mid-July 2015. 3 A/C were equipped during their regular C-Checks scheduled starting 20th July 2015 until 9th August 2015, because one day A/C ground time was needed for the GLS activation. However the time plan was very tight, since it was needed to transform the SBs into EOs (Engineering Order) and then into working cards before the C-Checks. The update of the documentation (FCOM, MMEL, ACD and AFM) needed to use the GLS was finished mid-August 2015.

SWISS

Our two aircraft were already equipped with GLS outside the AAL project. SWISS has teamed up with Lufthansa and the navigation database provider in order to define the coding and providing process of the trial procedure. The appropriate navigation database with the new approaches has been loaded to the aircraft and the flight crews were informed accordingly.

T 1.2.2 Ground Aspect Preparation [Germany]

DFS [TL]

All GBAS ground equipment is already operational at Bremen and Frankfurt. The implementation of the new FAS DB was done following the standard processes of DFS.

Fraport

The noise monitoring concept for RNP to xLS approaches in Frankfurt has been prepared. 11 fixed noise monitoring terminals (NMT) were used together with 3 mobile NMTs on trailer and with up to 3 portable NMTs (see Figure 17 and Figure 18). The concept of location of NMTs and measurement procedure involved RWYs 25L, 25R and 07. RWY 25 had higher priority as is has the higher percentage of the use.

In order to have a good statistical evidence, a minimum of 10 approaches per runway end and per aircraft type were needed to be flown. The tracking of the aircraft configuration was needed too in order to interpret/compare the noise levels correctly.

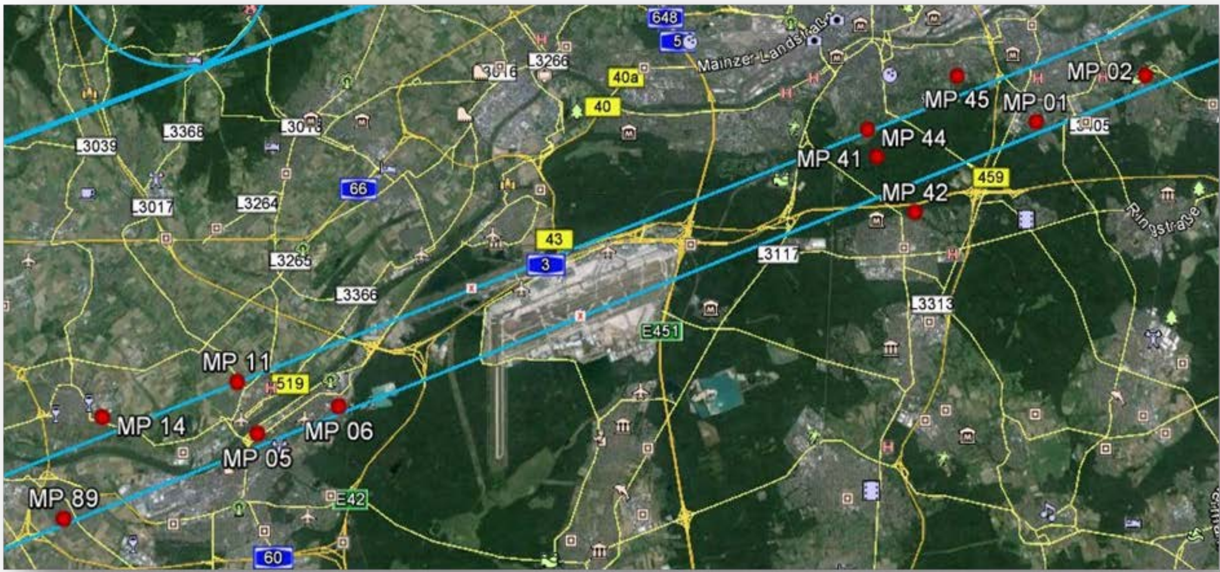


Figure 17: Noise Monitoring Terminals (NMTs) – fixed

Figure 18: Noise Monitoring Terminals (NMTs) – on trailer (left), portable (right)

T 1.2.3 Ground Aspect Preparation [Switzerland]

Skyguide [TL]

The operational trials required the implementation of two new GLS approaches, GLS X RWY14 and GLS Y RWY14. Each of these new GLS approaches required an own final approach segment (FAS) data block which has been generated by Honeywell. Afterwards, the FAS data blocks have been inspected for correctness.

The GBAS station at the airport of Zurich is operational navigation equipment, supporting the GLS RWY14 approach. The upload of the two new FAS data blocks in the existing equipment had to be carried out by certified ATSEP personnel according to defined Skyguide processes on planned work on ATM, AIM, CNS or infrastructure equipment. The task has been performed beginning of June 2015.

6.1.2.2 Exercise execution

Execution activities were covered by the SWP 1.3 "GBAS Trials". This SWP covered the flight trials activities and involved the airports in Germany (Frankfurt, Bremen) as well as in Switzerland (Zurich). This SWP included 7 main Tasks – Demonstration Plan 1st Review – Input to the consolidated version, Demonstration Plan 2nd Review – Input to the consolidated version, Coordination with Regulators Supported by EASA, Trial Preparation, Execution, Communication and Demonstration Report - Input.

Table 23 summarizes the actual demonstration schedule of the exercise. Figure 19 then details the timeline for demonstration flights campaign for all airports included in this exercise.

Table 23: EXE_0202_100 - Exercise execution/analysis dates

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise analysis start date	Actual Exercise analysis end date
EXE-02.02-D-100	GBAS/SBAS Advanced Procedures Feasibility and Benefits Demonstration	10 / 2015	9 / 2016	11 / 2015	10 / 2016

Figure 19: EXE_0202_100 - Exercise flight campaign timeline (note: *Sep 2015 in Zurich only preparatory activities by Swiss and DLH)

The following paragraphs details the achievements within this SWP per task.

T 1.3.1 Demonstration Plan 1st Review – Input

All inputs to the Demonstration Plan 1st Review were provided followed by the review of the partners.

T 1.3.2 Demonstration Plan 2nd Review – Input

All inputs to the Demonstration Plan 2nd Review were provided followed by the review of the partners.

T 1.3.3 Coordination with Regulators Supported by EASA

A flight inspection in LSZH has been carried out mid-June 2015 to verify that the FAS data block has been uploaded correctly and the signals emitted reflect the final approach segment as defined in the IFP. Based on this and based on the acceptance of the Skyguide Safety Assessment as well as the SWISS Operational Risk Evaluation all partners (Lufthansa, Swiss, Honeywell) got an approval from FOCA for demonstration flights to be performed in Zurich. With respect to demonstration flights in Frankfurt and Bremen, the procedures were published and therefore there was a need only for the approval for aircraft to be able to fly RNP 1 with transition to RF-leg. All partners (Lufthansa, Swiss, and Honeywell) have this type of approval for their fleet involved in this project.

T 1.3.4 Trial Preparation

DLH

The testing flight by Lufthansa was successfully performed on September 4th 2015 in Zurich (GLS X RWY14 approach). Results of this testing were very good, based on the results there were only some minor changes to the handouts to the pilots at this stage. The handout was adapted for the trials in EDDF and EDDW to familiarize pilots with the respective procedures and (especially for EDDF flown with A380 and B748) with the aircraft related topics.

HONEYWELL

Initial successful preparation flight tests were performed on July 31st 2015 in a US airport (Wickenburg) with mapped Zurich GLS X RWY 14 procedure. The objectives were to evaluate the xLS lateral and vertical capture behaviour, validate the lab findings with respect to temperature tolerance for vertical capture without temperature compensations active and nominal capture with temperature compensation active.

7 approaches were flown using both AMIKI and RILAX transitions, with different baro offsets to simulate compensated hot day, uncompensated hot day, and hot/cold errors. The initial findings were good, lateral performance was normal and vertical performance with temp comp (see Appendix B - Section B.1.3) active was normal.

As a preparation for the second phase of demonstration flights in June 2016, number of verification and corner case testing was performed in May 2016 in Wickenburg, including initial testing of new Honeywell FMS function to improve RNP to xLS Localizer/Glideslope capture for vertical errors (uncompensated non-standard temperature), and lateral errors.

SWISS

The testing flight by Swiss was successfully performed on September 16th 2015 in Zurich (GLS X RWY14 approach). The procedure went well and the pilots were impressed by the performance of the GLS and the absence of the "limitations" known by the ILS.

T 1.3.5 Execution

Demonstration flight campaign was started after the Project Gate (October 1st, 2015).

Based on the initial testing flights it was agreed to recommend for the trials to use same procedure that the one recommended by Airbus FCOM for ILS/GLS precision approaches. Airbus SOPs for ILS/GLS procedures should be followed: Press the APPR press button when cleared for approach and on the intercept trajectory for the final approach course [21] (see FCOM for more details). DHL SOP states that APP B should be pushed later on. For glideslope capture, the airlines are compensating for temperatures below ISA.

In total 277 successful demonstration flights were performed in Frankfurt, Bremen and Zurich by Honeywell (experimental flights) and Lufthansa and Swiss (revenue flights). In addition, corner cases testing (larger lateral and vertical errors) were executed with the experimental F900 by Honeywell in USA (Wickenburg airport) and also in Bremen (see Appendix B - Section B.1.3 for more details about corner cases testing). For details about exact numbers of flights performed see Table 24. It is to be noted that the difference between flown flights and analysed flights is caused by the fact that data were not recorded for some of the flights or crew feedback not available.

Table 24: EXE_0202_100: Total number of flight trials

Operator	EDDF	EDDW	LSZH	E25*	Total
DLH analysed	116	22	22	-	**160**
DLH flown	160	25	29	-	**214**
Swiss	-	-	17	-	**17**
Honeywell	27	23	28	22	**100**
Total analysed	**143**	**45**	**67**	**22**	**277**
Total flown	**187**	**48**	**74**	**22**	**331**

**NOTE: Corner cases testing in Wickenburg, US – E25 (only for preparation and testing flights) – performed in 2016.*

Using the data collected during demonstration campaign, the accuracy objective, flight tracks objective as well as feasibility of GBAS advanced procedures were evaluated (see Appendix B – Sections B.1 and B.2). Another integral part was the noise measurement evaluation for the procedures flown in Frankfurt. This evaluation was done for revenue flights as well as for revenue flights - for results see Appendix B (Section B.1.2).

Benefits simulations by Airbus, Honeywell, Lufthansa and Swiss were performed and results are presented in the Appendix B (Section B.4). These simulations were included in order to evaluate the environmental/fuel efficiency benefits such as fuel consumption and CO2 emissions. The reference scenarios for this project were the current legacy published procedures. The legacy published approaches were compared to the new RNP to GLS procedures and procedures with increased glideslopes as designed in the project. RNP to GLS procedures are flexible and enable to resolve customized challenges of each airport. For some airports there is a need for shorter flight path of new procedures which brings fuel savings as well as less CO2 emitted during the approach. For other airports the demand can be a flexible flight trajectory (which can be longer than the legacy one) in order to reduce noise in particular highly populated areas. This project aimed to demonstrate both types of benefits – fuel savings and less CO2 emissions with the new procedures in Bremen and Zurich and noise abatement benefit in Frankfurt. Increase of the glideslope brings additional benefit with respect to the noise abatement.

T 1.3.6 Demonstration Report – Input

All inputs to the Demonstration Report were provided followed by the review of the partners.

T 1.3.7 Communication

The communication activities were performed in accordance with the communication plan – see Section 7.

6.1.2.3 Deviation from the planned activities

Within WP1 a minimum of 10 RNP to GLS approaches by use of SWISS revenue service flights were planned. Due to a good cooperation with all internal and external stakeholders and partners a total number of 17 successful approaches was achieved.

Within WP1, more than 100 RNP to xLS approaches by use of Lufthansa revenue service flights were planned. Due to a good cooperation with all internal and external stakeholders and partners a total number of 160 successful approaches (120 RNP to GLS, 40 RNP to ILS) was achieved. Also A320 family (A320 and A321) was included addition to demonstrations of RNP to GLS on the Lufthansa side and flew RNP to ILS approaches do demonstrate feasibility as well.

Within WP1, a minimum of 30 demonstration flights were planned for testing flights (with Honeywell business A/C F900EX). During demonstrations, total 100 RNP to GLS successful flights were achieved. This number comprise of 62 RNP to GLS flights in Zurich, Frankfurt and Bremen, 9 vectored approaches which were used as a baseline for noise evaluation in Frankfurt, and also 29 approaches used for corner cases testing (22 in USA and 7 in Bremen) – for overview see Table 25.This higher number of approaches improved a statistical significance for data evaluation with respect to accuracy measurements as well as with respect to the human factors (feasibility) assessment. Also, corner cases testing was performed in addition to the Demonstration Plan and brought important results for confirmation of feasibility of this type of procedures. In USA, 22 approaches took part in the corner cases testing (8 of 22 trials were nominal RNP to GLS used for corner cases evaluation) and 7 corner cases testing approaches were performed also in Bremen. Corner cases testing included trials with intentional horizontal offset (0.5 and 0.3 NM) as well as with intentional vertical (baro) offset. Another important input to the corner cases testing was a new Honeywell FMS function that will significantly improve RNP to GLS Localizer/Glideslope capture. This new blending function provides a real-time correction of vertical errors induced by uncompensated non-standard atmospheric conditions (e.g. high/low temperatures) and also FMS lateral navigation errors induced by non-GPS position sensors (applicable to RNP to ILS only). For details see Appendix B (Section B.1.3).

Table 25: EXE_0202_100: Overview of testing flights (with Honeywell business A/C F900EX)

	TOTAL	nominal RNP to GLS	vectors	corner cases
LSZH	**28**	28	0	0
EDDF	**27**	18	9	0
EDDW	**23**	16	0	7 (GLS)
USA	**22**	0	0	22* (LPV)
TOTAL	100	62	9	29

**NOTE: 8 of 22 trials were nominal RNP approaches used for corner cases evaluation comparison.*

6.1.3 Exercise Results

6.1.3.1 Summary of Exercise Results

The results were assessed against the success criteria and it was decided if the Demonstration objective status is OK, POK or NOK. Overall assessment for all criteria (involving all exercises) is presented in the Table 8 in Section 5.1.

6.1.3.2 Analysis of Exercise Results

In the following sections the exercise results are summarized according to the demonstration objectives evaluation. For detailed analysis see relevant Appendixes.

6.1.3.2.1 Feasibility demonstration: OBJ_0202_011 (RNP to xLS), OBJ_0202_012 (IG)

Identifier	**OBJ_0202_011**
Objective	To demonstrate the feasibility of curved approaches with RNP to xLS.
Success Criterion	Curved approach with RNP to xLS procedure is feasible based on the feedback from ATC and pilots.
Addressed KPA	**Human Performance**

Identifier	**OBJ_0202_012**
Objective	To demonstrate the feasibility of GLS approaches with increased glideslopes of 3.2 deg.
Success Criterion	GLS approach with increased glideslope (3.2 deg) procedure is feasible based on the feedback from ATC and pilots.
Addressed KPA	**Human Performance**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_100	**SCN_0202_101**	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_102	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319	ILS	RNP to ILS approaches with GSL = 3.2 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_103	OBJ_0202_011 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 A380 B747-8 F900	GBAS	RNP to GLS approaches with GSL = 3 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_104	OBJ_0202_011 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 A380 B747-8	ILS	RNP to ILS approaches with GSL = 3 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_105	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_028	EDDW	A319 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Accuracy measurement.
	SCN_0202_106	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_028	LSZH	A319 A320 A321 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Accuracy measurement.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix B (Section B.2.1).

RESULTS ANALYSIS OVERVIEW

Three workshops with ATC controllers were organized in order to obtain feedback on the developed RNP procedures from an ATCo operational perspective. The first workshop was held in November 2015, just before the start of demonstrations on the Zurich RNP to GLS procedure. The second was held in February 2016, where Skyguide ATC shared their experience after three months of demonstration trials including testing and revenue flights in Zurich airport. Another workshop was organized in September 2016, where ATC from all three airports involved in the AAL project (Zurich, Frankfurt and Bremen) participated and provided their feedback on the RNP to xLS operation. In Section 8.1, see the summary of the outcomes from the workshops.

The perceived level of feasibility of the designed procedures was assessed using questionnaires, coordinated between the project partners. The questionnaires were completed by the pilots directly after each approach (DLH, Swiss, Honeywell) and with the presence of human factor scientists on board of the business aircraft. In Section 8.1, see the summary of the conclusions and recommendations.

6.1.3.2.2 Benefits demonstration: OBJ_0202_021 (Accuracy)

Identifier	**OBJ_0202_021**
Objective	To demonstrate accuracy of advanced procedures.
Success Criterion	TSE for advanced procedure approaches is within the relevant CTQ value.
Addressed KPA	**Safety**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_100	**SCN_0202_101**	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_102	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319	ILS	RNP to ILS approaches with GSL = 3.2 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_103	OBJ_0202_011 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 A380 B747-8 F900	GBAS	RNP to GLS approaches with GSL = 3 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_104	OBJ_0202_011 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 A380 B747-8	ILS	RNP to ILS approaches with GSL = 3 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_105	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_028	EDDW	A319 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Accuracy measurement.
	SCN_0202_106	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_028	LSZH	A319 A320 A321 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Accuracy measurement.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix B (Section B.1.1).

RESULTS ANALYSIS OVERVIEW

For Accuracy Assessment, the horizontal and vertical flight path accuracy was evaluated for the procedures. Flight path in the lateral direction on the RF leg is precisely provided and therefore the total system error (TSE) can be computed thanks to the use of truthing system - dual frequency receiver for flights with business aircraft; and FTE (provided by DLH and Swiss from GPS position) will be compared to CTQ. It should be noted, that according Doc9613 [45], for the FTE the limit value is 0.5 NM and for TSE the limit value is 1NM (as the CTQ is set). In Section 8.1, see the summary of the conclusions and recommendations.

6.1.3.2.3 Benefits demonstration: OBJ_0202_024 (Noise)

Identifier	**OBJ_0202_024**
Objective	To investigate the environmental impact of some advanced procedures in terms of local noise (at RNP to xLS transition and under increased glideslope).
Success Criterion	Noise measurements during approaches with some advanced procedures show a change in the noise by relevant CTQ value.
Addressed KPA	**Environment / Fuel Efficiency**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_100	**SCN_0202_101**	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_102	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319	ILS	RNP to ILS approaches with GSL = 3.2 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_103	OBJ_0202_011 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 A380 B747-8 F900	GBAS	RNP to GLS approaches with GSL = 3 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_104	OBJ_0202_011 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 A380 B747-8	ILS	RNP to ILS approaches with GSL = 3 deg. Noise Measurements on Ground. Accuracy measurement.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix B (Section B.1.2).

RESULTS ANALYSIS OVERVIEW

Noise was assessed in Frankfurt by Fraport for a total of 74 RNP to xLS approaches performed during the project for 4 different aircraft types. Thorough assessment taking into account atmospheric conditions and aircraft/microphone location was performed to estimate change in noise emission during an RF leg compared to a straight in segment, and also noise emission and noise exposure level change with increased glideslope of 3.2 degrees compared to a conventional 3 degree glideslope.

Note:

Emission: Sound pressure level emitted by a source, here aircraft, in 1m distance.

Immission: Sound exposure level at a receiver, here noise monitoring terminal. Referred to in the document as “exposure level”.

Footprint: The ground area beneath a flying aircraft in which the noise exceeds a specified level.

Changes in noise emission levels RNP to xLS approaches versus straight in approaches at the source

- **Conclusions:**
    - Sound emission for RNP to xLS approaches differs from ILS straight in approaches.

- Higher sound emission at the aircraft (up to 2dB), could be explained by differences in flap and power settings during turns and transitions.
- Speed, aircraft configuration and power setting are the main drivers for sound emission of landing aircraft.

- **Recommendations:**
  - When modelling flight procedure it is recommended to avoid turns and transitions to the final close to populated areas.
  - For calculating a noise foot print of an RNP to xLS approach an adaption of sound emission data, especially along sections of turns and transitions, is necessary to receive reliable noise exposure levels.

Changes in noise levels for approaches with glideslope 3.2° versus glideslope 3.0°

- **Conclusions:**
  - The difference in sound emission for approach with glideslope 3.0° and for approach with glideslope 3.2° is neglectable at the source.
  - Concerning noise exposure level (at the monitoring terminal on the ground) the benefits of increased glideslope is with 0.75 dB equal to the attenuation caused by geometric spreading at the noise measurement station.
- **Recommendations:**
  - Calculating a noise foot print for approach with glideslope 3.2° the sound emission data for glideslope 3.0° can be used without adaption to receive reliable noise exposure levels.
- **Overall statement/ way forward – out of scope of the noise assessment.**
  - Noise to populated areas can be decreased by placing the new RNP procedures with RF legs outside of them.

6.1.3.2.4 Benefits demonstration: OBJ_0202_025 (Fuel), OBJ_0202_026 (CO2)

Identifier	**OBJ_0202_025**
Objective	To demonstrate fuel efficiency benefits of some advanced procedures.
Success Criterion	Fuel consumption evaluation for some advanced approaches show a reduction on the fuel consumption by relevant CTQ value.
Addressed KPA	**Environment / Fuel Efficiency**

Identifier	**OBJ_0202_026**
Objective	To demonstrate environmental benefits of some advanced procedures in terms of CO_2 emitted.
Success Criterion	CO2 emission evaluation for some advanced approaches shows a reduction on CO2 emission by relevant CTQ value.
Addressed KPA	**Environment / Fuel Efficiency**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_100	**SCN_0202_107**	OBJ_0202_025 OBJ_0202_026	N/A	A319 A320 A380 F900 B747-8	GBAS ILS	Simulations to evaluate fuel consumption and CO2 emissions.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix B (Section B.3.1).

RESULTS ANALYSIS OVERVIEW

Evaluation of decreased fuel consumption for the new RNP to GLS approaches (transferable to RNP to xLS) compared to legacy published approaches implemented at Zurich and Bremen was performed using simulators during agreed conditions. Evaluation of the fuel and CO2 CTQs was in all cases made using the difference between absolute values of the measured fuel consumption and CO2 emission on the legacy procedure and the new RNP to GLS procedure. In Section 8.1, see the summary of the conclusions and recommendations.

6.1.3.2.5 Benefits demonstration: OBJ_0202_028 (Flight Tracks)

Identifier	**OBJ_0202_028**
Objective	To evaluate the quality of flight track compared to designed (theoretical optimum) RNP to xLS approach.
Success Criterion	Evaluation of the quality of flight track compared to designed (theoretical optimum) RNP to xLS approach provided.
Addressed KPA	**Environment / Fuel Efficiency**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_100	**SCN_0202_101**	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_102	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319	ILS	RNP to ILS approaches with GSL = 3.2 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_103	OBJ_0202_011 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 A380 B747-8 F900	GBAS	RNP to GLS approaches with GSL = 3 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_104	OBJ_0202_011 OBJ_0202_021 OBJ_0202_024 OBJ_0202_028	EDDF	A319 A380 B747-8	ILS	RNP to ILS approaches with GSL = 3 deg. Noise Measurements on Ground. Accuracy measurement.
	SCN_0202_105	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_028	EDDW	A319 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Accuracy measurement.
	SCN_0202_106	OBJ_0202_011 OBJ_0202_012 OBJ_0202_021 OBJ_0202_028	LSZH	A319 A320 A321 F900	GBAS	RNP to GLS approaches with GSL = 3.2 deg. Accuracy measurement.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix B (Section B.1.3).

RESULTS ANALYSIS OVERVIEW

A set of additional different aspects that were evaluated during the project, including lessons learned and recommendations for experience with different aircraft behavior, case with airspace breach, continuous descend operations, procedure sequencing on FMS, procedure design recommendations as well as high temperature compensations. In Section 8.1, see the summary of the conclusions and recommendations.

6.1.3.2.6 Feasibility/Benefit studies: OBJ_0202_041 (Study SBAS/GBAS)

Identifier	**OBJ_0202_041**
Objective	Evaluation of the cost of publishing a SBAS LPV approach overlaid to a GBAS GLS approach.
Success Criterion	Affordable cost implementation of SBAS approach in relation to the cost of GBAS implementation.
Addressed KPA	**Airport Capacity**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_100	**SCN_0202_108**	OBJ_0202_041	N/A	N/A	GBAS SBAS LPV	Procedure interoperability SBAS/GBAS from a procedure design perspective feasibility/benefits study.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix B (Section B.4.1).

RESULTS ANALYSIS OVERVIEW

This SBAS/GBAS interoperability study from a procedure design perspective shows that the additional effort and cost for implementing both approach types jointly (GLS together with LPV) is manageable and affordable.

Due to the same 3D path, lower workload and costs can be noted if GLS and LPV procedures are designed simultaneously, the cost of adding LPV approach being negligible. The underlying rational for facilitating the publication of both approach solutions is to help to obtain the critical mass of Airspace Users able to access those airports with those technologies, which is a necessary condition to benefit from the potential ILS infrastructure rationalisation.

Recommendation:

In order to support at least Cat 1 operation in major airports for a maximum of Airspace Users (for instance in case of ILS maintenance and/or rationalization), aim for the full implementation of GNSS based approach technologies including SBAS LPV and GBAS GLS. GBAS approaches will enable also CAT II and CAT III operations in short term future.

6.1.3.2.7 Feasibility/Benefit studies: OBJ_0202_042 (Study LPV)

Identifier	**OBJ_0202_042**
Objective	Having advanced RNP procedures to LPV (increased glideslope with the intercept RF Leg > 45deg), to describe how such an advanced procedure could facilitate independent RNP arrivals into business aviation satellite airports through complex TMAs.
Success Criterion	Fuel efficiency compared to present operation with a case study accessing Egelsbach through Frankfurt complex TMA.
Addressed KPA	**Environment / Fuel Efficiency**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_100	**SCN_0202_109**	OBJ_0202_042	N/A	N/A	LPV	Advanced RNP procedures to LPV feasibility/benefits study.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix B (Section B.4.2).

RESULTS ANALYSIS OVERVIEW

The study proposes to evaluate the potential benefits for Business Aviation of an advanced procedure into a satellite airport (Egelsbach airport (EDFE) as case study) starting above its neighboring main airport traffic flow (Frankfort Main airport (EDDF) as case study), as opposed to the legacy operation guiding the Business Aviation aircraft below and around the main traffic flow. The objective is to bring environmental benefits, while enabling to add a safety benefit by reducing the likelihood of hazardous encounters between IFR traffic and VFR traffic in uncontrolled airspace below the TMA floor.

Due to the traffic configuration during a Westerly flow of traffic into EDDF/EDFE, the proposed advanced procedure requires to extend a teardrop procedure at 4000ft and results in additional track miles. These additional track miles penalize the fuel efficiency of the advanced procedure. The fuel efficiency benefit of the advanced procedure compared to a sample of legacy operations shows to be negative for traffics coming from the North-East, and seems to be marginal for traffics coming from the North-West.

However, using the future concept of Visual RNAV reducing the procedure design constraints significantly would enable to propose an expeditious and realistic flight path from above EDDF down to EDFE, and shows a potential fuel efficiency benefit of -30% (from the top of descent at FL300 to the landing into EDFE). It has be noted however that the Visual RNAV concept can be operated only in fair weather conditions (typically with a cloud base of 5000 feet or higher), which nevertheless is a significant proportion of the operation.

Further studies need to be carried out in order to assess whether the separation of 2000 feet respectively 3000 feet above EDDF FAPs is sufficient. In order to be acceptable, this vertical separation must be sufficient to enable Frankfurt/Langen ATC to facilitate traffic coordination without additional workload in respect to the current operation, and without reducing EDDF capacity. Also, considering the proposed Visual RNAV solution in this study, the probable need for coordination between Frankfurt/Langen ATC and EDFE ATC need further consideration.

Based on this study, we propose two recommendations:

Recommendation 1:

This study brings to light the very good coordination of Langen ATC in terms of flight path shortening to vector the EDFE traffics below EDDF main flows and into Egelsbach approach for landing. However, this expeditious control comes with the cost of partly crossing uncontrolled airspaces, with the inconvenience described in Section 6. Considering also the trend of Frankfurt Main airport, Langen ATC and local Airspace Users to facilitate and operate as much as possible continuous descent operations, it is recommended that during the step-descent, Langen ATC could advise the EDFE traffics on the descent rate to apply so as to always remain in controlled airspace, above the floor of the several Frankfurt TMAs, while ensuring to be separated with the EDDF flow.

Recommendation 2:

Considering the very positive fuel efficiency benefit of the Visual RNAV concept, the fact that this operation could avoid uncontrolled IFR/VFR encounters during weather conditions when VFR traffics operate the most, and also the fact that this concept is compatible with the SESAR 2020 vision in terms of potential operational improvements, we recommend to follow-up on this study within SESAR 2020 Program.

See Figure 20 for an overview of the studied solutions.

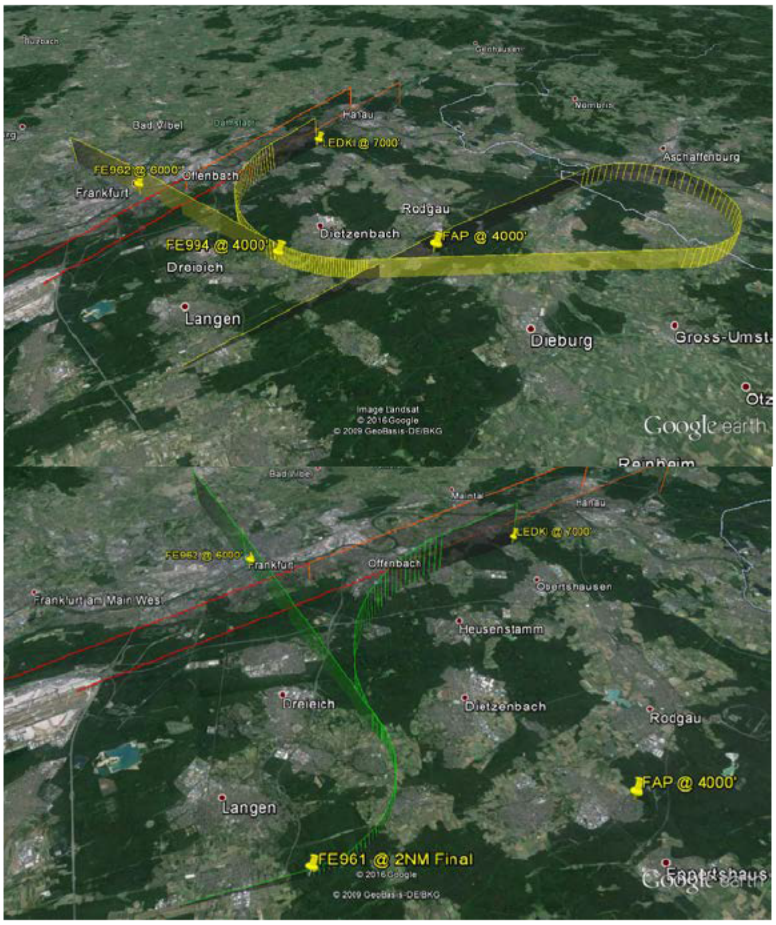


Figure 20: EDFE advanced procedure (Left) and Visual RNAV solution overview (Right)

6.1.3.3 Results per KPA

For EXE_0202_100 relevant KPI/metric and CTQs for all KPA are summarized in the Table 26. Results in form of status OK/POK/NOK are also stated.

Table 26: KPA, KPI/metric, CTQs and results for EXE_0202_100

KPA	KPI	Methodology	EDDF	EDDW	LSZH	Metric	CTQ definition	CTQ value	Status
Safety	Horizontal flight accuracy (RNP to xLS)	Flights	x	x	x	Evaluation of horizontal TSE for xLS approaches on the RF leg and transition to the final approach segment.	Horizontal TSE for xLS approaches is within CTQ limit.	within 1NM	OK*2)
	Vertical flight accuracy (RNP to xLS)		x	x	x	Evaluation of vertical path for xLS approaches on RF leg and the vertical transition to the final approach segment.	Vertical path for xLS approaches is within CTQ limit.	No descend below FAP constraint – 100ft (considering temperature compensations)**	OK*2)

KPA	KPI	Methodology	EDDF	EDDW	LSZH	Metric	CTQ definition	CTQ value	Status
Environment/ Fuel efficiency	Noise measured on ground (RNP to xLS)	Flights	x			Evaluation of difference in noise emission (at source) for straight-in wings level approach (legacy) and RNP RF leg (aircraft with bank angle) approach.	Change in noise distribution measured for a RF Leg	positive or negative for the local area	OK*3)
	Noise measured on ground (IG xLS)	Flights	x			Evaluation of difference in noise immission (exposure level) for approach with glideslope 3 deg (legacy) and for approach with glideslope 3.2 deg.	Decreased noise immission (exposure level) for approach with glideslope 3.2 deg (compared to 3.0 deg)	by at least 0.5 dB	OK*3)
	Fuel burned per approach (RNP to xLS)	RTS		x	x	Evaluation of difference in fuel consumption for legacy approach and RNP to xLS approach.	Decreased fuel consumption for RNP to xLS approach (compared to legacy approach).	by at least 5%	OK
	CO2 emission per approach (RNP to xLS)	RTS		x	x	Evaluation of difference in CO2 emission for legacy approach and RNP to xLS approach.	Decreased CO2 emission for RNP to xLS approach (compared to legacy approach).	by at least 5%	OK
	Quality of flight tracks in the horizontal (RNP to xLS)	Flights	x	x	x	Evaluation of the quality of flight tracks in the horizontal compared to designed (theoretical optimum) approach.	Flight tracks in horizontal evaluated.	YES	OK
	Quality of flight tracks in the vertical (RNP to xLS)	Flights	x	x	x	Evaluation of the quality of flight tracks in the vertical compared to designed (theoretical optimum) approach.	Flight tracks in vertical evaluated.	YES	OK
Human Performance	Perceived level of feasibility - ATC (RNP to xLS)	Flights + Questionnaires	x	x	x	Questionnaire to be completed by ATC for RNP to xLS approaches flown.	RNP to xLS approaches are feasible based on feedback form ATC.	YES >95% appr. successful	OK*1)

KPA	KPI	Methodology	EDDF	EDDW	LSZH	Metric	CTQ definition	CTQ value	Status
	Perceived level of feasibility - ATC (IG xLS)		x	x	x	Questionnaire to be completed by ATC for approaches with increased glideslope flown.	Approaches with increased glideslope are feasible based on feedback form ATC.	YES >95% appr. successful	OK
	Perceived level of feasibility - pilots (RNP to xLS)		x	x	x	Questionnaire to be completed by pilots for RNP to xLS approaches flown.	RNP to xLS approaches are feasible based on feedback form pilots.	YES >95% appr. successful	OK*1)
	Perceived level of feasibility - pilots (IG xLS)		x	x	x	Questionnaire to be completed by pilots for approaches with increased glideslope flown.	Approaches with increased glideslope are feasible based on feedback form pilots.	YES >95% appr. successful	OK
Accessibility	Cost effectiveness (SBAS/GBAS)	Interview (Study)	N/A			Cost of publishing a SBAS LPV approach overlaid to a GBAS GLS approach.	Affordable cost implementation of SBAS approach in relation to the cost of GBAS implementation.	YES (qualitative outputs of analysis)	OK
Environment/ Fuel efficiency	Fuel efficiency of specific arrival through complex TMA in satellite airport (RNP to LPV)	Analysis (Study)	N/A			Evaluation of the difference in terms of fuel consumption between new RNP to LPV procedure with current practice.	Decreased fuel consumption within complex TMA (compared to legacy operation).	less fuel burn within specific TMA	POK *4)

*1) *NOTE: The RNP procedures were rated as feasible by both ATC and pilots. However, there were number of lessons learned and recommendations for future noted by both groups that are captured in Section 8.1.*

*2) *NOTE: For WP1 only: Some of the Frankfurt mainline aircraft approaches seem to be going over the CTQ limit, but there is always an explanation and lessons learned provided (e.g. ATC vectoring) in Appendix B.*

*3) *NOTE:*
Emission: Sound pressure level emitted by a source, here aircraft, in 1m distance.
Immission: Sound exposure level at a receiver, here noise monitoring terminal. Referred to in the document as "exposure level".

*4) *NOTE: Fuel efficiency slightly negative with IFR procedure RNP to LPV due to airspace and airport configuration of EDDF/EDFE. However, positive fuel efficiency results with the concept of Visual RNAV. For more details see Section 6.1.3.2.7.*

** *The planned vertical path is at or above the FAP alt constraint (considering temperature compensation or not), and the total system error should be less than 100 ft in vertical.*

6.1.3.4 Results impacting regulation and standardisation initiatives

Impact on the regulations and standards and the importance of the results is due to the significant amount of data collected during demonstrations and due to the methodologies used during data processing and evaluation. Regarding the procedures in Frankfurt and Bremen, results (including both, flight data as well as the noise measurements) are very important for regulatory bodies for confirmation of feasibility and potential improvements of this type of procedures. Regarding the procedures in Zurich, demonstrations will provide important inputs for regulatory bodies to enable the approval for this kind of procedures in the future.

6.1.3.5 Unexpected Behaviours/Results

There were a few cases of unexpected behaviour mainly noted by DLH crews during Frankfurt approaches (e.g. case of airspace breach described in Appendix B – Section B.1.3). They led to lessons learned, proper mitigation methods (e.g. further pilot trainings) were applied and these were corrected during the course of the project. This was very valuable as the project was able to provide comprehensive lessons learned, and recommendations.

6.1.3.6 Quality of Demonstration Results

Demonstration flights were performed in various environment including the airports in Europe comprising major hubs as well as regional airports (Frankfurt - EDDF, Bremen - EDDW, Zurich - LSZH). Flight test data analysis itself were performed in a very detailed way. In order to check the sanity of the results, often more than one approach to perform the analysis was used. This enabled to critically assess the analysis results.

Demonstration flights campaign was supported by pilots in the loop simulations and human factors assessments on the feasibility of procedures and operations, real time simulations evaluating the environmental impacts (such as fuel consumption and CO2 emission) and several benefit studies and benefit assessments.

6.1.3.7 Significance of Demonstration Results

Procedures using ILS are usable by nearly all commercial aircraft, GBAS is about to follow as an upcoming technology. The exploration of the PBN element RF in combination with these final approach guidance systems is valuable, as it can improve approach procedures regarding noise and fuel efficiency.

Large amount of trials (277) by different aircraft types, operators at different airports in different countries ensures good operational and statistical significance. This exercise has a very good level of representativeness also due to the possibility of demonstrations on the revenue flights (177 flights). Correct behaviour was verified by simulators. Also corner cases were tested with experimental aircraft (testing flights).

Total number of flight trials within this exercise is 277. Table 27 provides details of A/C type and operator.

Table 27: EXE_0202_100: Total number of flight trials, A/C type and operator

Operator	A/C type		Number of successful RNP to GLS flight trials
Honeywell	Falcon 900EX	experimental	100*
Lufthansa	A380	revenue flights	27
	B 747-8	revenue flights	17
	A320 family	revenue flights	116**
SWISS	A320	revenue flights	14
	A321	revenue flights	3

**NOTE: 78 RNP to GLS, 22 RNP to LPV.*

***NOTE: 76 RNP to GLS with A319, 40 RNP to ILS with A319/320/321.*

6.1.4 Conclusions and recommendations

See Section 8.1.

6.2 Demonstration Exercise EXE_0202_200 Report

SVGS Advanced procedures feasibility and benefits demonstration. This exercise was executed within WP 2.

6.2.1 Exercise Scope

Demonstration Exercise EXE_0202_200 Plan is detailed in Demonstration Plan [27] in Section 5.2.

SVGS advanced procedures are linked to Operational Focus Area OFA 01.01.02 Pilot enhanced vision when the SVGS is industrialized enabler A/C-23a SVS and linked to AUO-0404 "Synthetic Vision for the Pilot in Low Visibility Conditions". According to the integrated roadmap [36], the enabler A/C-23a "Synthetic vision in low visibility conditions" within Step 2 (AUO-0404 — Synthetic Vision for the Pilot in Low Visibility Conditions) targets the IOC on 31.12.2016.

Regarding the related technology maturity level, the SVGS technology was not developed within SESAR program and therefore SESAR documentations relevant to the maturity assessment is not available. However, based on the internal maturity assessments, the SVGS technology maturity level is post-V3. The AAL project helps to speed up the industrialization and deployment phase for SVGS technology (i.e. V4&V5A levels) and therefore helps to enable an early use of benefits for users.

SVGS enables to support precision approach operations with independent monitoring aids that enhance both the reliability of the operation and the situational awareness of the crew. The project will aim at demonstrating operations with reduced minima (DH minus 50 feet). The study will feed regulation and standardisation bodies for potential operational credit opportunities.

The main KPAs included:

- Safety.
- Cost effectiveness with respect to cost reduction in crew training.
- Environment / fuel efficiency due to reduction of delays and diversions.
- Airport capacity.
- Human performance.

The SVGS approach is flown as a conventional, vertically guided approach to a published minimum altitude. This is distinctly different from EFVS operations which authorize pilots to descend below published minimum altitudes based on enhanced flight visibility provided by an EFVS. In contrast, SVGS approaches are flown to a published DH using a Special Authorization instrument approach procedure chart. At the DH the provisions of 14 CFR § 91.175(c)(1) through (c)(3) must be met before descent below DH is authorized. This includes ensuring that the aircraft is continuously in a position from which a normal descent to landing can be made using normal manoeuvres, and determining that the flight visibility is not less than the prescribed minimum visibility for the approach.

At the published minimum altitude the visual cues specified in 91.175(c)(3) must be distinctly visible and identifiable using natural vision. If the visual cues are not visible a missed approach is required. In this respect SVGS and standard CAT I approaches are operationally identical; both types of approaches terminate in a true visual segment in order to operate below the published minimum altitude to complete the landing.

The continuation of the approach to landing assumes normal functions of the pilot flying during the transition from minimums to landing. During the approach, the SVGS integrated display and monitoring system enables pilots to meet or exceed the performance standards for flight technical error normally required for operations at these approach minimums. [Refs: AC91-16, AC120-29A, and AC120-28D, FAA-S-8081-5F, Airline Transport Pilot Practical Test Standard]

Missed approaches are conducted using conventional procedures according the requirements of the approach being flown. There is no SVGS function allocated to the missed approach phase of flight. The missed approach altitude (DA or DH) shall be not less than that required to assure obstacle clearance in the missed approach path. Approach climb gradient requirements may be imposed as an external mitigation means if obstacle clearance is not available at the standard climb gradient of 200 ft/NM. The end to end system approach containment performance is designed to support safe operations to a DH of 150ft height above touchdown.

It is expected that SVGS approach operations will comply with the air traffic control requirements for SA CAT I operations as defined in FAA Order 8400.13D. Accordingly, SVGS operations will require an operational Air Traffic Control Tower (ATCT) to ensure separation of airborne and ground traffic. For SVGS operations based on ILS approach, the tower will also ensure protection of localizer and glideslope critical areas and monitor ground equipment.

6.2.2 Conduct of Demonstration

This section details the preparatory activities (Section 6.2.2.1) and execution activities (Section 6.2.2.2) and description of deviations from the planned activities (Section 6.2.2.3).

6.2.2.1 Exercise Preparation

Preparatory activities were covered by the SWP 2.1 “SVGS Definition” and SWP 2.2 “SVGS Systems”.

SWP 2.1 “SVGS Definition” provided the SVGS definition activities and involved the airports in the Czech Republic (Ostrava, Brno and Karlovy Vary). This SWP included 2 main Tasks – Procedures definition and Safety Assessment.

SWP 2.2 “SVGS Systems” included preparation of all necessary airborne equipment for SVGS trials. It covered an integration of SVGS into the experimental aircraft.

The following paragraphs details the achievements within these SWPs per task and per contribution of each partner separately.

SWP 2.1 SVGS Definition

T 2.1.1 Procedures Definition [Czech Republic]

ANS CR [TL]

Procedure design had not to be changed. All required procedures were published and no special charts were necessary for experimental flights. Proposal of charting was implemented into documentation of the project, but not published in the Czech AIP.

T 2.1.2 Safety Assessment

ANS CR [TL]

Safety assessment was finished early-September 2015. A necessary input for realization of this SSA was a project description with detailed information about test flights. No hazards were expected from ATC perspective. Test flights were approved by the Czech CAA.

SWP 2.2 SVGS Systems

T 2.2.1 Aircraft Modification

Honeywell [TL]

The F900 was fitted with the Test Interface Unit (TIU). The TIU integrates with the existing avionics, gathers/records aircraft bus data, runs the experimental SVGS display software, and distributes the display to the PFD and repeater displays in the cabin.

6.2.2.2 Exercise execution

Execution activities were covered by the SWP 2.3 “SVGS Trials”. This SWP covered the flight trials activities and involved the airports in the Czech Republic (Ostrava, Brno and Karlovy Vary). This SWP included 7 main Tasks – Demonstration Plan 1st Review – Input to the consolidated version, Demonstration Plan 2nd Review – Input to the consolidated version, EASA Coordination, Trial Preparation, Execution, Communication and Demonstration Report – Input to the consolidated version.

Table 28 summarizes the actual demonstration schedule of the exercise. Figure 21 then details the schedule for demonstration flights campaign for all airports included in this exercise.

Table 28: EXE_0202_200 - Exercise execution/analysis dates

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise analysis start date	Actual Exercise analysis end date
EXE-02.02-D-200	SVGS Advanced Procedures Feasibility and Benefits Demonstration	10 / 2015	5 / 2016	11 / 2015	8 / 2016

Figure 21: EXE_0202_200 - Exercise flight campaign timeline

The following paragraphs details the achievements within this SWP per task.

T 2.3.1 Demonstration Plan 1st Review – Input

All inputs to the Demonstration Plan 1st Review were provided followed by the review of the partners.

T 2.3.2 Demonstration Plan 2nd Review – Input

All inputs to the Demonstration Plan 2nd Review were provided followed by the review of the partners.

T 2.3.3 Coordination with Regulators Supported by EASA

A F2F meeting was held together with ANS CR and the Czech CAA in order to provide a detailed explanation of the concept of the SVGS approaches planned to be flown in the Czech Republic. There was a tight cooperation of ANS CR and Honeywell with respect to the necessary documentation preparation. Based on this, the CAA approval for exception for the experimental flights was obtained at the end of September 2015.

T 2.3.5 Execution

Demonstration flight campaign was started after the Project Gate (October 1st, 2015). The first phase was conducted in November 2015 including 48 approaches at 3 different airports – Brno, Ostrava and Karlovy Vary. The second phase of demonstrations was then conducted in May 2016 including 28 approaches involving the same 3 airports (LKTB, LKMT and LKKV). Both phases covered the intended types of procedures – ILS 200'-50' DH and LPV 250'-50' VTH. In total 74 demonstration flights on 3 airports therefore ensured a good statistical significance for data evaluation with respect to accuracy measurements as well as with respect to the feasibility assessment.

Benefit studies, evaluating the SVGS advanced procedure benefits, were provided and results are presented in the Appendix C (Section C.3). These studies evaluated an impact of SVGS on environment/fuel efficiency, airport capacity and cost-effectiveness area.

T 2.3.6 Demonstration Report – Input

All inputs to the Demonstration Report were provided followed by the review of the partners.

T 2.3.7 Communication

The communication activities were performed in accordance with the communication plan – see Section 7.

6.2.2.3 Deviation from the planned activities

Flights in Brno (LKTB) and Karlovy Vary (LKKV) were planned as opportunities, when one or the other was intended to be chosen to fly LPV approaches. Eventually, the demonstrations included both airports for the flights and moreover, both – ILS and LPV procedures – were flown on these airports. Therefore demonstrations showed results based on bigger variety of airports for LPV procedure as well as for ILS procedure scenarios.

Within WP2, at least 30 demonstration flights were planned. During demonstrations in total 74 successful flights have been achieved. This improved a statistical significance for data evaluation with respect to the accuracy measurements as well as with respect to the feasibility assessment.

6.2.3 Exercise Results

6.2.3.1 Summary of Exercise Results

The results were assessed against the success criteria and it was decided if the Demonstration objective status is OK, POK or NOK. Overall assessment for all criteria (involving all exercises) is presented in the Table 8 in Section 5.1.

6.2.3.2 Analysis of Exercise Results

In the following sections the exercise results are summarized according to the demonstration objectives evaluation. For detailed analysis see relevant Appendixes.

6.2.3.2.1 Feasibility demonstration: OBJ_0202_013 (SVGS DH-50 ILS 200'), OBJ_0202_014 (SVGS VTH-50 LPV 250')

Identifier	**OBJ_0202_013**
Objective	To demonstrate feasibility of SVGS DH-50ft on ILS 200'.
Success Criterion	SVGS DH-50ft on ILS 200' procedure is feasible based on the feedback from pilots.
Addressed KPA	**Human Performance**

Identifier	**OBJ_0202_014**
Objective	To demonstrate feasibility of SVGS VTH-50ft on LPV 250'.
Success Criterion	SVGS VTH-50ft on LPV 250' procedure is feasible based on the feedback from pilots.
Addressed KPA	**Human Performance**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_200	**SCN_0202_201**	OBJ_0202_013 OBJ_0202_021	LKMT LKTB* LKKV*	F900	SVGS	SVGS approach DH-50ft on ILS 200'.

EXE_0202_200	**SCN_0202_202**	OBJ_0202_014 OBJ_0202_021	LKTBL KKV	F900	SVGS	SVGS approach VTH-50ft on LPV 250'.

**NOTE: Not initially planned, added during demonstration flights (opportunity).*

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix C (Section C.2.1).

RESULTS ANALYSIS OVERVIEW

The perceived level of feasibility was evaluated for SVGS procedures performed with ILS (200') and LPV (250'). At the end of each approach, where subjective human performance analysis was conducted, the pilot completed a NASA Task Load Index (TLX) workload rating scale and a Modified Cooper-Harper (MCH) scale for the adequacy of the SVGS display to support intended functions (assigned to an execution of the SVGS approach DH-50ft on ILS 200' or VTH-50ft on LPV 250') during demonstration flights. The results indicated an acceptable level of workload in all measured aspects experienced by pilots within ILS and within LVP approaches. No specific issues were identified by participants regarding the workload relative to the SVGS approach. The acceptable level of display support for the ILS and LVP approaches was indicated by results in the conditions tested. The MCH rating corresponded to the scale response of "Very minor issues not hindering performance". Results were balanced and the workload level can be considered to be acceptable also from the perspective of meeting the system's intended functions. Summarizing, the pilots flying the SVGS approach reported low workload scores during the approach and landing phase. The subjective data collected during the demonstration confirmed the feasibility of the SVGS approach as evidenced by the modified Cooper-Harper ratings. The CTQ value, which was set to 95% of approaches are feasible based on feedback form pilots, was met.

6.2.3.2.2 Benefits demonstration: OBJ_0202_021 (Accuracy)

Identifier	**OBJ_0202_021**
Objective	To demonstrate accuracy of advanced procedures.
Success Criterion	TSE for advanced procedure approaches is within the relevant CTQ value.
Addressed KPA	**Safety**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_200	**SCN_0202_201**	OBJ_0202_013 OBJ_0202_021	LKMT LKTB* LKKV*	F900	SVGS	SVGS approach DH-50ft on ILS 200'.
	SCN_0202_202	OBJ_0202_014 OBJ_0202_021	LKTB LKKV	F900	SVGS	SVGS approach VTH-50ft on LPV 250'.

**NOTE: Not initially planned, added during demonstration flights (opportunity).*

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix C (Section C.1.1).

RESULTS ANALYSIS OVERVIEW

In total 74 approaches were flown with Honeywell experimental F900, 23 in Ostrava (LKMT), 40 in Brno (LKTB) and 11 in Karlovy Vary (LKKV), all successful. In Ostrava only ILS approaches were flown, in Brno and Karlovy Vary both, ILS and LPV procedures were demonstrated. In total 45 ILS 200'-50'DH and 29 LPV 250'-50'VTH approaches were performed. Also, some approaches were flown with autopilot coupled and some were flown manually.

Observed accuracy performance (horizontal and vertical TSE) was well within the CTQ value of ±1 dot. The deviation for the lateral direction was always within ±0.4 dot; and for the vertical direction within usually within ±0.4 dot and maximum within ±0.7 dot. Larger deviations were usually caused by various environmental conditions (wind, etc.) and were usually manually flown. Comparison of horizontal and vertical TSE performance of SVGS approaches with ILS and LPV separately confirmed the assumption that that GNSS based performance is better than ILS based (nevertheless, for both cases the performance was within the CTQ limit). Another example of benefits of GNSS based navigation compared to conventional ILS was observed in Ostrava, where the ILS signal seems to be deformed by a hilly terrain which is located before runway (i.e. aircraft flies through a "valley"). This data confirms that GNSS based systems are not susceptible to the terrain distortion and navigation is smoother. Evaluating the landing performance, all landings were well within defined CTQ value, i.e. inside the touchdown zone of particular runway (the first third of the runway).

6.2.3.2.3 Benefits demonstration: OBJ_0202_027 (Div/Del/Go-Around)

Identifier	**OBJ_0202_027**
Objective	Estimate reduction of number of diversion, delay or go-around.
Success Criterion	Evaluation shows decreased number of diversion, delay or go-around by relevant CTQ.
Addressed KPA	**Environment / Fuel Efficiency**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_200	**SCN_0202_203**	OBJ_0202_027 OBJ_0202_029 OBJ_0202_031	N/A	N/A	SVGS	Study to evaluate impact of SVGS on environment/fuel efficiency, airport capacity and cost-effectiveness area.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix C (Section C.3.1).

RESULTS ANALYSIS OVERVIEW

Based on the SESAR 9.29 CBA [19], this analysis considered three potential impacts of Low Visibility Conditions (LVC) for a flight - flight delay (when weather conditions at a destination airport are lower than approved landing minima for aircraft or crew qualification, the aircraft can hold near to the airport and wait for better weather conditions), flight diversion (a situation when LVC occur during a flight or a holding duration exceeds time available, the aircraft lands at an alternate airport) and cancellation of a flight (when low visibility conditions at a destination airport last longer than the specified time, the flight is cancelled even at the airport of origin). Uniform estimation has been used for the probability of LVC across all benefit models. This probability has been estimated at 4.84% of the time on the basis of 2010 meteorological data from five airports with predominant regional and business traffic aviation and broadly covering Europe, especially in the areas with a higher probability of low visibility conditions. The chosen model compared the performance of the ILS CAT I approach (baseline scenario) for the dedicated airport and runway with EFVS and combination SVGS+EFVS performance level (solution scenarios). For evaluation 2 baselines scenarios were considered – scenario EU ILS and USA ILS, when the main difference was in the approach lightening systems (ALSF1 for EU, MALSR for USA). The consumption and pollutant emissions have been also evaluated and calculated with the use of Piano X tool that uses the ICAO standard engine library.

The three effects mentioned above (delay, diversion and cancellation) have been used to quantitatively analyse the benefits. However, it should be noted that these disruptions are the first in a sequence of effects. Secondary effects may have similar order of magnitude as the first group of effects. This benefit analysis, especially the quantitative part, should be taken as a very conservative approach. Furthermore, the tool considers the proposal to be implemented in AC 90-106A, when you can land as long as you see the enhanced cues and that RVR is >1000ft (i.e. DH is not strictly considered). This has direct impact also on flight cancellation. Also, the results are very conservative as the ceiling limit was set as DH+10ft. In reality, when using EFVS, A/C may descend below DH even in case of ceiling lower than DH if pilot sees the enhanced cues and that RVR is >1000ft. Therefore results presented are very conservative and are expected to be better in reality.

Results showed that for both ILS baseline scenarios the combination of SVGS and EFVS helps to increase the number of on-time arrivals in LVC compared to ILS (by 33% for EU ILS scenario and by 35% for EU ILS scenario). As expected, improvements are bigger for USA ILS scenario due to higher RVR value. Also significant improvement was observed when using the combination of SVGS+EFVS compared to EFVS only usage.

Regarding the environmental impact of SVGS+EFVS implementation, there was a saving of 127 kg of the fuel and 401 kg of CO_2 emission per flight in LVC for EU ILS scenario (and saving of 136 kg of the fuel and 428 kg of CO2 emission per flight in LVC for USA ILS scenario). Again, savings for combination of SVGS+EFVS showed to be bigger than for EFVS only usage.

6.2.3.2.4 Benefits demonstration: OBJ_0202_031 (Airport Eligibility)

Identifier	**OBJ_0202_031**
Objective	To demonstrate airport eligibility for advanced procedures.
Success Criterion	Airport eligibility evaluation for advanced approaches show reachability to relevant CTQ value.
Addressed KPA	**Airport Capacity**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_200	**SCN_0202_203**	OBJ_0202_027 OBJ_0202_029 OBJ_0202_031	N/A	N/A	SVGS	Study to evaluate impact of SVGS on environment/fuel efficiency, airport capacity and cost-effectiveness area.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix C (Section C.3.2).

RESULTS ANALYSIS OVERVIEW

In the airport eligibility assessment, there were identified 6 IFR airports with instrument 3D approaches in the Czech Republic there and 5 IFR airports with instrument 3D approaches in Slovakia. For these airports the instrument 3D approach procedures (involving ILS, LPV or LNAV/VNAV) are published. SVGS may be used in conjunction with all these procedures and therefore positively impact the airport throughput in LVC by lowering the published minima by 50ft. It can be concluded that the number of airports in the Czech Republic and Slovakia with instrument 3D approaches that are eligible to SVGS operation is 100% (CTQ was determined as 80%).

6.2.3.2.5 Benefits demonstration: OBJ_0202_029 (Cost)

Identifier	**OBJ_0202_029**
Objective	To estimate cost-effectiveness benefits of advanced procedures, such as cost savings for the crew qualification.
Success Criterion	Evaluation shows decreased cost for the crew qualification.
Addressed KPA	**Cost-Effectiveness**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_200	**SCN_0202_203**	OBJ_0202_027 OBJ_0202_029 OBJ_0202_031	N/A	N/A	SVGS	Study to evaluate impact of SVGS on environment/fuel efficiency, airport capacity and cost-effectiveness area.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix C (Section C.3.3).

RESULTS ANALYSIS OVERVIEW

In the cost assessment, it was pointed out that the increase of the crew qualification costs is significant for CAT II operations due to higher demand on skilled crew (compared to CAT I). Crew qualification training comprises the initial training and the recurrent trainings. Crew qualification cost can be reduced by the SVGS utilization since CAT II training is not foreseen when using SVGS (it is envisioned that some initial SVGS training would be required). Expert evaluation was used for the crew qualification cost savings assessments. It is assumed that an initial and recurrent CAT II trainings would be contracted (i.e. provided by e.g. by FSI or CAE, not by operator). In some cases the prices may be lower due to contractual conditions (e.g. discounts) and therefore the actual savings may be lower than indicated in this assessment. However, reduced prices are not taken into consideration in the assessment as they are contract dependent and therefore hardly estimable.

Assuming 10 years of SVGS usage, total cost for CAT II training is $25,000 and for SVGS $12,000. This represents 52% cost savings ($13,000) which is well above the CTQ (20%).

6.2.3.3 Results per KPA

For EXE_0202_200 relevant KPI/metric and CTQs for all KPA described above are summarized in the Table 29. Results in form of status OK/POK/NOK are also stated.

Table 29: KPA, KPI/metric and CTQs for EXE_0202_200

KPA	KPI	Metho dology	Metric	CTQ definition	CTQ value	Status
Safety	Horizontal Flight accuracy (SVGS)	Flights	Evaluation of horizontal TSE for SVGS approaches.	Horizontal TSE for SVGS approaches is within CTQ limit.	within 1 dot	OK
	Vertical Flight accuracy (SVGS)		Evaluation of vertical TSE for SVGS approaches.	Vertical TSE for SVGS approaches is within CTQ limit.	within 1 dot	OK
	Successful touchdown (SVGS)	Flights	Measure of the touchdown footprint for SVGS approaches.	Touchdown footprint for SVGS approaches is within CTQ limit.	in touchdown zone*	OK
Environ ment/ Fuel efficienc y	Reduction of number of diversion and delay (SVGS)	Study	Evaluation of the percentage of successful landing on destination airport in LVC.	Increase the percentage of landing on destination airport in LVC.	N/A (not quantifiable in absolute, depends on each operator activity)	OK
Airport Capacity	Airport procedure and installation eligibility (SVGS)	Study	Evaluation of the percentage of eligible airports for SVGS operations.	The number of airports in the Czech Republic and Slovakia with instrument 3D approaches that are eligible to SVGS operation is better than CTQ.	at least 80%	OK
Human Perform ance	Perceived level of feasibility – pilots (SVGS)	Flights + Questio nnaires	Questionnaire to be completed by pilots for SVGS approaches flown.	SVGS approaches are feasible based on feedback form pilots.	YES >95% appr. successful	OK
Cost-effective ness	Cost savings (SVGS)	Study	Estimate of the cost savings for the crew qualification.	Decreased cost for the crew qualification.	by at least 20%	OK

** Touchdown zone is defined as the first third of the runway.*

6.2.3.4 Results impacting regulation and standardisation initiatives

Procedure design for SVGS demonstrations had not to be changed as all required procedures were published and no special charts were necessary for experimental flights, as a guidance from ANS CR. Proposal of charting was implemented into documentation of the project (but not published in the Czech AIP) as not seen necessary. Safety assessment was finished early-September 2015 and test flights were approved by the Czech CAA, also for low visibility procedures. No hazards were seen from ATC perspective, as expected. Overall it may be concluded that demonstrations were successful and showed benefits of SVGS technology and also feasibility from operational perspective in a real environment. Demonstration flights results together with real operational experience with SVGS described above may provide a valuable contribution to the future support of a preparation of a formal application for a European certification of this system. WP2 activity may also contribute to the future work of RTCA SC213 / EUROCAE WG79.

Work was also conducted with the FAA, mainly with respect to discussions on SVGS on LPV, assumptions on the constellation fault modes, as well as other requirements that would be applicable. The work is still ongoing.

More details with respect to Next Steps toward Standardization can be found in Section 8.2.

6.2.3.5 Unexpected Behaviours/Results

There are no unexpected behaviours/results for WP2.

6.2.3.6 Quality of Demonstration Results

Demonstration flights were successfully performed in a real environment including 3 European regional airports (LKMT, LKTB, LKKV). Testing approaches including the HF questionnaire evaluation also involved several testing pilots in order to get a good representativeness of the results. Flight test data analysis itself was performed in a detailed way in order to enable critical assessments of the analysis results (accuracy assessment, feasibility assessment).

Demonstration flights campaign was supported by several benefits studies and benefits assessments. Overall, flight trials in a real operational environment together with benefits studies brought very good quality and representativeness of the results of the SVGS technology demonstrations.

6.2.3.7 Significance of Demonstration Results

Demonstration flights were performed in real operational environment in the EU ensuring good operational significance. Such demonstrations could give a stepping stone for publishing of similar procedures in the Czech Republic, and possibly showing way forward to other European ANSPs.

Total number of successful flight trials performed within this exercise is 74, providing very good statistical significance. Table 30 provides details about the number of approaches per airport and per flown procedure.

In summary, significant number of flight trials in a real operational environment brought very good statistical and operational significance of the results of the SVGS technology demonstrations.

Table 30: EXE_0202_200: Total number of flight trials

AP/Proc.	ILS 200'-50'HD	LPV 250'-50'VTH	TOTAL
LKTB	17	23	40
LKKV	5	6	11
LKMT	23	0	23
TOTAL	45	29	74

6.2.4 Conclusions and recommendations

See Section 8.2.

6.3 Demonstration Exercise EXE_0202_300 Report

EFVS Advanced procedures feasibility and benefits demonstration. This exercise was executed within WP 3.

6.3.1 Exercise Scope

Demonstration Exercise EXE_0202_300 Plan is detailed in Demonstration Plan [27] in Section 5.3.

EFVS advanced procedures are linked to Operational Focus Area OFA 01.01.02 “Pilot enhanced vision”. Relevant AUO-0403 "Enhanced Vision on Head Up display for the Pilot in Low Visibility Conditions” was replaced by AUO-0405 “Equivalent Visual Landing operations in Low Visibility Conditions“ by OFA 01.01.02. All vision systems (EVS, SVS, CVS) are covered into one AUO for Landing operation. Regarding the related technology maturity level, according to the integrated roadmap [36], the enabler A/C-23b “Combined Vision for Equivalent Visual Landing operations in LVC” within Step 2 (SDM-0301 — Improved access into small airports in low visibility conditions) targets the IOC on 31.12.2020.

EFVS enable to support approach operations with vertical guidance through enhanced vision capabilities displayed to the flight crew. The project aimed at demonstrating EFVS to land in reduced visibility conditions (reduced RVR, possibly down to 300 m), with the Pilot Flying conducting the visual approach through the heads up EFVS system to touch down, while the Pilot Non Flying monitors the approach by using navigation data and visual crosscheck. The study aimed to feed regulation and standardisation bodies for potential operational credit opportunities

The EFVS to land demonstration contributed to the deployment and promotion of APVs with decreased minima through different elements:

- It will quicken the definition of the regulatory basis for EFVS to land type and operational certification in Europe.
- It will provide practical recommendations in terms of training of air crews for EFVS to land.
- It will provide practical recommendations in terms of integration in air operators’ manuals.
- It will provide guidelines for operators seeking competent authority operational approval of EFVS to land operations.
- It will provide operators of smaller airports, without CAT 2/3 capacities, with recommendations based on practical experience on the method to implement low visibility APVs and other low visibility (“LVP light” or “EVP”).

The main KPA benefits were:

- Safety and Human Performance, through reduced crew workload.
- Environment / Fuel Efficiency, through reduced go around and diversions brought by the increased reliability.
- Airport Capacity, through increased access to smaller airports in bad weather conditions, and consequently decreased congestion at nearby main hubs.

As a consequence it will make EFVS to land and more generally low visibility APVs a reality in Europe.

EFVS to land is based on the operational concept standardized in RTCA DO-315B and EUROCAE ED-179B and supported by FAA through the notice for proposed rulemaking NPRM published in federal register N°112 Vol. 78 in June 2013. Based on the demonstrated and prescribed extent of the visual range provided by the EFVS for weather conditions encountered, the crew is allowed to begin and to continue an instrument approach down to the published minimum altitude as a conventional way. Arrived at the minimum altitude, EFVS (via the enhanced flight visibility) and HUD symbolism enable the pilot to control and the copilot to monitor the aircraft trajectory in the visual segment during the approach and landing until safe taxi speed is reach. This concept is made possible provided RVR is greater of 300m RVR (and enhanced flight visibility can be maintained for US).

In case a normal descent to landing cannot be made by using normal maneuvers, or if the enhanced flight visibility is less than the prescribed visibility for the approach, the crew will initiate a go around using conventional procedure. Approach climb gradient requirement may be imposed in some situation.

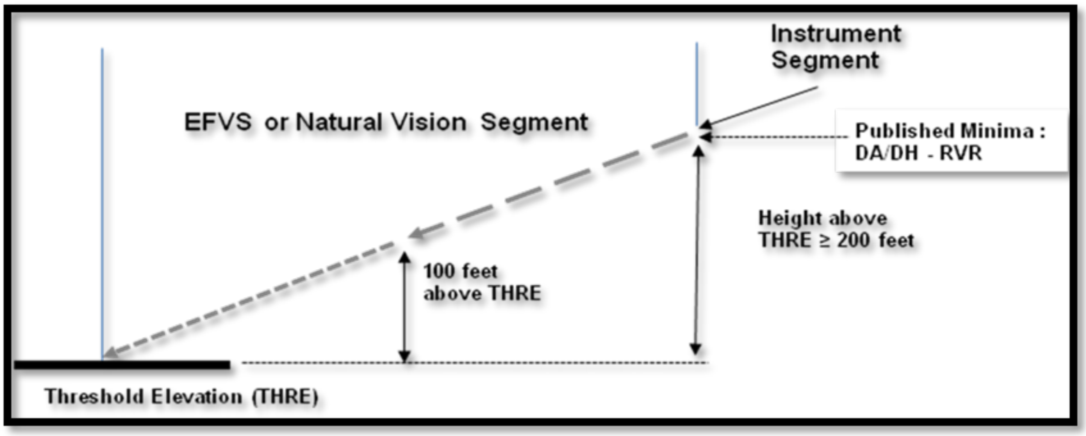


Figure 22: New EFVS concept/EFVS to land operation [source EUROCAE WD-179B]

AUO-0403 "Enhanced Vision on Head Up display for the Pilot in Low Visibility Conditions" was replaced by AUO-0405 "Equivalent Visual Landing operations in Low Visibility Conditions" by OFA 01.01.02. All vision systems (EVS, SVS, CVS) are covered into one AUO for Landing operation.

6.3.2 Conduct of Demonstration Exercise

This section details the preparatory activities (Section 6.3.2.1) and execution activities (Section 6.3.2.2) and description of deviations from the planned activities (Section 6.3.2.3).

6.3.2.1 Exercise Preparation

SWP 3.1 "EFVS Definition" covered the definition of the Air operational procedure and the definition of small/medium aerodrome impacts and also related safety assessments for the EFVS to land operations. EFVS definition also covered the study related to the increase of small medium airport capacity and aerodrome eligibility study.

SWP 3.2 "EFVS Systems" covered the preparations of the means which were used during the trials (F8X Full Flight Simulator level D, F7X, Fog Chamber) and also the deployment of the DASSAULT safety procedure to perform the tests safely on small/medium airports in visibility lower than those published.

The following paragraphs details the achievements within these SWPs per task and per contribution of each partner separately.

SWP 3.1 EFVS Definition

T 3.1.1 Air Operational Procedure [France]

Dassault [TL]

The EFVS to land operation is envisaged at CATII/III airports without any change and at other IFR airport either controlled or uncontrolled with AFIS providing they are compliant with the aerodrome/ ATM recommendation proposed. Furthermore, the EFVS to land operation is envisaged on approaches with published and approved vertical guidance path: ILS CAT1, RNAV LPV and RNAV LNAV VNAV (which correspond to 3D type A & type B CAT1 of new Annex 6 classifications). The AIR operation is based on dual HUD with flare guidance and is a subset of a global concept integrated in an EASy Cockpit (aural, RAAS system...). From a general standpoint, PF (Pilot Flying) uses the HUD/EFVS to fly the aircraft, and the PM (Pilot Monitoring) refers to HUD/EFVS and Head down to monitor the approach. The concept consists in using EFVS image in combination with other flight information below published

DA/DH, and to perform GO AROUND in case of inconsistency. For safety reasons, natural vision has to be checked before landing.

T 3.1.2 Safety Assessment - Airborne

Dassault [TL]

The safety assessment task has been started in parallel of the ConOPS. Based on the CS 25 1309 standard process, this activity has permitted to define the list of the relevant abnormal test cases and special events that were assessed by pilots in the FFS.

T 3.1.3 Small/Medium Airports Procedure

DSNA [TL]

A review (ongoing process) of the CHEA (French regulation for airport homologation) by a college of experts (ATC, procedure designer...) has confirmed the need for specific airport procedure (EVP) and in some rare cases the need for infrastructure adaptations to support EFVS operations below 550m RVR and down to 300m RVR. As a consequence, EFVS to land operations are envisaged on controlled or AFIS airports, and a homologation/ approval of airports capable of EFVS has to be obtained (AIP impacted).

T 3.1.4 Safety Assessment - Small/Medium Airport procedures

Dassault [TL]

EPIS/CA (preliminary study of impact on safety/ traffic management) was published by the DSNA local authorities for the three French airports intended for the tests. For controlled airspace (LFBD-Bordeaux and LFBE-Bergerac), this study will covers all the phases of the flight, from approach to go around. For uncontrolled airspace (LFBX-Perigueux), EPIS/CA will cover the first phases (coordination and handover to AFIS).

SWP 3.2 EFVS Systems

T 3.2.1 Fog Chamber Modification

Elbit [TL]

The fog chamber has been upgraded for the SESAR tests (new sensors to measure environmental conditions, new lights...). Validation plan has been discussed and successfully executed. The fog chamber permitted to support the validation of the performance of the EFVS camera in real controlled fog conditions.

T 3.2.2 Full Flight Simulator Modifications

Dassault [TL]

Dual HUD and simulation of both infrared airport environment and EFVS sensor were performed. Specific failure conditions to support assessment of EFVS to land in abnormal situations were also implemented. FFS permitted to successfully perform the tests in abnormal conditions defined.

T 3.2.3 Aircraft Modifications

Dassault [TL]

Falcon 7X experimental Aircraft was fitted with dual HUD and EFVS camera. Tests in single HUD were successfully performed. Tests in dual HUD are going on.

T 3.2.4 Airports Procedure Modifications

DSNA [TL]

As part of the EFVS to land concept of operation, no modification of the published procedure is planned. Only coordination procedure (agreement, schedule, EPIS/CA) was defined between ATC and airports for Bordeaux and Bergerac, or ATC and AFIS then AFIS and airport for Perigueux. ATC and persons from different airport services concerned with procedures defined for EFVS operation were informed and trained accordingly.

6.3.2.2 Exercise execution

Execution activities were covered by the SWP 3.3 "EFVS Trials". This SWP covered the definition of the EFVS trials including the Demonstration Plan description, the authorization to fly experimental EFVS to land operations, the executions of the tests and the production of the tests report.

Table 31 summarizes the actual demonstration schedule of the exercise.

Table 31: EXE_0202_300 - Exercise execution/analysis dates

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise analysis start date	Actual Exercise analysis end date
EXE-02.02-D-300	EFVS Advanced Procedures Feasibility and Benefits Demonstration	02 / 2016	10 / 2016	03 / 2016	10 / 2016

Figure 23: EXE_0202_300 - Exercise flight campaign timeline

The following paragraphs details the achievements within this SWP per task.

T 3.3.1 Demonstration Plan 1st Review – Input

All inputs to the Demonstration Plan 1st Review were provided followed by the review of the partners.

T 3.3.2 Demonstration Plan 2nd Review – Input

All inputs to the Demonstration Plan 2nd Review were provided followed by the review of the partners.

T 3.3.3 Authorization to Fly Experimental EFVS to land Operation

DASSAULT has developed a specific process supported by dedicated means like independent DGPS and procedures allowing to guaranty safety during EFVS flight tests. Based on the flight test safety analysis resulting from that process, DASSAULT has obtained a DOA from EASA that permit to do flight tests below published minima. This DOA does not require any authorization from different ANSP to do the experimental flight tests. Airports are just informed.

For aerodrome flight check, reduced low visibility procedure proposed in the DGT 153396 was deployed. An aerodrome safety analysis (EPIS CA) was performed by DSNA and local authorities to support such experimentation (provided in Appendix D "*Experimentation/ Demo flight in Bordeaux/ Bergerac and Périgueux aerodromes document*")

T 3.3.4 Link with EASA

DASSAULT initiated discussions about EFVS to land operation with EASA certification experts and rulemaking task team dedicated to low vis operation including EFVS with Operational credit (RMT0379) the 28th May of 2015 in Koln.

Four other F2F occurred between May 2015 and September 2016 in Koln, one of them in presence of the DSNA. These meeting were dedicated to the presentation of ConOPS, the aerodrome activity, the FFS and the flight tests plan. For aerodrome, recommendations proposed jointly with DSNA were presented in detail to the EASA aerodrome rulemaking officer and have supported the drafting of the new EFVS with operational credit regulation, including AMC and GM. Recommendation will be presented with DSNA and DASSAULT to ANTWERP airport on 26th of October 2016 in presence of FLYING GROUP, EASA and BELGOCONTROL.

T 3.3.5 Execution

Regarding aerodrome/ ATM, this activity started in February 2015. 13 workshops were organized with DSNA and local authorities involving many experts from different domains. Flight check was performed in LFBE and LFBX mid of February.

For Air segment, ConOPs was published Q1 2016 and then shared with EASA and FAA. Flight and FFS test plan based on safety analysis process was discussed with EASA Q1 2016. First Flight test session in real low visibility conditions was performed in February 2016. Demo flight is going on over Europe till the end of October 2016. FFS tests were performed on the new F8X dual HUD simulator end of august 2016 at Flight safety Paris Le Bourget facility.

For performance prediction, the table was computed by DASSAULT beginning of 2016. Fog chamber was prepared in 2015 and tests were performed in September 2016.

Capacity studies, evaluating the EFVS to land operation benefits were performed in 2015 and in 2016.

T 3.3.6 Demonstration Report – Input

All inputs to the Demonstration Report were provided followed by the review of the partners.

T 3.3.7 Communication

The communication activities were performed in accordance with the communication plan – see Section 7.

6.3.2.3 Deviation from the planned activities

Within WP3, 50 trials were expected to be performed in flight (Dassault F7X). As of early October 2016, 9 approaches were achieved, but flights in real low visibility conditions are going on and 10 more approaches are expected before the end of the project (end of October 2016. The analysis of these additional flights will be performed by Dassault, but will not be part of this report due to time constraints.

- 3 of the trials were dedicated to the consolidation of the aerodrome/ ATM low visibility procedure. These flights have demonstrated the adequacy of procedures to regional and small airports, including those with AFIS.
- 6 of the trials have been performed to partially validate the EFVS to land concept of operation in fog conditions with RVR as low as 300m. This validation was partial and limited because the DUAL HUD which is part of the full EFVS to land concept was not fully ready in the proper time for demo due to development delay encountered during the latest stage of validation of this complex system. Nonetheless, evaluation conducted in single HUD, associated to FFS runs performed in DUAL HUD configuration permitted to validate the major key points of the EFVS to land concept of operation.
- DUAL HUD is now available and flights have resumed with the objective to assess the concept in more low visibility conditions and more environments.

All the data gathered in flight were considered for prediction performance validation.

Within WP3, 40 conditions were initially planned to be simulated inside the fog chamber. It was finally possible to simulate 12 scenario combining the lighting level with different types of fog and lights. This scenario permitted to obtain preliminary conclusions for part of the weather conditions of interest.

Confirmation of those conclusion and extension to other conditions will require fog chamber modifications and further analysis before continuing the tests

Within WP3, 15 conditions resulting from flight tests were expected to be played-back inside the Fog chamber. Finally one flight condition had been replayed with good correlation between flight test results and Fog Chamber play-back results.

Beyond WP3 objectives:

The aerodrome/ ATM impact activity was widely shared with other than AAL stakeholders:

- The results were discussed with EASA in the frame of the ongoing rulemaking task RMT0379. All the work done jointly with the DSNA is considered as the major input to support the drafting of aerodrome EFVS related GM/AMC materials.
- The results will be presented by DASSAULT and the DSNA to ANTWERP airport 26th of October. FLYING GROUP and EASA will attend. This should consolidate the work done with French authorities.
- The results were presented and officially disseminated to the FAA regulation and certification offices.

Regarding performance prediction activity, DASSAULT compared computed EFVS performance with real flight test data. This activity highlighted the effect of the SVR to RVR ratio which is a major concern in the determination of the EFVS performance prediction.

Regarding the Full flight Simulator activity, the list of special events and safety failure cases considered for the demo was shared with EASA certification authorities.

6.3.3 Exercise Results

6.3.3.1 Summary of Exercise Results

The results were assessed against the success criteria and it was decided if the Demonstration objective status is OK, POK or NOK. Overall assessment for all criteria (involving all exercises) is presented in the Table 8 in Section 5.1.

6.3.3.2 Analysis of Exercise Results

In the following sections the exercise results are summarized according to the demonstration objectives evaluation. For detailed analysis see relevant Appendixes.

6.3.3.2.1 Feasibility demonstration: OBJ_0202_015 (EFVS)

Identifier	**OBJ_0202_015**
Objective	To demonstrate feasibility of EFVS approaches.
Success Criterion	EFVS approach procedure is feasible based on the feedback from pilots.
Addressed KPA	**Human Performance**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_02 02_300	**SCN_02 02_302**	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions; day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).
	SCN_02 02_306	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: FlyingService NV (Dassault Subcontractor), Airbus, Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions: day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix D (Section D.1.1).

RESULTS ANALYSIS OVERVIEW

In total, 60 runs were performed in DASSAULT Falcon 8X Level D FFS in normal and abnormal conditions, and 6 approaches were flown as of today with DASSAULT experimental Falcon 7X in real operational environment and RVR300m.

In normal conditions, the visual acquisition (EVS and natural), the task sharing and crew collaboration, the crew workload, the situational awareness and the capacity to perform a safe landing and rollout were assessed. In abnormal situations, the ability of the pilot to check consistency of EVS image with HUD information, his capacity to timely detect failures, or the capacity to perform a safe go- around were assessed.

FFS runs permitted to assess the EFVS to land concept of operation over a wide range of limit situations combined with most severe low visibility conditions, which would be extremely difficult to get together in flight. It also permitted to test some failure cases that would be not feasible in flight. Runs were performed at 8 different airports with different geographical environments, various runway and approach characteristics, various lighting systems and weather conditions.

The main limitation of the representativeness of the FFS for EFVS to land concept assessment is the flatness of the real lights perceived through the HUD in low visibility conditions for day situations. For this reason, runs were performed in night conditions.

Flights have permit to assess the conOPS in real operational environment, in particular with real ambient lighting conditions, with real lighting system and real atmosphere characteristics affecting visual acquisition. This evaluation in flight is still in progress till the end of October to cover more conditions and involve more crews.

For simulator session, 3 crews with different ages, different background and various experiences were involved. One DASSAULT flight test crew involved in the preparation of the flight simulator took also part to the human factor assessment. For flight, and as of today, two DASSAULT test pilots were involved in flight Demo in Low vis. Demo analysis was supported by a human factor questionnaire resulting from a CS25 1302 analysis.

Tests were performed with and without AP or AT.

Main conclusions are that the procedure proposed has been found feasible, even with abnormal cases. The principle of flying the aircraft by following guidance and by using the EVS image for verification of trajectory has been validated. The three Go Around gates were very clear and unambiguous and allowed an effective decision making.

The HUD CVS mode proposed was assessed as intuitive and comfortable allowing a good trajectory and environment awareness.

The PF/ PM standard task sharing was found appropriate to the EVS operation. Dual HUD and CVS were considered as valuable features and demonstrated an efficient crew decision making and much better situation awareness than with EVS only. However, as the workload has been found high in manual by some pilots, the use of autopilot and auto-throttle should be recommended. Moreover, a clear briefing and training guideline including demonstration of consequences for potential deficiencies or overreliance to the system are proposed.

FFS tests also revealed that decrab manoeuver, when required, may be challenging in extreme low visibility situations such as RVR300m in case of absence of centreline on large runway. This point should be further assessed.

In conclusion, more flight tests in real operational environment with more adverse weather situations and involving more air users have to be performed to envisage the deployment of the EFVS operation.

Details are provided in Appendix D: "*DEV 110182: Test Report - F8X EVS to land Simulator Evaluation Report*" in the attachment "*Appendix D and I to Final Demonstration Report B2_SimReport.pdf*".

6.3.3.2.2 Benefits demonstration: OBJ_0202_021 (Accuracy)

Identifier	**OBJ_0202_021**
Objective	To demonstrate accuracy of advanced procedures.
Success Criterion	TSE for advanced procedure approaches is within the relevant CTQ value.
Addressed KPA	**Safety**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_02 02_300	**SCN_02 02_301**	OBJ_0202_021 OBJ_0202_022 OBJ_0202_030	FFS	FFS	EFVS	Realization of multiple approaches run in a full flight simulator F7X level D equipped by HUD and EVS simulation in low visibility conditions with different pilots: Dassault operational and tests pilots.

	SCN_02 02_302	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions; day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).
	SCN_02 02_305	OBJ_0202_021 OBJ_0202_022 OBJ_0202_030	FFS	FFS	EFVS	Realization of multiple approaches run in a full flight simulator F7X level D equipped by HUD and EVS simulation in low visibility conditions with different pilots: FlyingService NV (Dassault subcontractor), Airbus, Dassault operational and tests pilots.
	SCN_02 02_306	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: FlyingService NV (Dassault Subcontractor), Airbus, Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions: day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix D (Section D.1.2).

RESULTS ANALYSIS OVERVIEW

The procedure proposed has been found safe even with abnormal cases. The principle of flying the aircraft by following guidance and by using the EVS image for verification of trajectory has been validated.

None of the crew was tempted to maneuver the aircraft with the help of the image instead of following the guidance. Measured accuracy performance (horizontal and vertical TSE) was well within the CTQ value of ±1 dot, even for the most severe cases of failures such as the GPS error on RNAV approach. All landing were safe and terminated in touchdown zone. All the abnormal cases inducing trajectory deviation were timely detected by the crew and resulted in an appropriate decision to go-around. Thus no negative impact on safety was observed.

Although all landing terminated in touchdown zone, tests revealed that flare cue would nonetheless be appreciated in some situation.

Charts illustrating the trajectory following quality are provided in Appendix D: in "*DEV 110182: Test Report - F8X EVS to land Simulator Evaluation Report*" in the attachment "*Appendix D and I to Final Demonstration Report B2_SimReport.pdf*".

6.3.3.2.3 Benefits demonstration: OBJ_0202_022 (Operational Credit)

Identifier	**OBJ_0202_022**
Objective	The operational concept of “EFVS to Land” is safe and the operational credit obtained with EFVS is significant compared to exiting EFVS concepts.
Success Criterion	Approaches successfully flown on FFS and Flight Tests.
Addressed KPA	**Safety**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_02 02_300	**SCN_02 02_301**	OBJ_0202_021 OBJ_0202_022 OBJ_0202_030	FFS	FFS	EFVS	Realization of multiple approaches run in a full flight simulator F7X level D equipped by HUD and EVS simulation in low visibility conditions with different pilots: Dassault operational and tests pilots.
	SCN_02 02_302	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions; day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).
	SCN_02 02_305	OBJ_0202_021 OBJ_0202_022 OBJ_0202_030	FFS	FFS	EFVS	Realization of multiple approaches run in a full flight simulator F7X level D equipped by HUD and EVS simulation in low visibility conditions with different pilots: FlyingService NV (Dassault subcontractor), Airbus, Dassault operational and tests pilots.
	SCN_02 02_306	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: FlyingService NV (Dassault Subcontractor), Airbus, Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions: day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix D (Section D.1.3).

RESULTS ANALYSIS OVERVIEW

Approaches performed in FFS and in flight (see other sections of the Section 6.3.3.2) demonstrated the overall benefit of the EFVS to land concept proposed by DASSAULT with Dual HUD, synthetic Runway and CVS compared to existing EFVS 100ft concept.

The "*Analysis of reduced Runway Visual Range and low Ceiling regarding operational minima for European aerodromes usually frequented by Falcon aircrafts Potential benefit for EFVS concepts*" study provided in Appendix D (attachment "*Appendix D and I to Final Demonstration Report B2_ReducedRVR_Study.pdf*") reveals to what extent the operational credit provided by the EFVS to land concept could be beneficial compared to EFVS 100ft.

Section 4.2.3.1.2 in particular illustrates the fact that a significant part of RVR are higher than 300m (which is the lower limit for the EFVS to land concept) and lower than RVR published minus 30%, - (which is currently the maximum operational credit allowed by table 6 of AMC6 SPA.LVO.100 of European regulation for 100ft concept). This shows clearly the potential interest for such an EFVS to land concept. From a global point of view, considering macroscopic study based on 128 airports, and a published RVR of 800m which is representative of most of secondary airports that are usually not equipped with full approach lighting systems, EFVS to land concept would permit to operate in more than twice of RVR situations compared to EFVS 100ft concept. This is for example the case for Bergerac (see §4.3.3.1.1) where EFVS to land would have permit to erase 65 low visibility situations compared to 32 with EFVS 100ft.

6.3.3.2.4 Benefits demonstration: OBJ_0202_023 (Reliability)

Identifier	**OBJ_0202_023**
Objective	Reliability of EFVS to land operations in various weather conditions.
Success Criterion	Predicted Enhanced Flight vision is consistent with flight test results and fog chamber tests results.
Addressed KPA	**Safety**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_300	**SCN_0202_302**	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions; day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).
	SCN_0202_306	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: FlyingService NV (Dassault Subcontractor), Airbus, Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions: day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix D (Section D.1.4).

RESULTS ANALYSIS OVERVIEW

SESAR-AAL has for objective to validate the performance predictive table designed for EFVS systems. The EFVS predictive table is intended to be used by the crew to determine in advance the capability of the EFVS system to see visual references in the expected conditions. To be more precise, the objective of this table is to determine the EFVS segment (eRVR) corresponding to a forecasted RVR. This new tool will thus enable to assist the pilot for flight planning and during approach preparation: For a specific weather situation, if the eRVR is greater than the RVR from predicated in the IAC, OPS credit can be envisaged. Otherwise, other destination, diversion or go around will have to be considered.

The performance prediction activity consists in two parts. One part is a comparison of DASSAULT advanced simulation results with data gathered in flight. Second part is a comparison of ELBIT fog chamber results with flight data and simulation.

<u>Comparison of DASSAULT advanced simulation results with flight data</u>:

This study highlighted that the high level difficulty of predicting EFVS performances comes from the fact that RVR cannot be directly compared to what is seen by a pilot from the cockpit (called as the slant visual range or SVR). The EFVS performance prediction has been thus discomposed in two independent parts:

1. The determination of the transfer function between what is really seen from the cockpit by the pilot during approach (SVR) and what is measured on ground (RVR): SVR = f_1(RVR).
2. The determination of the performance provided by EFVS during approach (eSVR) from what is seen by the pilot from the cockpit without EFVS in similar conditions (SVR): eSVR =f_2 (SVR).

The first part is not specific to the EFVS and also deals with basic approach operations such as CATI or CATII. Data gathered in the 60-70's in UK and in the USA concluded that for most fog; SVR was most of the time less than RVR and depends with height and from fog profiles. This is well reflected inside *ICAO Doc 9328* and inside EASA *Implementing Rule AIR Operation GM1 SPA.LVO.100(c),(e) Low visibility operations for CATII and CATIII minimum RVR regulation*. However, although very approximate relationships were suggested, no standard factor is proposed at this time.

This part has been partially addressed with SESAR-AAL flight tests for a 300m reported RVR in fog condition by day. Conclusions are consistent with prior experimentations:

- SVR is less than RVR and depending on inhomogeneity of the atmosphere, factors from 0.56 to 0.62 were observed.
- Beyond SESAR AAL, a larger study is recommended with the involvement of weather office department and the use of weather/ atmosphere statistical data to confirm if such a relationship can be determined for CATI and EFVS operations, for fog and for other weather conditions.

The second part deals with EFVS sensor performance and can be addressed by the EFVS system manufacturer. However, full EFVS performance prediction remains complex, mainly because of two reasons:

- A business jet can encounter various weather conditions that may result in the same reported RVR but not in the same EFVS performance.

  Examples: Homogeneous radiative fog, fog in formation, cloud layers and patches of fog…

- Pilot has access to very limited information regarding weather characteristics and environmental conditions: RVR, type of precipitation or obscurant and cloud layer density are the only weather information that is reported.

Due to the complexity of the problematic, the EFVS performance table was first limited to pure fog condition. Moreover, as there is no standard for the LED spectrum characteristics, the analysis was restricted to incandescent lights.

The validation of EFVS performance was performed using SESAR-AAL flight tests performed in low visibility conditions. Real measurements were analyzed and compared to EFVS predicted performance (eRVR, eSVR) resulting from advanced simulation that takes into account scene model, atmosphere model and sensor model.

The experiment is based on 5 test points for fog condition by day with 300m of RVR. It reveals that:

- Regarding eSVR = f_2 (SVR), eSVR was predicted with an accuracy of 26% with the current simplified prediction model which could be adjusted with a larger sample of flights.
- There is a delay between pilot detection in flight and post-process detection (on video playbacks after flight) that should be taken into account for performance prediction.

To conclude:

- The ability to predict the EFVS performance for fog seems achievable provided the relationship SVR= f_1 (RVR) is determined.
- In order to go further on the validation of an EFVS performance table for fog, the following activities are recommended:
    - To characterize the SVR= f_1 (RVR) relationship. We recommend to involve weather office and to consider inhomogeneous atmosphere models in addition to previous results from experimentations performed for fog in UK and in US.
    - To consider a larger sample of flight covering a range of SVR up to 2000 m for fog (maximum of possible published RVR), for day and night.
- In order to extend the validation of performances prediction to other conditions than fog, such similar experimentations should be considered for rain and snow.
- Finally, in order to validate performance prediction for LED, more information about these light equipment is necessary to define a standard LED spectrum candidate for prediction.

Details results of the analysis are provided in Appendix D: in "*DGT 156549: SESAR AAL- EFVS performances predictive table*" in the attachment "*Appendix D and I to Final Demonstration Report B2_PredictiveTable.pdf*" (it is to be noted that this attachment is classified as confidential and therefore is not included in the deliverable).

Comparison of ELBIT fog chamber results with flight data and simulation:

ELBIT "fog chamber" was originally planned to be used for SESAR-AAL, as a complementary mean to flight tests to validate the EFVS performance predictive table for weather conditions not encountered during SESAR flight test.

The "Fog Chamber" is a 30 m long chamber inside which synthetic advective or radiative fogs can be reproduced. Measurements are based on the detection of a bulb light by the EFVS system inside the "Fog Chamber". Several devices placed inside the chamber allow the operator to control the effective transmission of the produced fog, the ambient luminance and the type, position and intensity of the targeted light bulb.

The challenge of the "Fog Chamber" validation activities is to prove that the conditions created inside the 30 m chamber can be compared to real scaled fog. Elbit System determined the relationship R that allows the operator to make the link between "Fog Chamber" tests and real scaled tests that is to be used according to the principle described in Figure 24.

To validate this method, both simulation and flight test playbacks have been used. As reflected in Figure 24, to assess the reliability of the method, results of EFVS performances from Elbit simulation or flight tests are compared to results obtained inside the "Fog chamber" for R equivalent conditions.

During SESAR-AAL, validation by simulation has been assessed through 12 different scenarios:

- Radiative fog with 800m visibility by Day and Night (LEDs and Incandescent bulb light)
- Radiative fog with 500m visibility by Day and Night (LEDs and Incandescent bulb light)
- Advective fog with 300m visibility by Day and Night (LEDs and Incandescent bulb light)

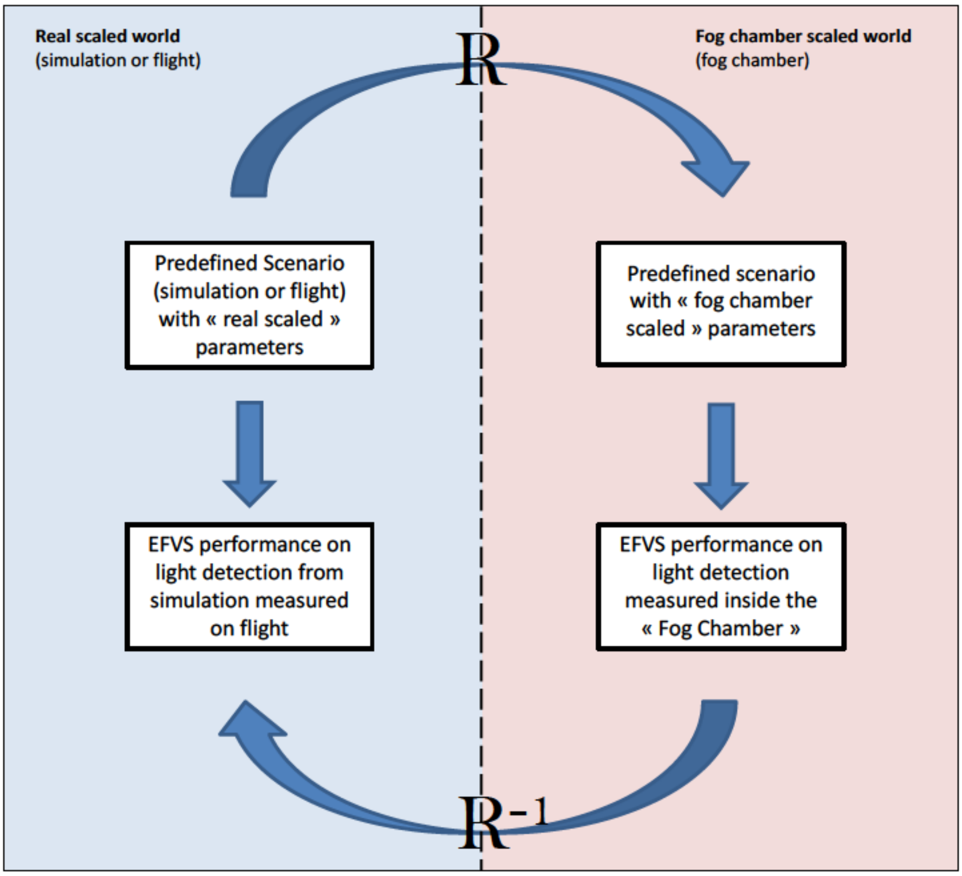


Figure 24: Principle of comparison between fog chamber results and real scaled results

For those conditions, fog scaled simulated scenarios are accurate with real scaled simulated scenarios with an error up to 25%. This error is such that "Fog Chamber" results are always lower than Elbit simulation results for all tested conditions. These discrepancies seem due to inhomogeneity of fog inside the "Fog Chamber", and insufficient ability to measure of the visibility along the chamber, further studies are needed to confirm this hypothesis and improve the laboratory.

For the validation part with flight test, one flight test has been playback inside the "Fog Chamber". The reason is that only well characterized, homogeneous and dense fog can be reproduced inside the "Fog Chamber". Other available flight tests for SESAR-AAL were not homogeneous enough because of fog or clouds layers. As a result, they could not have been used for "Fog Chamber" validation activities. For the existing adequate flight test data, the comparison between results of playback inside the "Fog Chamber" and real results were good but a single flight test is not enough to conclude on validation.

As a conclusion, the validation of the "Fog chamber" seems achievable but the following activities are recommended:

- To confirm the inhomogeneity inside the chamber as the root cause for the 25% discrepancies on measurements and to upgrade the chamber accordingly.
- To enlarge the sample of flight tests to extend the validation to real condition (and not only simulation).
- To consider a larger sample of simulation scenarios to tune the model.

After performing the recommended validation activities, the "Fog Chamber" could be used to validate EFVS performance prediction.

Details results of fog chamber activities are provided in Appendix D containing the 2 following documents: "*Fog Lab scenario Simulations for EVS Performance Testing*" and "*Fog Lab Flight Simulations for EVS Performance Testing and Correlation to Real Flights*" (it is to be noted that these attachments are classified as confidential and therefore are not included in the deliverable).

6.3.3.2.5 Benefits demonstration: OBJ_0202_027 (Div/Del/Go-Around)

Identifier	**OBJ_0202_027**
Objective	Estimate reduction of number of diversion, delay or go-around.
Success Criterion	Evaluation shows decreased number of diversion, delay or go-around by relevant CTQ.
Addressed KPA	**Environment / Fuel Efficiency**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_300	**SCN_0202_307**	OBJ_0202_027 OBJ_0202_031	N/A	N/A	EFVS	Study to evaluate impact of EFVS on airport capacity and deduce direct consequences on environment/fuel efficiency

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix D (Section D.2.1).

RESULTS ANALYSIS OVERVIEW

An Analysis of reduced Runway Visual Range and low Ceiling situations regarding operational minima for European aerodromes usually frequented by Falcon aircrafts has been performed. Potential benefit for EFVS concepts have been analyzed.

This analysis looks to what extent a CATI crew will be unable to land due to limited RVR or too low CEILING, causing delays, diversions or cancellations.

It identifies the amount of time the RVR or / and the CEILING are below the published minima (RVR and DA/H) for which EFVS operation is permitted.

This study focuses on European airports among the most frequented by business aviation.

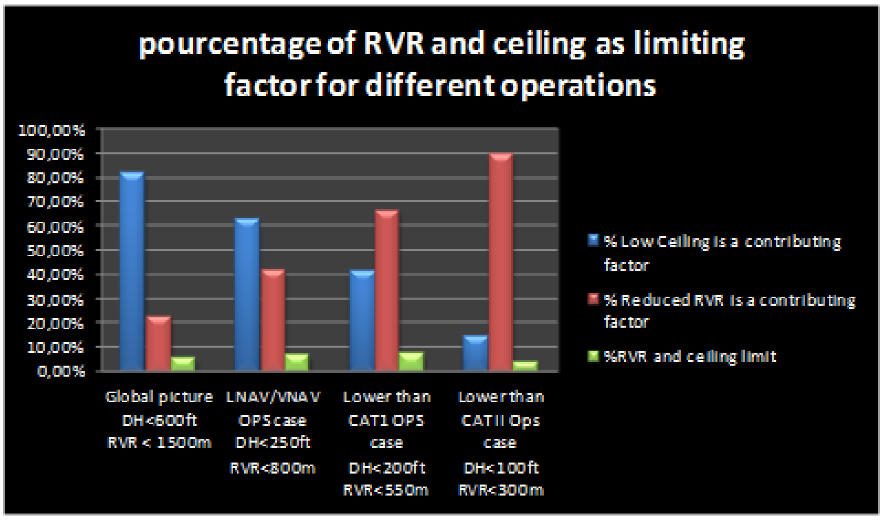
In the SESAR perspective of the deployment of the EFVS operation with operational credit in Europe, this study is a key input to assist all the stakeholders in their assessment of the real benefit of that new capacity (i.e. aircraft manufacturer, AIR operator and aerodrome operator).

This study contains two parts:

- A macroscopic analysis considering RVR and CEILING for a large numbers of airports in Europe (128)
- A focused analysis given RVR and CEILING figures for some airports (19) by taking into account their real operational characteristics such as real published minima or real opening hours.

Macroscopic analysis revealed that:

- the *low visibility* conditions considered in that broad range study (128th European airports with minima in the RVR1500m/DH600ft envelope) are observed in less than 5% of the total amount of time, and 3.6% in case the scope of the study is restricted to opening hours.
- When reduced RVR or low CEILING occur, they are observed in combination in less than 8% of the amount of time.
- The correlation between the low CEILING proportion and reduced RVR proportion is as follows:
  - The reduced RVR is the main limiting factor when operational minima become low (up to 89% for CATIII operational minima).
  - The low CEILING is the main limiting factor when operational minima is high (up to 77% for global picture case).



- With respect to the EFVS to land concept with RVR down to 300m, and without any sensor performance consideration, 85% of situations where RVR was lower than 800m would have led to successful landing. Considering the 128th airports analyzed, EFVS to land concept would have permit to save 2500h of operations and only 450h would have required a more advanced concept. This demonstrates the big potential of such a concept. If we consider a much more conservative approach -to better reflect the state of art of EFVS sensors that are or will be in service in the coming years-, by assuming for example that sensor would be not capable to see through cloud (ceiling), EFVS to land would have still permitted to land:
    - In 60% of the situations for which RVR < 800m or ceiling < 200ft. This corresponds to 2210 hours.
    - In 41% of the situations for which RVR < 550m or ceiling < 200ft. This corresponds to 1054 hours.

Focused analysis revealed that:

- The results may significantly vary depending on the airports local characteristics,
- For the eleven CATI airports considered in that study:
    - Low visibility conditions proportion varies from 0.2% to 2.8%. This corresponds to a volume of 15h to 160h and has affected from 10 to 63 different days over 2014.
    - RVR is more often a limiting factor than CEILING. Some airports are exclusively limited by RVR (100%) while CEILING was a limited factor in no more than 66% for the most constrained airport.
    - Reduced RVR is observed with low CEILING in a proportion from 0% to 41%
    - The number of slots where RVR is less than 300m vary between 1 and 49
    - EFVS to land concept would have been permit to save between 9h to 144h, affecting between 11 and 63 days.
- For the height CATII/III airports, where EFVS operation with operational credit is possible for a CATI crew, the results are:
    - Low visibility conditions proportion varies from 0.3% to 3%. This corresponds to a volume of 25h to 260h and has affected from 16 to 54 different days over 2014.

- Reduced RVR is a limiting factor in comparable proportion of low CEILING. Limitation of RVR vary from 56% to 98%. Limitation of CEILING vary from 56% to 84%.
- Reduced RVR is observed with low CEILING in a proportion from 0% to 27%
- The number of slots where RVR is less than 300m vary between 2 and 84
- EFVS to land concept would have been permit to save between 25h to 250h, affecting between 16 and 54 days.

For the full study "*Analysis of reduced Runway Visual Range and low Ceiling regarding operational minima for European aerodromes usually frequented by Falcon aircrafts, Potential benefit for EFVS concepts*" see Appendix D: attachment "*Appendix D and I to Final Demonstration Report B2_ ReducedRVR_Study.pdf*".

6.3.3.2.6 Benefits demonstration: OBJ_0202_030 (AP Capacity)

Identifier	**OBJ_0202_030**
Objective	Definition of the impacts on the small/medium airport infrastructure and procedures to enable EVS operations in low visibility conditions.
Success Criterion	Procedures and possible requirement for specific infrastructure to do EFVS to land Operations on small/medium airports are defined.
Addressed KPA	**Airport Capacity**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE_0202_300	**SCN_0202_301**	OBJ_0202_021 OBJ_0202_022 OBJ_0202_030	FFS	FFS	EFVS	Realization of multiple approaches run in a full flight simulator F7X level D equipped by HUD and EVS simulation in low visibility conditions with different pilots: Dassault operational and tests pilots.
	SCN_0202_302	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions; day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).
	SCN_0202_303	OBJ_0202_030	Fog chamber	Fog chamber	EFVS	The conditions met during the first flight test campaign will be replayed in the fog chamber (except for Flight tests in rain and snow Condition). • In different sun light conditions: day, night, dusk, dawn. • In different airport approach landing lights system. • In different weather conditions: mist, fog with different RVR. About 15 different conditions will be replayed.

	SCN_02 02_304	OBJ_0202_030	Fog chambe r	Fog chamber	EFVS	The conditions of inputs of the "predicted EFVS table" are simulated in the fog chamber (except snow and rain condition): • Weather conditions o Fog/Mist o Different RVR • Time of the day o Night o Dusk o Day o Dawn • Type of approach lights (Incandescent/LED). About 40 different conditions will be simulated.
	SCN_02 02_305	OBJ_0202_021 OBJ_0202_022 OBJ_0202_030	FFS	FFS	EFVS	Realization of multiple approaches run in a full flight simulator F7X level D equipped by HUD and EVS simulation in low visibility conditions with different pilots: FlyingService NV (Dassault subcontractor), Airbus, Dassault operational and tests pilots.
	SCN_02 02_306	OBJ_0202_015 OBJ_0202_021 OBJ_0202_022 OBJ_0202_023 OBJ_0202_030	LFBE LFBD LFBX	F7X	EFVS	Pattern approach will be performed in low visibility condition with different pilots: FlyingService NV (Dassault Subcontractor), Airbus, Dassault operational and tests pilots. • In different airport terrain environment, mountainous, rural, urban. • In different sun light conditions: day, night, dusk. • In different airport approach landing lights system. • In different airport type of runway and runway status (dry, humid...). • In different weather conditions: heavy rain, shower, snow, mist, fog. In different category of approach (ILS, LPV).

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix D (Section D.1.5).

RESULTS ANALYSIS OVERVIEW

DASSAULT and DGAC/DSNA have conducted a joint analysis about the impacts on ATM-aerodrome regulation of the EFVS operation with OPS credit in RVR as low as 300m. This detailed activity was based on the review of the requirements contained in the seven annexes of comprehensive CHEA regulation (French aerodrome homologation regulation) and has involved a large team of ATM-aerodrome expert and aerodrome operational people such as aerodrome director, AFIS and controller managers, air operation department and rescue and firefighting service manager.

The main result of that study is that EFVS operation should be possible:

- at CATII/III airports without any change,
- and, at all other controlled IFR airport or uncontrolled IFR airport with AFIS, that are compliant with the recommendation proposed in the 6 following domains:
    - Installation such as RVR measurement is available…
    - Low Visibility Procedures such as one movement at one time…
    - Procedure design criteria such as VSS clear of obstacle…
    - Publication changes such as EVS with Ops credit 300m possible…
    - Phraseology such as Request for RNAV LPV with EVS…
    - Flight Plan such as EVS300m is mentioned in field 18 of the flight plan…

The recommendations and their substantiations are detailed in the DGT153396 document in Appendix D (Section D.1.5). The recommendations proposed by DSNA-DASSAULT have been reviewed by local authorities of BORDEAUX/ BERGERAC and PERIGUEUX and consolidated by a demo flight (see in Appendix D - Section D.1.5 the document "Experimentation/ Demo flight in Bordeaux/ Bergerac and Périgueux aerodromes"). The conclusion is that the proposed recommendations could be envisaged without any installation modification or significant procedure changes at these three regional/ secondary airports.

Recommendation made in the DGT153396 were presented by DASSAULT and DSNA to EASA and has been considered as an input to support the ongoing EASA rulemaking task RMT0379 regarding All Weather Operation, in defining the aerodrome-ATM criteria necessary for EFVS with Ops credit operations (AMC/GM of ADR part). It was also disseminated to FAA certification and rulemaking offices.

Beyond this, and to ensure that EFVS operation with operational credit can be operated the same way all over European countries, recommendations have been shared with ANTWERP airport and will be discussed with local authorities by the end of October. The EASA aerodrome rulemaking Officer, BELGOCONTROL authorities and the FLYING GROUP operator will attend in addition to the joined team DASSAULT-DSNA.

Before large consideration, DASSAULT-DSNA recommends to extend the sharing of that study with other CAA(s) who expect big benefits from EFVS operations with operational credit and to lead full aerodrome approval process for some of them.

DASSAULT is proposing such activity in the frame of SESAR2020.

For the full reports "*DGT153396: SESAR Project - AAL EFVS OPERATION WITH OPERATIONAL CREDIT - Impact on ATM-Aerodrome*" and "*SESAR Project - AAL EFVS OPERATION WITH OPERATIONAL CREDIT Impact on ATM-Aerodrome Experimentation/Demo flight in Bordeaux/ Bergerac and Périgueux aerodromes*" see Appendix D - attachments "*Appendix D and I to Final Demonstration Report B2_DGT153396.pdf*"' and "*Appendix D and I to Final Demonstration Report B2_Aerodrome_Test.pdf*".

6.3.3.2.7 Benefits demonstration: OBJ_0202_031 (Airport Eligibility)

Identifier	**OBJ_0202_031**
Objective	To demonstrate airport eligibility for advanced procedures.
Success Criterion	Airport eligibility evaluation for advanced approaches show reachability to relevant CTQ value.
Addressed KPA	**Airport Capacity**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
	SCN_02 02_307	OBJ_0202_027 OBJ_0202_031	N/A	N/A	EFVS	Study to evaluate impact of EFVS on airport capacity and deduce direct consequences on environment/fuel efficiency

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix D (Section D.2.2).

RESULTS ANALYSIS OVERVIEW

According to eAIP [39], in France continental, in 2016, 89% (98 aerodromes) of the airports dedicated to civil aviation and having at least one IFR approach procedure published (2D or 3D) are eligible* EFVS to land, and this number will significantly growth in the coming years with the deployment of the PBN (see Figure 25). 38% of the French airports eligible EFVS to land are managed by AFIS (37 airports).

*NOTE: An airport is here considered eligible EFVS to land if of at least one 3D approach is published (RNAV LPV or RNAV LNAV VNAV or ILS).

Beyond the number of airports, 85% (162 QFU) of the QFU having an IFR approach are eligible to EFVS with Ops credit operation. The repartition is as follows (see Figure 26):

- 46% of runway end are fitted with a mixed of several 3D procedures*
- 26% of runway end are fitted with LPV only,
- 11% of runway end are fitted with ILS only,
- 2% of runway end are fitted with LNAV/VNAV only,

*Note: Either LNAV/VNAV or ILS, or LNAV/VNAV and LPV (e.g. Dinard), or ILS and LPV (e.g. Brives 29), or LNAV/VNAV and ILS and LPV e.g. Bergerac 28).

89% (144) of the QFU elligible for EFVS to land have RNAV with LPV minima. 52% (70) of these QFU with RNAV with LPV minima procedures have no ILS procedures.

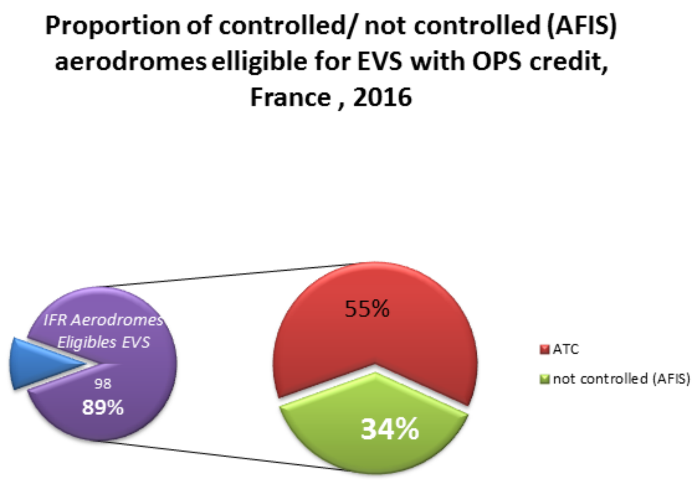


Figure 25: Proportion of controlled/not controlled (AFIS) aerodromes eligible for EFVS credit, France, 2016

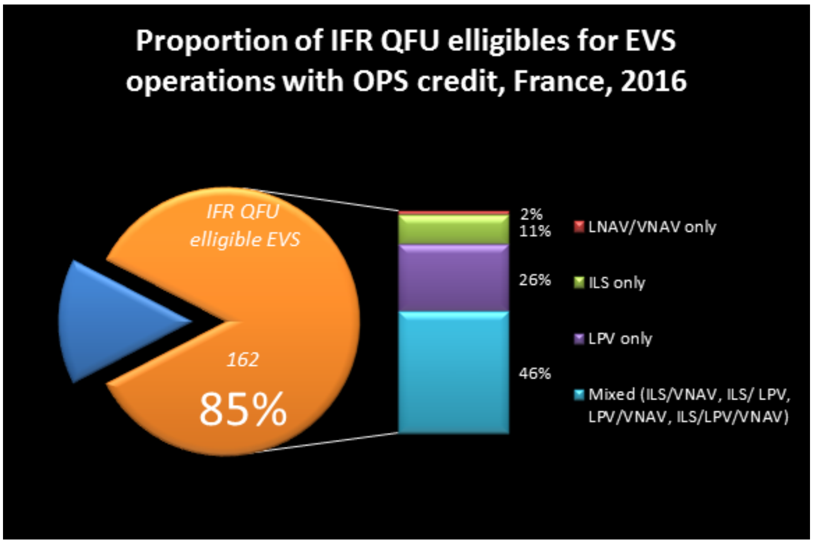


Figure 26: Proportion of IFR QFU eligible for EVS operations with OPS credit, France, 2016

6.3.3.3 Results per KPA

For EXE_0202_300 relevant KPI/metric and CTQs for all KPA described above are summarized in the Table 32. Results in form of status OK/POK/NOK are also stated.

Table 32: KPA, KPI/metric and CTQs for EXE_0202_300

KPA	KPI	Methodology	Metric	CTQ definition	CTQ value	Status
Safety	Crew workload reduction (EFVS)	Simulation + Flights	Evaluation of the crew capacity to perform EFVS operation (acquisition of visual references, stabilized approach).	The global workload is within CTQs limits	major difficulties (level 7/10 Cooper Harper)	OK
	Horizontal Flight accuracy (EFVS)		Evaluation of horizontal TSE for EFVS approaches.	Horizontal TSE for EFVS approaches is within CTQ limit	within 1 dot	OK
	Vertical Flight accuracy (EFVS)		Evaluation of vertical TSE for EFVS approaches.	Vertical TSE for EFVS approaches is within CTQ limit	within 1 dot	OK
	Successful touchdown (EFVS)		Measure of the touchdown footprint for EFVS approaches.	Touchdown footprint for EFVS approaches is within CTQ limit	in touchdown zone*	OK
Environment/ Fuel efficiency	Reduction of number of diversion and GO AROUND (EFVS)	Study	Evaluation of the percentage of successful landing on expected destination airport.	Increase the number of landing on expected DEST airport	N/A (not quantifiable in absolute, depends on each operator activity)	OK
Airport Capacity	Airport procedure and installation eligibility (EFVS)	Study	Evaluation of the percentage of eligible airports for EFVS operations.	The number of controlled (AFIS or ATC) French airports with instrument 3D approaches that are eligible to EFVS to land operation is better than CTQ	at least 80%	OK
	Small/medium airport visibility capacity enhancement (EFVS)	Simulation + Fog Chamber	Evaluation of the effective eRVR compared to actual RVR.	The effective eRVR is greater than actual RVR	eRVR is at least 420m (for RVR of 300m in day FOG conditions)	OK

KPA	KPI	Methodology	Metric	CTQ definition	CTQ value	Status
Human Performance	Perceived level of feasibility – pilots (EFVS)	Flights	Evaluation of pilot's perceived difficulty to do EFVS operation. Evaluation of pilot's perceived accuracy during EFVS to land operation. Use of questionnaires to be completed by PF and PM.	The EFVS to land approach is feasible (based on feedback form pilots) without any excessive difficulty and with adequate accuracy for at least CTQ	YES >90% appr. successful	OK

** Touchdown zone is defined as the first third of the runway.*

6.3.3.4 Results impacting regulation and standardisation initiatives

Each of the results of SESAR AAL WP3 have been or will be shared with EASA and FAA certification authorities in the frame of the DASSAULT regular certification activities and through DASSAULT participation to rulemaking task RMT0379 dedicated to low vis operations including EFVS.

In particular, aerodrome/ ATM impact activity has been shared and discussed with the RMT0379 Operational and aerodrome team. The material produced in SESAR is considered as a major input for the drafting of the aerodrome GM/AMC related to EFVS to land operation.

Beyond EASA regulation, aerodrome / ATM impact results will be a valuable contribution to the future homologation of some aerodromes desiring to start deployment of EFVS to land operation.

The tight collaboration between DASSAULT and EASA will continue beyond SESAR.

6.3.3.5 Unexpected Behaviours/Results

The difference between SVR and RVR significantly affects the EFVS performance prediction and a specific study should be conducted and a specific study should be conducted.

In FFS in day low visibility conditions, the rendering of the lights was not found as bright as it is in reality. It impairs the pilot's acquisition of real lights through the HUD with EVS as part of the EVS to land concept. For this reason, visual acquisition aspect must be assessed in flight.

6.3.3.6 Quality of Demonstration Results

An aerodrome impact study involving many experts from various domains and local aerodrome authorities (LFBD, LFBE, LFBX), demonstration flights in low visibility and in real operational environment, FFS runs in limit conditions, benefit studies on 128 European aerodromes frequented by bizjet and a performance prediction validation study were achieved.

These five coherent and complementary activities federated by SESAR and with EASA in the loop have permit to push forward EFVS to land operation in the perspective of its deployment.

6.3.3.7 Significance of Demonstration Results

Impacts on aerodrome / ATM identified jointly with DSNA and shared with EASA and FAA were consolidated by a flight demo (3 approaches) achieved at both secondary (LFBE) and AFIS (LFBX) aerodrome in real operational environment. Impacts on aerodrome / ATM will be presented to Antwerp aerodrome on 26th of October.

60 runs were performed at 8 different airports in FFS8X dual HUD by FLYING GROUP, AIRBUS and DASSAULT crews, in normal and abnormal conditions, and for large set of situations such as RVR as low as 300m. Test cases were shared with EASA. Feasibility of the operation was supported by human factor questionnaires resulting from a CS 25 1302 methodology and using a Lickert adapted scale.

A study of the impact of the EFVS to land operation on the capacity was carried out. It is based on the analysis of weather data for 128 European aerodromes frequently used by Bizjets. 19 aerodromes were also analyzed in detail. An IFR procedure review was also done for France to precise the proportion of aerodrome that would be capable to accommodate the EFVS to land operation.

EFVS performance prediction validation study based on 12 fog scenario replayed in fog chamber was conducted. It was supplemented by a comparison with 2 flights in low visibility conditions.

6 approaches in RVR300m with F7X single HUD were performed in real operational environment.

Table 33: EXE_0202_200: Total number of flight and FFS runs trials

	EHGG	LFBE	LFBX	European aerodrome with low Vis conditions	Total
DAS (in Flight)	6	2	1	*10 by end of October 2016*	9 *(19)*
FLYING GROUP (FFS)	x	x	x		24
AIRBUS (in FFS)	x	x	x		24
DASSAULT OPS (in FFS)	x	x	x		19
TOTAL					*76 (86)*

In summary, significant number of FFS trials addressing limit cases, and flight in a real operational environment brought very good operational significance of the results of the EFVS to land operation demonstrations. For flights, 10 more approaches are expected to be performed in more aerodrome environment and in more real low vis conditions by end of October. This will enable to validate some specific points that cannot be checked in FFS. Some of approaches will be performed in dual HUD.

6.3.4 Conclusions and recommendations

See Section 8.3.

6.4 Demonstration Exercise EXE_0202_400 Report

Enhanced Flight Planning & Advanced Information benefits demonstration. This exercise was executed within WP 4.

6.4.1 Exercise Scope

Demonstration Exercise EXE_0202_400 Plan is detailed in Demonstration Plan [27] in Section 5.4.

Enhanced Flight Planning & Advanced Information is linked to the Operational Focus Area OFA AIM "Aeronautical Information Management" and related to IS-0201 "Integrated Pre-Flight Briefing" and lately to IS-0205 "Digital Integrated Briefing for pre-flight phase" within DS15. According to the integrated roadmap [36], the enabler AIMS-07 "Generation of pre-flight briefing information" within Pre-step1 (IS-0201 — Integrated Pre-Flight Briefing) has targeted the IOC on 31.12.2007 and FOC on 31.12.2011. The enabler AIMS-07a "Generation of Enhanced Pre-flight Briefing based on digital data" within Step1 (IS-0205 — Digital Integrated Briefing for pre-flight phase) targets the end of V3 on 31.12.2016 an IOC on 31.12.2022.

Regarding the technology maturity level, the EFP&AI technology was not developed within SESAR program and therefore SESAR documentation relevant to the maturity assessment is not available. However, based on the internal maturity assessments, the EFP&AI technology maturity level is V4/V5. The AAL project helps to speed up the industrialization and deployment phase for EFP&AI technology (i.e. V4&V5A levels) and therefore helps to enable an early use of benefits for users.

AUs without FOC would be enabled to act as a full equipped FOC by their crew members. The application covers all activities from flight planning, flight briefing, flight operations related messages, and instant access to actual AIS/MET data during flight.

The main KPAs included:

- Human Performance (relevant information in user-friendly format).

6.4.2 Conduct of Demonstration Exercise

This section details the preparatory activities (Section 6.4.2.1) and execution activities (Section 6.4.2.2) and description of deviations from the planned activities (Section 6.4.2.3).

6.4.2.1 Exercise Preparation

Preparatory activities were covered by the SWP 4.2 "Tools for EFP & AI". This SWP covered the preparation of the tools relevant to demonstrations and the training of the pilots for the EFP&AI software loaded to iPad to be used during demonstrations in SWP 4.3.

The following paragraphs details the achievements within these SWPs per task and per contribution of each partner separately.

SWP 4.2 Tools for EFP & AI

T 4.2.1 Tools Preparation

Honeywell [TL]

Enhanced Flight Briefing software tools were prepared for the demonstration. The hardware platform has been arranged; software has been installed on the platform and tested for required functions.

Human factors (HF) expert was trained for working with the application. The questionnaires for flight crew were prepared by HF expert. Flight operations personnel training assisting with the demonstration was finished too.

6.4.2.2 Exercise execution

Execution activities were covered by the SWP 4.3 "EFP&AI Trials". This SWP covered the demonstration activities and involved the airports in the Czech Republic (Ostrava and Brno/Karlovy Vary), i.e. demonstrations were part of WP2 trials. Demonstrations were also part of WP1 demonstrations performed in Zurich, Frankfurt and Bremen with business A/C. This SWP included 6 main Tasks – Demonstration Plan 1st Review – Input to the consolidated version, Demonstration Plan 2nd Review – Input to the consolidated version, Trial Preparation, Execution, Communication and Demonstration Report – Input to the consolidated version.

Table 34 summarizes the actual demonstration schedule of the exercise. The execution was part of trials performed within EXE_0202_100 and EXE_0202_200.

Table 34: EXE_0202_400 - Exercise execution/analysis dates

Exercise ID	Exercise Title	Actual Exercise execution start date	Actual Exercise execution end date	Actual Exercise analysis start date	Actual Exercise analysis end date
EXE-02.02-D-400	EFP&AI Benefits Demonstration	10 / 2015	5 / 2016	11 / 2015	8 / 2016

The following paragraphs details the achievements within this SWP per task.

T 4.3.1 Demonstration Plan 1st Review – Input

All inputs to the Demonstration Plan 1st Review were provided followed by the review of the partners.

T 4.3.2 Demonstration Plan 2nd Review – Input

All inputs to the Demonstration Plan 2nd Review were provided followed by the review of the partners.

T 1.3.4 Trial Preparation

The hardware platform (iPad) has been arranged; software has been installed on the platform and tested for required functions.

T 4.3.4 Execution

The exercise execution was connected with the RNP to GLS demonstration flights with business A/C (EXE_0202_100) and SVGS demonstration flights (EXE_0202_200). Demonstration flight campaign was started after the Project Gate (October 1st, 2015) and continued till September 2016 (for more information see Sections 6.1.2.2 and 6.2.2.2). WP4 demonstrations were part of the WP1 and WP2 demonstrations in form of pre-flight preparation. Special sessions (information update demonstrations) were organized as well.

T 4.3.6 Demonstration Report – Input

All inputs to the Demonstration Report were provided followed by the review of the partners.

T 4.3.7 Communication

The communication activities were performed in accordance with the communication plan – see Section 7.

6.4.2.3 Deviation from the planned activities

Initially it was planned, that WP4 demonstrations will be part of WP2 demonstrations only. In order to increase the variety of evaluation participants involved in the demonstrations and therefore increase the significance and representativeness of the results, several changes to the initial plan were made:

- WP4 demonstrations were also executed during some WP1 demonstrations (testing flights with business A/C) in order to involve more testing pilots.

- Special sessions were arranged (replacing scenario SCN_0202_402) in order to be able to involve also commercial pilots with different level of flying experience and of different age. Therefore the variety of participants involved was increased. Moreover, on these sessions the commercial mainline aircraft pilots as well as commercial business jets pilots were participating.
- Flight ops dispatcher was involved in the questionnaire special session too.

As mentioned above, scenario SCN_0202_402 (In-aircraft information update) was changed to scenario of Special sessions. Expected data were obtained.

6.4.3 Exercise Results

6.4.3.1 Summary of Exercise Results

The results were assessed against the success criteria and it was decided if the Demonstration objective status is OK, POK or NOK. Overall assessment for all criteria (involving all exercises) is presented in the Table 8 in Section 5.1.

6.4.3.2 Analysis of Exercise Results

In the following sections the exercise results are summarized according to the demonstration objectives evaluation. For detailed analysis see relevant Appendixes.

6.4.3.2.1 Feasibility demonstration: OBJ_0202_016 (EFP&AI)

Identifier	**OBJ_0202_016**
Objective	To demonstrate benefits of EFP&AI (e.g. relevant information successfully obtained in user-friendly format).
Success Criterion	EFP&AI is usable based on the feedback from Pilots.
Addressed KPA	**Human Performance**

Scenarios used for evaluation are detailed in table below.

Exercise ID	Scenario ID	Objective ID	Airport	A/C	Technology	Scenario Description
EXE 02 02_400	**SCN_0202 _401**	OBJ_0202_016	LKMT LKTB LKKV EDDF EDDW LSZH	F900	EFP&AI	Flight planning before departure.
	SCN_0202 _402	OBJ_0202_016	N/A	F900	EFP&AI	Special session - information update.

Paragraph below provides an overview of the results analysis regarding this objective. For detailed description of results and analysis see the Appendix E (Section E.1.1).

RESULTS ANALYSIS OVERVIEW

Seven pilots (six male and one female) participated in the demonstration. They were testing and commercial pilots of mainline as well as of business aircraft with different level of flying experience and of different age. Flight ops dispatcher was involved as well. This big variety of participants was involved in the demonstrations in realistic environment, what ensured good significance and quality of demonstrations results.

During evaluations, introduction to the EFP&AI was given by Flight Ops specialist and the basic functionality was demonstrated. Commented hands-on practice and tasks including typical pre-flight briefing duties were completed. All subjects tried to complete simple tasks under supervision of Flight Ops Specialist and then they went through the evaluation scenario independently. At the end of the session set of Post-exercise questionnaires were completed in order to get feedback on benefits. The

CTQ value was set to 'no major issues identified' assuming 5 point Likert Scale. Osgood's semantic differential methodology using the bipolar adjective pairs was used for the assessment as well.

The analysis of general usability showed, that the application reached the rating in the positive spectrum of the bipolar scale in all measured aspects (using 7-point distance Osgood's semantic differential methodology). Additional results on usability where evaluated using 5-point Likert-type scale. All but two items reached median value 4 (1=strongly disagree, 5=strongly agree). Usability of specific flight planning tasks was evaluated as well. Median scores ranged between 2 and 4 on the Likert-type scale (1=very unsatisfied, 5=very satisfied). Very positive feedback was given while participants were commenting the tasks execution. They especially liked route selection, departure/destination selection and Trip Kit. In general, the usability of the application was considered to be good. Lower ratings on intuitiveness and confidence in application use are likely related to the fact that five of seven participants were novice users. The application was originally developed for the US market and these demonstrations helped to identify the customization features for European users' needs.

Summarizing, during evaluation of the perceived level of feasibility of EFP&AI technology from pilots' perspective, no major issues identified and therefore the CTQ defined in the project was met. Moreover, positive feedback was obtained by participants during the tasks execution.

6.4.3.3 Results per KPA

For EXE_0202_400 relevant KPI/metric and CTQs for all KPA described above are summarized in the Table 35. Results in form of status OK/POK/NOK are also stated.

Table 35: KPA, KPI/metric and CTQs for EXE_0202_400

KPA	KPI	Metho dology	Metric	CTQ definition	CTQ value	Statu s
Human Performa nce	Perceived level of feasibility - pilots (EFP&AI)	Questi onnaire s	Questionnaire to be completed by pilots for EFP&AI (5 point Likert Scale).	Acceptable assessment of evaluated usability aspects.	No major issues identified	OK

6.4.3.4 Results impacting regulation and standardisation initiatives

There are no results impacting regulatory and standardisation activities for WP4.

6.4.3.5 Unexpected Behaviours/Results

There are no unexpected behaviours/results for WP4.

6.4.3.6 Quality of Demonstration Results

In order to ensure good quality and representativeness of the results, variety of evaluation participants involved in the demonstrations was considered. The group that went through the demonstration and questionnaires sessions involved testing and commercial pilots of mainline as well as of business aircraft with different level of flying experience and of different age. Flight ops dispatcher was involved as well. Therefore a good quality and representativeness of the results for the EFP&AI technology demonstrations was ensured.

6.4.3.7 Significance of Demonstration Results

Pilots' evaluation of the EFP & AI application was performed together with RNP to GLS and SVGS flight trials in real environment and operation. Moreover, special sessions were arranged. The group that went through the demonstration and questionnaires sessions involved testing and commercial pilots of mainline as well as of business aircraft, with different level of flying experience, and of different age. Flight ops dispatcher was involved as well. There were 7 questionnaires' respondents in total, what together with a big variety of people involved in the demonstrations ensured good significance of demonstrations results.

6.4.4 Conclusions and recommendations

See Section 8.4.

7 Summary of the Communication Activities

During the preparation phase, the main objective of the communication activities was to inform the aviation community about the project, and to focus on the project's key messages, which include the following:

1. **Provide Important Benefits**: Important benefits, including noise abatement, reduced emissions, lower fuel consumption, improved accessibility, and alleviated airport and airspace traffic, can be validated by developing and demonstrating the feasibility of several advanced augmented approach procedures at all types of airports, based on the five technologies (RNP, GBAS, SBAS, SVGS, and EFVS).
2. **Replace Current Limited Systems**: The project will pave 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, and which does not offer the flexibility to optimise the flight path for fuel efficiency and noise abatement.
3. **Contribute to ATM Modernisation by Speeding-up Deployment**: During the AAL project, the supporting technologies under development will be demonstrated and validated in conjunction with new airport procedures, which will rapidly generate solutions, speed up deployment, and contribute to the goal of Air Traffic Management (ATM) modernisation.

This has been accomplished by the release of the AAL kick-off Press Release on the 15th of December 2014, as well as the production of 500 AAL Leaflets which formed the agreed basis for any open communication. The kick-off Press Release received good coverage in the press, and the Leaflet was distributed by each of the AAL Partners and the SJU, as well as at events such as EBACE2015 and EBACE2016. Furthermore, the project submitted a paper at the AEGATS2016 conference. Appendix J to Final Demonstration Report B2 provides the kick-off Press Release, reports on the press coverage, the AEGATS paper and the AAL Leaflet.

During the execution phase, the project agreed to concentrate the press activities once the demonstrations are completed and the conclusions and recommendation agreed. This activity will start end November 2016 with the production of the Final Press Release. However, Fraport produced a Press Release in May 2016 announcing the beginning of the testing of new approach procedures at Frankfurt Airport. Appendix J to Final Demonstration Report B2 also provides the Press Release from Fraport, as well as the Final Press Release. The Final Press Release will be followed up by several events and interviews, some of which are already scheduled in the Communication Table below.

Additionally, on the basis of the Leaflet information as well as the results, conclusions and recommendations of the Demonstration Report, the project has developed a dedicated website that also contains links to communication tools, such as the published articles and the videos produced on the AAL project. See more at: www.aaldemo.eu.

Evidence of the communication activities can be found in Appendix J.

Note 1: the AAL Final Press Release is still under validation by Partners. The approved Final Press release will be available through the AAL website, Press page, once approved and disclosed.

Note 2: the Airbus RNP to xLS video is still under development. The SJU has been provided with an interim version, and was able to review it. The final Airbus video will be available through the AAL website, Demonstrations page, once finalised.

Note 3: the Dassault Aviation EFVS video is still under development. Appendix J to Final Demonstration Report B2 will include a description of the current progress of the video production. The final Dassault Aviation video will be available through the AAL website, Demonstrations page, once finalised.

Note 4: The AAL website (www.aaldemo.eu) is finalised with extracts from the Demonstration Report.

Table 36 describes the communication activities including a description of the communication activities, key dates, who is responsible for the execution of this activity and results of the activity.

Table 36: Communication activities timeline and results

Item	Activity	Distribution	Date	Notes / Results
#1.0	Information Leaflet V1 - General Project Info	Consortium members, SESAR JU, EBAA	12/2014	#1.0 was replaced by #4.0
#2.0	Press Release - PROJECT KICK OFF (Trials to Start: GBAS, SVGS, EFVS, EFP & AI)	Consortium members, Industry Associations, media, etc.	12/2014	Sent: December 2014 / Media Monitoring available
#2.1	Web presence (news, blogs, etc.) - kick off	Industry Associations: EBAA, CANSO, ACI, IATA, ERA, etc. / Consortium members	12/2014	EBAA, CANSO
#2.2	Web presence (news, blogs, etc.) - kick off	SESAR JU, EUROCONTROL	12/2014	Social media only
#2.3	Newsletter News Items - EBAA Members Newsletter / EBAA MEP Quarterly newsletter - kick off	EBAA	2/2015	2 x members newsletter 1x MEP newsletter
#2.4	Event - CorpJet Investor (CorporateJet Investor) - London - kick off	EBAA speech (incorporate msg into existing speech)	10.02.2015	Yes - [redacted]
#2.5	Event - World ATM Congress (CANSO) - Madrid	SESAR JU (coordinate with comms team)	10 - 12.03.2015	Yes, [redacted] in SESAR booth
#2.6	Event - EBAA AGM - Brussels	EBAA speech (incorporate msg into existing speech)	17.03.2015	Yes - Fabio Gamba
#2.7	Event - EBACE 2015 (EBAA) - Geneva	EBAA speech (incorporate msg into existing speech)	19 - 21.05.2015	Yes - [redacted] (OGS, Media Luncheon, leaflet on EBAA booth)
#2.8	16th International GBAS Working Group (IGWG)	Industry Associations	1-5.6.2015	Yes, info about project – [redacted]
#2.9	Event - Air Transport IT Summit (SITA) - Brussels		17-19.06.2015	No presence
#3.0	Event - Aerodays 2015 - Farnborough		20 - 23.10.2015	No presence
#4.0	Information Leaflet by NetJets - General Project Info. - Demonstration Plan 2nd Review	Consortium members, SESAR JU, EBAA	3/2015	Created, distributed
#4.1	Web presence (news, blogs, etc.) - Demonstration Plan 2nd Review Final	Consortium members, SESAR JU, EBAA	1/2016	EBAA Newsletter "On the Radar" of June 2016. EBAA Press Release on SESAR Show Case including AAL experience. Press release Fraport: Beginning of Frankfurt RNP to xLS trials.

Item	Activity	Distribution	Date	Notes / Results
#4.2	17th International GBAS Working Group (IGWG) - Oslo	Industry Associations	18-21.4.2016	Yes, two presentations – [redacted]-general project overview, and Hon initial results; [redacted] – DLH initial results
#4.3	Web presence – SJU extranet/news – End of Trials all WPs (EFP & AI, GBAS, SVGS, EFVS)	SJU extranet, Consortium members, EBAA	31.8.2016	Abandoned
#4.4	AEGATS 2016 - Paris	Aviation Community in General	12-14.4.2016	AAL presented by Dassault
#5.0	Press Release - Final Demo Report (all WPs)	Consortium members, SESAR JU, Industry Associaions, & all distribution channels	11/2016	Expected to be released on 28th of Nov 2016 (if SJU approval) -> together with 8.1 and 8.2
#5.1	Web presence (news, blogs, etc.) - Final Demo Report	Industry Associations: EBAA, CANSO, ACI, IATA, ERA, etc. / Consortium members	11/2016	Creation of an AAL webpage using AAL Leaflet with web interaction (results/link to articles/videos)
#5.2	Web presence (news, blogs, etc.) - Final Demo Report	SESAR JU, EUROCONTROL	11/2016	Creation of an AAL webpage using AAL Leaflet with web interaction (results/link to articles/videos)
#5.3	Newsletter News Items - EBAA Members Newsletter / EBAA MEP Quarterly newsletter - Final Demo Report	EBAA	11/2016	EBAA MEP June 2016 Quarterly Newsletter – SESAR Show Case and AAL
#6.0	Press Release - GBAS Demonstration Report (technical)	Consortium members, Industry Associations, media, etc.	after 14.10.2016	Post-Project activity
#6.1	Video (Airbus) – RNP to GLS	Airbus / Consortium members / EBAA	11/2016	Post-Project activity
#7.0	Press Conference (Dassault) - EFVS Final Demo Report	Dassault (specialised media: news & magazine articles)	11/2016	Post-Project activity
#7.1	Video (Dassault) - EFVS	Dassault / Consortium members / EBAA	11/2016	Post-Project activity
#8.0	Magazine Interviews x3 – TBC actual media (Air Transport World, Air Traffic Technology International, Business Airport International, ACI World - Airports Council Int'l)	EBAA, Consortium members	after 31.10.2016	Coordinated with #8.1
#8.1	EBAA Annual Safety Conference and Press Event in Vienna	EBAA Community	28-29.11.2016	Post-Project activity
#8.2	RAISG presentation in Prague	ANSP/Operator/Airport community	30.11-1.12.2016	Post-Project activity

Item	Activity	Distribution	Date	Notes / Results
#8.3	Noise Conference in Frankfurt	Aviation Community + Frankfurt	11/2016	Post-Project activity
#8.4	Avionics conference	Aviation Community	4/2017	Paper submitted by: Airbus (RNP to xLS) Honeywell (SVGS)
#8.5	IGWG – International GBAS Working Group	Aviation Community	5/2017	WP1 results, Post-Project activity

7.1 Cooperation within SESAR Programme

Tight cooperation with related work packages, OFAs and projects was kept. Details about coordination activities are summarized below:

- **WP16 (R&D Transversal areas):**
  - Support from [redacted] (Airbus) for Environmental assessment methodology.
  - OFA 2.1.1 (Optimised 2D/3D routes).
  - Discussions on the Solutions that AAL can support.
  - Complementarities with AAL WP1.
  - Complementarities with several projects (Project 9.10 & Project 6.8.8).
  - Extension of RNP to LPV solution (Project 5.6.3).
- **Project 6.8.8 (Enhanced arrival procedures to reduce occupancy time using GBAS):**
  - Complementarities with AAL WP1 (RNP to xLS).
  - Several Partners involved in both, P6.8.8 and AAL (Airbus, DFS, Fraport, Honeywell, Lufthansa, NetJets and Zurich Airport).
- **OFA 1.1.2 (Pilot Enhanced Vision):**
  - Solutions demonstrated through AAL WP2 and AAL WP3.
  - Complementarities with Project 9.29 (Honeywell lead).
- **WP11 (Flight and Wing Operations Centres):**
  - Complementarities with AAL WP4.

<u>AAL Demonstration Report review by other SESAR projects:</u>

Due to the complex consolidation of results and due to time constraints at the end of the project, it was not possible to execute an external review of the AAL Demonstration Report. However, participation of relevant AAL Partners in SESAR P6.8.8 ensured that all Parties were informed on the latest developments, and the inclusion of Eurocontrol in several AAL workshops helped to enhance the quality of the AAL Demonstration Report. Regarding SESAR Solution #9 "Automatic RNP to xLS transition", the project was able to forward its consolidation to OFA 2.1.1 prior the Release 5 SE#3 batch 2 review which addresses this solution.

8 Next Steps, Conclusions and Recommendations

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 large scale demonstrations, and the participation of all possible stakeholders, the AAL 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 ultimate goal of ATM modernization.

This project addressed the full 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 trial flights in such variety of operational conditions that the obtained results will be appealing, relevant, and applicable for the majority of the European airports.

The demonstrated technologies were GBAS (Ground Based Augmentation System), SBAS (Satellite Based Augmentation System), RNP with RF Leg, SVGS (Synthetic Vision Guidance System), and EFVS (Enhanced Flight Vision System). In addition, the AAL project targeted also airspace users without their own Flight Operation Centre providing EFP&AI (Enhanced Flight Planning & Advanced Information).

With over 360 successful demonstration flights the project has shown the feasibility of WP1 GBAS/SBAS Advanced Procedures (RNP to xLS with increased glideslope), WP2 – SVGS Advanced Procedures, WP3 EFVS Advanced Procedures as well as WP4 EFP&AI usability.

Sections 8.1, 8.2, 8.3 and 8.4 will detail next steps, conclusions and recommendations separately for each WP/technology.

8.1 EXE_0202_100 (WP1): GBAS/SBAS Advanced Procedures

The project has successfully demonstrated the feasibility of WP1 GBAS/SBAS Advanced Procedures.

The following sections provide conclusions, recommendations and lessons learned for several aspects of GBAS/SBAS Advanced Procedures investigated within WP1.

Within WP 1 GBAS/SBAS Advanced Procedures over 330 RNP to xLS demonstrations were conducted. The project included large hubs, such as Frankfurt and Zurich, as well as smaller airports such as Bremen. GBAS was used for RNP to GLS demonstrations at all the three airports, and in Frankfurt both RNP to GLS and ILS were used.

For Frankfurt and Bremen, DFS designed and published ICAO compliant RNP 1 initial and intermediate approaches including RF leg in the initial segment with transition to ILS or GBAS final with increased glideslope of 3.2 degrees and 3 degrees. In Zurich, the project was challenging the current conservative ICAO criteria for intermediate segment requiring a straight in segment before the Final Approach Point. Skyguide designed RNP 1 initial and intermediate approach segments including RF legs in both segments, with the RF leg in the intermediate segment connected directly to the GBAS final approach with increased glideslope of 3.2 degrees.

Large number of demonstration approaches was conducted with different aircraft types (A320 family, A380, B747-8, F900), on revenue flights with Lufthansa and Swiss and as experimental flights by Honeywell. These include 206 RNP to GLS and 40 RNP to ILS. Additionally, 22 RNP to LPV approaches were conducted by Honeywell experimental aircraft, testing the project designed procedures in a municipal US airport in nominal and large error conditions. All trials were analyzed in detail by the respective partners, and data collection as well as feedback from ATC and pilots' show the procedures as feasible with lessons learned and recommendations summarized below.

It is important to note that all the approaches were performed during nominal wind and temperature as well as operational conditions. A number of corner case trials were performed to test large vertical and lateral deviations with Honeywell experimental aircraft for all procedures. A few tests of the Frankfurt procedures at ISA +40 were performed with airline Full Flight Simulator for 747-400.

Fraport installed a number of noise measurement stations, and conducted a thorough noise analysis study, confirming noise decrease with increased glideslope at the noise measurement point and recommendations on RF leg placement due to noise.

The main project KPAs, with respect to environment noise impact (Frankfurt), fuel efficiency (length of approach path) and safety in terms of flight accuracy were successfully met.

The GBAS/SBAS procedure interoperability study, and the cost effectiveness of publishing a SBAS LPV approach overlay to a GBAS approach was evaluated using interviews with DFS procedure designers and in-house expertise from DLR/Skyguide/DFS and NetJets. Also, NetJets and DLR analyzed the benefits of RNP to LPV procedures for satellite business aviation airports near major hubs, taking the example of Egelsbach, and provided recommendations.

With respect to **WP1 GBAS/SBAS Advanced Procedures (RNP to xLS),** 5 KPAs were evaluated. Four of these KPAs – Safety, Environmental/Fuel efficiency, Human Performance and Accessibility were rated OK based on the achieved results. Fuel efficiency of specific arrival through complex TMA in satellite airport (RNP to LPV) was rated partially OK with respect to decreased fuel consumption compared to legacy operation. Please refer to the sections below for full explanation of the aspects and recommendations.

Safety:

- The **horizontal flight accuracy** (TSE and/or FTE) results for the RNP part were in general very accurate and well within the required CTQ of **1NM, in general usually well within 0.3NM**.
- For **vertical flight accuracy**, the flights were **within the requirements** – i.e. no descend below FAP constraint minus 100ft considering temperature compensations.
- Some of the Frankfurt mainline aircraft approaches seem to be going over the CTQ limit, but there is always an explanation provided (e.g. ATC vectoring) and corresponding lessons learned in Appendix B.

Environment/Fuel Efficiency:

- **The SESAR P6.8.8 confirmed that curved approaches can be designed to reduce the amount of population impacted by noise. However, the noise emission levels for curved approaches versus straight in continuous descent approaches** measured in the last RF leg prior the RNP to xLS transition resulted in higher sound emission at the aircraft (up to 2dB), due to differences in flap and power settings during turns and the transition.
- To maximize the benefits of these curved procedures by facilitating continuous descent operations below 7000 feet above the ground, a set of lessons learned and recommendations are proposed, such as procedure design recommendations, better management of procedure sequencing on FMS, , as well as new aircraft functions for automatic RNP to xLS transition.
- Concerning **noise exposure level** (at the monitoring terminal on the ground) the benefits of increased glideslope showed **0.75 dB decrease** in noise on the ground.
- Potential benefits were observed during simulations for **the fuel and CO2 emission** using the new RNP procedures with increased glideslope in both test cases (Zurich, Bremen). Savings are primarily given by the difference between the lengths of the legacy conventional/RNAV to ILS and the new curved RNP procedures which were designed to be shorter in the investigated airports. ***Results range between 14 – 57% of saved fuel and CO2***. *Note 1: Simulation results only, based on the difference between the legacy and the new procedure flight tracks, without the consideration of potential ATC vectoring activity. Note 2: Outside of the simulations, a basic analysis (non-scientific study) of the real data was performed for revenue aircraft in Frankfurt and indicated positive results in the sense that for some of the aircraft there is even lower fuel burnt on the new procedures. However, statistical significance of this basic evaluation is only very limited.*

Human Performance:

- The RNP to xLS procedures together with increased glideslope to 3.2 degrees were in general **perceived as feasible from both pilot and ATC perspective** which was shown with over 268 of successful demonstration flights. *Note 1: However, the integration of RNP to xLS* *procedure in a complex environment needs further work. Note 2: Procedures with an increased glide slope of 3.2-degrees were demonstrated on A320 family and F900 aircraft types.*

- Number of **lessons learned, recommendations on trainings for pilots, ATC and procedure designers** is summarized in Section 8.1.

Accessibility:

- The SBAS/GBAS interoperability study from a procedure design perspective shows that the **additional effort and cost** for implementing jointly GLS together with LPV approach types **is manageable and affordable**.

Fuel efficiency of specific arrival through complex TMA in satellite airport:

- The case study of Egelsbach close to Frankfurt Main shows that using the future concept of Visual RNAV would enable to propose an expeditious and realistic flight path from above Frankfurt Main down to Egelsbach final approach, which stays completely in airspace Charlie, and **shows a potential fuel efficiency benefit of -30%** (from the top of descent at FL300 to the landing into EDFE) when this visual operation can be performed.

The sections below describe detailed conclusions, lessons learned as well as recommendations with respect to the evaluated exercises. These include conclusions from airports' perspective, feasibility of RNP to xLS approaches from ATC and pilots' perspective, accuracy of these procedures, environmental impact with respect to noise, as well as simulated CO2 and fuel benefits. Quality of flight tracks assessment include aspects such as continuous descend operations, high temperature aspects, and procedure design recommendations. Conclusions and recommendations were prepared also for training of ATC and crew, charting as well as standardization. Also, recommendations are provided for cost effectiveness of LPV approach and the definition of advanced RNP to LPV procedure in Egelsbach.

The section ends with general next steps and next steps for the particular airports.

8.1.1 WP1 Conclusions from Airports' Perspective

Frankfurt Airport: The trials demonstrated that RNP to xLS procedures are feasible at major airports. The flight track accuracy observed for the published RNP procedures are better than expected and make RNP procedures a promising tool for arrival and departure procedures. These procedures might be an efficient measure to decrease noise at the vicinity of an airport. Noise to populated areas is decreased by placing the new RNP procedures with RF legs outside of them. In the future, the procedure design should be of lower complexity than in these trials. The usage of the procedures should start in low density traffic. It is important that ICAO adapts the regulations to allow RNP operations in independent parallel runway operations environment like Frankfurt. The benefits of increased glideslope were validated. Even the combination of curved RNP to xLS operations with increased glideslope created no operational problems.

Zurich Airport: Traffic Demand in Zurich is exceeding our capacity, and RNP to GBAS with radius to fix is an important mean to support our efforts to increase the capacity and airport efficiency. The trial flights were successful and showed that curved RNP to GBAS with radius to fix are very promising and have the potential to better adapt approach procedures to the geographic situation of Zurich airport.

8.1.2 WP1 Perceived Level of Feasibility from ATC Perspective

Three workshops with ATC controllers were organized in order to obtain feedback on the developed RNP procedures from an ATCo operational perspective. The first workshop was held in November 2015, just before the start of demonstrations on the Zurich RNP to GLS procedure. The second was held in February 2016, where Skyguide ATC shared their experience after three months of demonstration trials including testing and revenue flights in Zurich airport. Another workshop was organized in September 2016, where ATC from all three airports involved in the AAL project (Zurich, Frankfurt and Bremen) participated and provided their feedback on the RNP to xLS operation. Below, see the summary of the outcomes from the workshops.

Curved Approaches

- **<u>In General – the indications / conclusions are:</u>**
  - **Low/medium complexity environment (Bremen, Zurich in low traffic):** Reduction in ATC voice communication, workload equivalent, no issue in RNP transition to GLS.
    - **Bremen**: Easy procedure, easy to handle after initial experience, flight path as expected, basically no change in workload.
    - **Zurich**: Procedure deviation from ICAO criteria (RF leg directly connected to FAP) did not reveal any showstoppers during the trials.
  - **High complexity environment (Frankfurt):** Difficult to assess aircraft spacing on the RNP for the ATC, sequencing and merging become more complex than the straight in legacy approach with vectoring; both RNP to GLS and RNP to ILS worked well with respect to sensor change and transitions in nominal conditions without any showstoppers.

  The trials in Bremen and Zurich were all RNP to GLS finals, in Frankfurt RNP to GLS and ILS finals, and in the US RNP to LPV finals. We can assume similar results / conclusions could be extended to RNP to xLS procedures in general, however this was not explicitly tested within the project.

  We can also note a few advantages of RNP to LPV/GLS approaches, since from their nature they prevent the side-lobe issue (relevant for ILS). The increase in separation in CAT II/III operations as compared to CAT I is less for GNSS augmentations and MLS than for ILS, as not the ILS protection areas, but only the obstacle free zones need to be protected, if that system can be used below 200ft DH. Shorter final segments (2-3NM) also in low visibility conditions are foreseen in the future for GLS as shown in [50], thanks to shorter stabilization period after capture than on ILS.

- **<u>Recommendations:</u>**
  - **Keep the published procedures** (Frankfurt) and use them in low density traffic to keep getting more experience and training on both ATC and pilot's side.
  - **Encourage the deployment of RNP to xLS** at airports where these procedures are beneficial for capacity or noise reasons and start the operations in low density traffic where it could serve also for training purposes. This includes regional as well as larger airports.
  - **Trainings** -> during ATC briefings it became obvious that "RNP" is relatively new name. Difference of RNP/RNAV has to be explained. ATCO's in general are interested but not skilled in new procedures, too many new names/procedures during last years.
    - **Further guidance/training** should be established and provided to ATC to improve their experience (e.g. not to vector directly to RF legs).
    - ATC should have a better understanding of aircraft behaviour.
  - **Sequencing and merging: New tools should be investigated to support ATC on merging and sequencing** – time based separation tools, ghosting tools (e.g. FAGI tool developed by DFS), and new layout for ATC with distance to go marks on the procedure overlay, etc. The future development of the predicted aircraft 4D trajectory transmitted by airborne systems to the ground through the EPP report could provide valuable information to support such tools (to be validated by SESAR 2020 PJ31).
  - **Procedure design should take into account aircraft/FMS behaviour, especially when the procedures are combined with CDO.**
  - **Currently working in mixed traffic** – most flights are radar vectored. More benefits foreseen when more traffic would fly RNP (6.8.8 study [51]).

Increased Glideslope

- **<u>Conclusions:</u>**

- o Increased glideslope to 3.2 degrees did not pose any issues to the ATC and worked as usual.
- o However, from regulatory perspective, while in Frankfurt, with 3.1 degree PAPI, both 3 degree and 3.2-degree operations are allowed, German CAA will not allow for a 3.2-degree glideslope with a 3-degree PAPI in Bremen. (It was approved for AAL trials only). The stakeholders in the project agree this should not pose a safety issue (especially quoting ICAO Annex 14, chapter 5.3.5.36 (see below, in recommendations section), that unfortunately only applies to ILS and MLS at the moment), and no problems were noted during the flights, neither by ATC nor by pilots.

- **Recommendations:**
  - o Recommendation to ICAO to add GNSS (GLS and LPV) to the current regulation as follows:
    - "When the runway is equipped with an ILS and/or MLS and/or GLS and/or LPV, the siting and the angle of elevation of the light units shall be such that the visual approach slope conforms as closely as possible with the ILS and/or the minimum glide path of the MLS and/or **GLS** and/or **LPV, as appropriate**."
    - Note: In accordance with ICAO Annex 14 chapter 5.3.5.36 which currently notes: "When the runway is equipped with an ILS and/or MLS, the siting and the angle of elevation of the light units shall be such that the visual approach slope conforms as closely as possible with the glide path of the ILS and/or the minimum glide path of the MLS, as appropriate."

8.1.3 WP 1 Perceived Level of Feasibility from Pilot's Perspective

The perceived level of feasibility of the designed procedures was assessed using questionnaires, coordinated between the project partners. The questionnaires were completed by the pilots directly after each approach (DLH, Swiss, Honeywell) and with the presence of human factor scientists on board of the business aircraft.

Curved Approaches

- **Conclusions:**

  In general, the pilots perceived the procedures at all three airports as feasible. Nevertheless a few objections where stated for the Frankfurt procedures, mainly addressing the crossing of finals and the profile. During the trials pilots gave different feedbacks in respect to flyability. Main differences were seen between Long Haul (LH) and Short Haul (SH) crews, where the SH crews, with globally more on the job training level than LH crews, had less issues and also stated after flying more approaches and being more familiar with A/C & FMS behaviours the workload dropped to normal. The LH crews reported higher workload to cope with the complexity of the new procedures as well as with ATC communication. Probably due to more complex energy management, after long flight times and more conservative, and due to generally flying less approaches.

  The feedback between ATC and pilots is correlated, and is also correlated with the complexity of the considered airport. It needs to be taken into account that airports with high density traffic (e.g. Frankfurt) or in general high complexity airspace is always more difficult with respect to any procedure implementation in general compared to smaller/less complex airports. Reasons for this are mainly the higher traffic loads and demands; and the mixed traffic using old and new procedures with different tasks and a certain unfamiliarity on both sides (ATC/CREW) with the new procedures. The option for common Training with ATCOs and CREWS (e.g. JOINT Platform) could ease the understanding of the other parties behaviour and/or workflows. This understanding will also contribute to a higher acceptance and increasing capacity. Furthermore a procedure design which fits better in existing procedures with less waypoints and more direct connections could reduce complexity.

  The results of trials in both Zurich and Bremen, which were initially flown by pilots that have been involved in the project and/or personally briefed, showed almost no negative findings and crews reported to be very confident with the procedure and the A/C behaviour as well as the fly ability in general. The fact that ATC "made everything possible" to make the trials happen (e.g. no vectoring on the procedure) also contributes to the positive feedback given by Crews. It could be clearly shown by comparison of all trials at the three airports, that there were less ATC induced deviations from the published procedures, leading to a higher acceptance from crews as well as less deviations and a decrease in workload.

With regard to some approaches in Frankfurt, which were flown by pilots with a briefing handout only or even without briefing on a few occasions, the findings and feedbacks from Crews demonstrate the **importance of pilot training**. This in combination with a more complex environment and more traffic showed that the procedure must:

a) be designed and published so that it can be easily understood and,

b) pilots need to be able to familiarize with the procedure (especially long haul crews that generally fly less approaches).

The mainline trials were flown on revenue flights.

Business aviation trials were carried out in experimental mode with well-trained and briefed pilots. The pilots reported low workload scores during approach and landing phase. The subjective data collected during these demonstration flights confirm the feasibility of the RNP to GLS approach with RF legs combined with a 3.2 degree glideslope in Cooper-Harper ratings (results of 0- 1; scale 0 is good , poor is 10).

Zurich LSZH:

- The deviation from ICAO criteria in terms of procedure design (RF leg direct to FAP) caused no negative findings during the trial flights for the RNP to GLS procedures.
- The flight crew feedback was consistently positive; the new procedure in Zurich had no (negative) impact on flight safety and flight crew workload. Less voice communication with ATC (clearance given before entering RF leg and no further communication required).
- No major potentially blocking issues for the transition of RNP to GLS procedures into full implementation (wherever feasible) have been identified.

Bremen EDDW:

- The flight crew feedback was mainly positive; the new procedure in Bremen had no (negative) impact on flight safety and only little increase in flight crew workload. Less voice communication with ATC (clearance given before entering RF leg and no further communication required).
- No major potentially blocking issues for the transition of RNP to GLS procedures into full implementation (wherever feasible) have been identified. Nevertheless it must be stated that ATC made the trial flights possible without making the aircraft/crew deviate from the full published procedure. This is only possible in low density traffic and/or needs to adapt procedures accordingly.

Frankfurt EDDF:

- As stated above the complexity of the procedure must be kept to the absolute minimum and it should be aimed for as little deviation from the published procedure as possible.
- Crew feedback and the evaluation of flight tracks have shown that a standardized "handling" on ATC as well as on Crew side must be achieved and trained for. For example vectoring directly to or shortly before an RF Leg shall not be done. Another finding was the need of proper descent planning; altitudes given by ATC must match the average profile of the aircraft (→ SESAR ODP - Optimized Descend Profile Project "Aircraft Profile Study").
- From a human performance point of view, the feedbacks have clearly shown that the complexity did not only increase due to the procedures themselves but also because a lot of unexpected vectoring has been done to fit the trials in regular traffic. This leads to an increase in programming the FMS and preparation of the approach.

- The observations show that legacy procedures are used to initialize the arrival and then the procedure is mostly not flown as published till the end (e.g. short cuts are taken by vectoring). For RNP to xLS it is the opposite -> the airplane should enter the procedure as early as possible and stay on it (reduction of vectoring). This illustrates the change in mindset which is expected from ATCOs.

- **Recommendations:**
  - Having live procedures published to be able to train both pilots and ATC.
  - To maximize the noise benefits the airplanes should fly CDO and/or using automatic RNP to xLS transitions. Change of mindset (acceptance) of the pilots and ATC would come with more training and familiarization with these procedures.
  - Recommendations on trainings: Feedback and «lessons learned» from AAL flights will be fed into a LH Group wide pilots training concept («Navigation Study Guide») with main focus on PBN, combination of CBT (computer based training) and simulator training is seen to be needed.
  - **Training must emphasize the following aspects:**
    - **Handling of the different flight guidance modes** – e.g. not pressing the approach button too early on an Airbus aircraft.
    - **Handling of the auto flight system** – e.g. interception of waypoints, radial in/direct to.
    - **Handling of the FMS system** - e.g. manual input of waypoints of the procedure will lose the RF leg information in the procedure.
    - **Handling of the go-around procedures** – e.g. mode change during automated go-around.
    - **Handling of environmental aspects** – e.g. crew awareness of the system behaviour during high temperatures.
    - **Handling of Continuous Descend Operations** – e.g. how to do this manually/automatically.

    The behaviour differs per aircraft type/manufacturer and FMS manufacturer, specific aspects on how to handle each aircraft are not detailed here.
  - In order to ensure that the aircraft does not descend below the FAP altitude without proper xLS glideslope capture, the Altitude Selector shall be set at the FAP altitude.
  - These recommendations are to be added to EASA AMC guidance.

Increased Glideslope

- **Conclusions:**
  - **Zurich:**
    - Speed/Altitude management can be sometimes challenging for 3.2° increased glideslope (e.g. heavy A321 with tailwind). Especially if speed and altitude reduction is required by ATC at the same time during initial and intermediate approach.
    - Use of speed brakes sometimes needed also for business aviation flights, minor speed adjustments assigned to the aircraft characteristics and performance.
    - No specific workload was indicated in relation to increased GS during business ac trials.
  - **General:**
    - The flight data evaluation have shown that 3.2 degrees and GBAS worked well and there were no negative findings in respect to feasibility.

- **Recommendations:**

- DLH Crews are familiar with the Increased G/S concept as they are already available in Frankfurt and have not yet found to be unfeasible.
- Swiss and Hon crews also familiar with the concept and provided no specific recommendation.

8.1.4 WP1 Accuracy Assessment

For Accuracy Assessment, the horizontal and vertical flight path accuracy was evaluated for the procedures. Flight path in the lateral direction on the RF leg is precisely provided and therefore the total system error (TSE) can be computed thanks to the use of truthing system - dual frequency receiver for flights with business aircraft; and FTE (provided by DLH and Swiss from GPS position) will be compared to CTQ. It should be noted, that according Doc9613 [45], for the FTE the limit value is 0.5 NM and for TSE the limit value is 1NM (as the CTQ is set).

Curved Approaches

- **Conclusions:**
  - The results with respect to TSE and/or FTE were in general very accurate and well within the required CTQ of 1NM, in general usually well within 0.3NM.
  - Few cases where larger deviations can be observed happened due to various reasons: tight vectoring on or shortly before RF leg and problems of intercepting, realigning and stabilizing. Procedure wrongly entered into FMS (e.g. DIR TO between waypoints), therefore radius information lost and missing connection between STAR and the procedure. When the procedures were cleared and flown completely as published, track accuracy was very good.
- **Recommendations:**
  - The observations lead to similar recommendations as already provided before:
    - **ATC trainings** (e.g. no vectoring into RF leg, or shortly before)
    - **Crew trainings** (e.g. familiarization with FMS for RNP procedures)
    - **Procedure design recommendations**

Increased Glideslope

- **Conclusions:**
  - With respect to increased glideslope, the accuracy of the flight tracks was well within the CTQ limits, and no specific negative findings were observed.

8.1.5 WP1 Quality of Flight Tracks

A set of additional different aspects that were evaluated during the project, including lessons learned and recommendations for experience with different aircraft behaviour, case with airspace breach, continuous descend operations, procedure sequencing on FMS, procedure design recommendations as well as high temperature compensations.

Experience with Different Aircraft Behaviour

Experience with different aircraft behaviour as a lessons learned is explained below, with respect to its automatic and manual behaviour (e.g. level off, but CDO can be achieved by manual flight).

- **F900:** Continuous descend operation was achieved on all the tested approaches in Zurich, Frankfurt and Bremen without any issues. The RNP to GLS transition on RF-leg was demonstrated to be safe for both GLS glideslope capture, from below and from above.
- **Airbus:** General good and predictable behaviour, FMS conservative in descent planning, therefore intermediate level offs. With appropriate training CDO can be achieved in the selected mode. Track accuracy good and turns flown smoothly.
  - Zurich procedure was flown exclusively in managed mode by Swiss.

- **Boeing:** General good and predictable behaviour, descent planning very good (CDO). Track accuracy good and turns flown smoothly.

Case with Airspace Breach

- **Conclusions:**
  - Most of the flights were flown with a continuous descent (manually or managed). Some profiles show a "stepped" descent with the aircraft flying down to the next published altitude with a level segment before descending again. This lead to a suspension of the IBLUS arrival by ATC due to aircraft flying into airspace with only 200ft separation to possible VFR traffic or into airspace E (depending on procedure).
- **Recommendations:**
  - The problem could be mitigated by a procedure design that considers both, step descend and CDO, when assessing the existing airspace structure. Procedures should be kept as far as possible in airspaces C and D.

Continuous Descend Operations

- **Conclusions:**
  - CDO was demonstrated on approaches to EDDF, EDDW and LSZH and is a preferred solution for RNP to xLS approach by airspace users (DLH, Swiss, NetJets) and also for the benefit of noise reduction, and fuel efficiency.
- **Recommendations:**
  - Promote Continuous Descend Operations during trainings of both ATC and CREW and explain how to achieve this on different aircraft types (manually/automatically).
  - Ensure procedures are published (e.g. LIDO and Jepessen) to promote this type of operation (e.g. clearly stating "CDO preferred", and having "AT or ABOVE" constraint at the point before FAP or altitude gates).

Procedure Sequencing on FMS (procedure design aspect)

- **Conclusions & Recommendations:**
  - The project looked at the sequencing of procedures between the descent phase and the initial approach phase, considering that legacy STAR procedures are used by ATCOs in the descent phase for pre-sequencing in medium to high complexity environment, whereas when connecting to an RNP to xLS intermediate and final approach segments are used to gain noise benefits.
  - Potential solutions:
    - The descent ATCo is able to clear the aircraft on the RNP to xLS and manages the pre-sequencing with vectors.
    - The procedure design merges the legacy STAR and the RNP to xLS into one procedure, fulfilling the pre-sequencing needs of the descent controller at the beginning of the STAR, and transitions to the RNP to xLS for the medium to last parts of the STAR. This probably would require an open loop procedure design, or a clearance limit with instructions at the clearance limit point.
    - The FMS is able to manage two different STARs, one being active, the other one being on standby (e.g. with a function "activate RNP to xLS approach", similarly to the existing function "activate vectors").

Procedure Design Recommendations

- **Conclusions & Recommendations:**
  - Procedures were not designed to the theoretical optimum (lateral mainly) – which could differ based on airport/airspace users' needs and can be a combination of less noise, less fuel, less workload, etc.; to the best compromise for the particular airport. More work to be done on optimization of the procedures.

- Procedure design should take into account all the required stakeholders: ATC, operators, airframe manufacturers to provide safe and optimal procedures.
- In the case of multiple runways at an airport, avoid, as far as possible, procedures crossing the extended centreline of the other runways.
- Do not vector AC directly into RF leg or shortly before, as it will overshoot the trajectory (as expected); this can be overcome by good training of ATC.
- In order to get more predictability, a waypoint could be defined at the minimum stabilization distance before the entry into a RF-leg.
- Better definition of descend (CDO, gates) would help. Facilitate CDO with altitude gates giving more predictability of the vertical profile.
- Vertical gates must be established to set the altitude parameters for RF-leg-calculations (to enable procedure design).
- Better depiction on charts (e.g. Jepessen and LIDO) to promote CDO is needed – waypoint prior to FAP should be a clear "AT or ABOVE" (or a vertical gate) and additional marking promoting CDO on the chart is needed.
- Charts should not seem to include MANDATORY constraint at the last point before FAP, as this would force the airplane to descend early (e.g. level off), and would not allow for a continuous descend operation (e.g. FRA – GLS X25L).
- Facilitate vectoring "direct to" the RNP part of the procedure by adding pseudo waypoints at an appropriate distance before the RF legs.
- Independent parallel operation: Further work needed (e.g. within ICAO IFPP and other/follow up SESAR projects) to enable independent parallel operation using RNP to xLS (ILS and GLS/LPV) procedures, maybe only on one runway initially (with the other one operating straight-in approaches).

High Temperature Compensations

- **Conclusions:**
    - Without temperature compensations there are potential issues with the aircraft capturing the glidepath under certain temperature conditions (this is not specific only for these approaches).
    - During simulations done by DLH, the aircraft behaviour on Frankfurt procedures have been tested to ISA +40 on 747-400 full flight simulator. For the business aircraft F900 temperature range without compensations on the LSZH procedure was established between -2 and 36 deg C (field temperature).
    - During the trials, with the Honeywell test aircraft, a new FMS function was implemented and tested that improves RNP to xLS GS/LOC capture, thanks to real-time corrections of vertical errors induced by uncompensated non-standard atmospheric conditions (e.g. high/low temps), or FMS lateral nav errors induced by non-GPS position sensors. Lateral offsets of up to 0.5NM and baro (vertical) offsets of up to 400ft were tested and capture successfully demonstrated with the F900, as well as their combination. This is below denoted as "aircraft functionality" and is an example of a possible means to achieve capture even in stringent conditions.
- **Recommendations:**
    - Enable the design of RNP to xLS procedures with RF Leg connected to the FAP. ICAO IFPP would be the competent body to develop such criteria. The project has tested RNP to GLS with RNP directly connected to FAP in Zurich on 67 approaches. **The project is aware of the fact that more validation and criteria work would need to happen to ensure such design.**
        - It must be ensured that LOC/GS can be safely captured – this can be achieved by either high temperature limitation or aircraft functionality.

- Encourage the Airlines to equip their aircraft with relevant satellite navigation technology and operational capability – GLS, LPV and A-RNP and to get operational approval.

8.1.6 WP1 Noise

Noise was assessed in Frankfurt by Fraport for a total of 74 RNP to xLS approaches performed during the project for 4 different aircraft types. Thorough assessment taking into account atmospheric conditions and aircraft/microphone location was performed to estimate change in noise emission during an RF leg compared to a straight in segment, and also noise emission and noise exposure level change with increased glideslope of 3.2 degrees compared to a conventional 3 degree glideslope.

Note:

Emission: Sound pressure level emitted by a source, here aircraft, in 1m distance.

Immission: Sound exposure level at a receiver, here noise monitoring terminal. Referred to in the document as "exposure level".

Footprint: The ground area beneath a flying aircraft in which the noise exceeds a specified level.

Changes in noise emission levels RNP to xLS approaches versus straight in approaches at the source

- **Conclusions:**
  - Sound emission for RNP to xLS approaches differs from ILS straight in approaches.
  - Higher sound emission at the aircraft (up to 2dB), could be explained by differences in flap and power settings during turns and transitions.
  - Speed, aircraft configuration and power setting are the main drivers for sound emission of landing aircraft.
- **Recommendations:**
  - When modelling flight procedure it is recommended to avoid turns and transitions to the final close to populated areas.
  - For calculating a noise foot print of an RNP to xLS approach an adaption of sound emission data, especially along sections of turns and transitions, is necessary to receive reliable noise exposure levels.

Changes in noise levels for approaches with glideslope 3.2° versus glideslope 3.0°

- **Conclusions:**
  - The difference in sound emission for approach with glideslope 3.0° and for approach with glideslope 3.2° is neglectable at the source.
  - Concerning noise exposure level (at the monitoring terminal on the ground) the benefits of increased glideslope is with 0.75 dB equal to the attenuation caused by geometric spreading at the noise measurement station.
- **Recommendations:**
  - Calculating a noise foot print for approach with glideslope 3.2° the sound emission data for glideslope 3.0° can be used without adaption to receive reliable noise exposure levels.

Overall statement/ way forward – out of scope of the noise assessment.

- Noise to populated areas can be decreased by placing the new RNP procedures with RF legs outside of them.

8.1.7 WP 1 CO_2 & Fuel Simulation Conclusions

Evaluation of decreased fuel consumption for the new RNP to GLS approaches (transferable to RNP to xLS) compared to legacy published approaches implemented at Zurich and Bremen was performed using simulators during agreed conditions. Evaluation of the fuel and CO_2 CTQs was in all cases made using the difference between absolute values of the measured fuel consumption and CO_2 emission on the legacy procedure and the new RNP to GLS procedure.

- **Conclusions & Recommendations:**
    - Potential benefits were observed for the fuel and CO_2 emission using the new RNP to GLS procedures with increased glideslope in both test cases (Zurich, Bremen) during simulations.
    - Savings are primarily given by the difference between the lengths of the legacy conventional/RNAV to ILS and the new RNP to GLS procedures which were designed to be shorter in the investigated airports. Results range between 14 – 57% of saved fuel and CO_2.
    - Fuel savings results are influenced by aircraft energy management and aircraft vertical profile.
    - Shorter RNP to GLS procedures in Zurich and Bremen also suggests additional potential savings from fuel planning perspective. Lower fuel consumption using the new RNP to GLS procedures with RF leg on approach to destination airport or alternate could also enable planning lower fuel for the flight depending on the company fuel policy and approach procedure availability during approach time. Decrease in carried fuel leads to lower aircraft weight and consumption that might create additional fuel and CO_2 saving. The longer the flight the higher fuel and CO_2 savings.
    - *NOTE: Different procedure designs will lead to different results. For example, optimizing for noise may (but does not have to) lead to longer tracks in order to avoid highly populated areas. Also, simulations provide estimation of the savings for the test cases under the specified conditions; they do not assume winds and other conditions that may change the actual results.*
    - Actual fuel benefits in operation will be also dependent on how the controller will manage the aircrafts in low/medium/high complexity environments with the support of RNP to xLS procedures

8.1.8 WP1 Benefit Study – GBAS/SBAS Procedure Interoperability Study – Cost Effectiveness

The GBAS/SBAS procedure interoperability study, and the cost effectiveness of publishing a SBAS LPV approach overlay to a GBAS approach was evaluated during interviews with DFS procedure designers and in-house expertise from DLR/Skyguide/DFS.

- **Conclusions:**
    - This SBAS/GBAS interoperability study from a procedure design perspective shows that the additional effort and cost for implementing both approach types jointly (GLS together with LPV) is manageable and affordable.
    - Due to the same 3D path, lower workload and costs can be noted if GLS and LPV procedures are designed simultaneously, the cost of adding LPV approach being negligible. The underlying rational for facilitating the publication of both approach solutions is to help to obtain the critical mass of Airspace Users able to access those airports with those technologies, which is a necessary condition to benefit from the potential ILS infrastructure rationalisation.
- **Recommendations:**
    - In order to support at least Cat 1 operation in major airports for a maximum of Airspace Users (for instance in case of ILS maintenance and/or rationalization), aim for the full

implementation of GNSS based approach technologies including SBAS LPV and GBAS GLS. GBAS approaches will enable also CAT II and CAT III operations in short term future.

8.1.9 WP1 Benefit Study – Definition of Procedures into Selected BA Airport near Major Hub (Egelsbach) with Advanced RNP to LPV Assessment

- **<u>Conclusions:</u>**
    - The objective was to bring environmental benefits by guiding Business Aviation aircrafts above its neighbouring main airport traffic flow, while enabling to add a safety benefit by reducing the likelihood of hazardous encounters between IFR traffic and VFR traffic in uncontrolled airspace below the TMA floor.
    - Using the future concept of Visual RNAV would enable to propose an expeditious and realistic flight path from above Frankfurt Main down to Egelsbach final approach, which stays completely in airspace Charlie, and shows a potential fuel efficiency benefit of -30% (from the top of descent at FL300 to the landing into EDFE) when this visual operation can be performed.
- **<u>Recommendations:</u>**
    - Legacy operation: Sensibilize ATC on the need to remain in controlled airspace (e.g. by advising on a suggested V/S).
    - Access from above the main airport and Visual RNAV to the Business Aviation airport: Study the impact on ATC if the Business Aviation aircraft is guided 2000 to 3000 feet above the main airport general traffic flow, and demonstrate the feasibility of this operation in SESAR 2020.

8.1.10 Standardization

Based on the conclusions and recommendations, the project has identified number of aspects below to disseminate and recommend in international standardization bodies. The list can be found below. As this is a demonstration project, a recommendation means that stakeholders would like to see this happen, not necessarily that all the required validation effort was achieved.

- **ICAO IFPP:**
    - Recommend to develop proper criteria to connect RF leg directly to FAP for RNP to xLS e.g. as demonstrated with RNP to GLS on the Zurich procedure.
    - Recommend to extend existing standard for RNP to LPV final.
    - Provide accuracy results from the flown procedures.
- **ICAO SASP:**
    - Recommendation to work on and approve Independent parallel operations for GLS and LPV. It must be noted that the project did not test/demonstrate any independent parallel operations within its scope.
    - Recommendations to work on and approve RNP to xLS independent parallel operations.
- **ICAO Annex 14** (The Aerodrome Panel):
    - Recommendation with respect to PAPI to ICAO to add GNSS (GLS and LPV) to the current regulation as follows:
        - “When the runway is equipped with an ILS and/or MLS and/or GLS and/or LPV, the siting and the angle of elevation of the light units shall be such that the visual approach slope conforms as closely as possible with the ILS and/or the minimum glide path of the MLS and/or GLS and/or LPV, as appropriate.”

  - Note: In accordance with ICAO Annex 14 chapter 5.3.5.36 which currently notes: "When the runway is equipped with an ILS and/or MLS, the siting and the angle of elevation of the light units shall be such that the visual approach slope conforms as closely as possible with the glide path of the ILS and/or the minimum glide path of the MLS, as appropriate."

- **EASA AMC:**
  - The project outcomes would feed the training recommendations for PBN.
  - Recommendation to develop EASA AMC for the A-RNP specification to allow a more cost-efficient certification of this navigation specification.

8.1.11 Next Steps / View on Deployment

View on next steps is described below per airport environment for all the three airports participating to the demonstration activities – Frankfurt, Zurich and Bremen. Also general recommendations on a next steps not related to an airport is included.

- **In the Frankfurt environment:**
  - **All procedures shall be kept in AIP for training.**
  - **Assessment of RWY 07L/R – 40 approaches** approved by noise committee (via IBLUS)
  - **Procedures may be updated based on lessons learned**, and published again (18 month to publish them).
  - **Noise contours will be calculated**, then these can be officially maintained published pending future noise committee consultations.
  - **Mid-term (2018) – flights between 22:00 – 24:00** (which extends the current time window).
  - **Research of Independent Parallel Runways** -> this would also help to increase the acceptance of these procedures.
  - **Preparation for PCP mandate (2024)** – implementation ATM functionalities, one on PBN to have RNP 1 with RF legs, LNAV/VNAV and LPV.
- **In the Zurich environment:**
  - Investigating the possibility to publish a LPV 200 approach.
  - Approach ICAO IFPP with the result of the RNP to GLS with RF leg direct to final, recommending amending the current rules and regulations.
  - Preparation for PCP mandate (2024) – implementation ATM functionalities, one on PBN to have RNP 1 with RF legs, LNAV/VNAV and LPV.
- **In the Bremen environment:**
  - Provide recommendations to ICAO to update regulation to include GLS and LPV to the current PAPI requirements to enable 3.2 degrees with a 3 degree PAPI.
  - Operator (DLH) would appreciate to keep the procedures for training purposes (training school in Bremen).
- **General:**
  - The knowledge gathered within the project should be provided further to stakeholders. These include ICAO, EASA, as well as other forums indicated within the project's communication activities.
  - Continuation in an open call towards GBAS CAT II operations on GBAS CAT I.

8.2 EXE_0202_200 (WP2): SVGS Advanced Procedures

The project has successfully demonstrated the feasibility of WP2 SVGS Advanced Procedures in the European environment.

This section details the outcomes of the demonstrations of SVGS Advanced Procedures (WP2). Section 8.2.1 focuses on conclusions, Section 8.2.2 on the next steps and Section 8.2.3 then provides the conclusions and Section 8.2.4 view on SVGS deployment.

8.2.1 Conclusions

Demonstrations of SVGS advanced procedures within WP2 were successful. They are expected to further speed up deployment of these procedures within Europe as well as outside. Using data collected during demonstration campaign, good accuracy as well as feasibility of SVGS advanced procedures from pilots' perspective were confirmed. Real trials were supported by several studies, showing benefits regarding environment, cost or airport eligibility aspects. All CTQs determined in the Demonstration Plan were successfully met. Thanks to the synergy and good cooperation of stakeholders in WP2, this part of demonstrations provided a holistic view on SVGS deployment aspects.

With respect to **WP2 SVGS Advanced Procedures,** 5 KPAs were evaluated. All of these KPAs – Safety, Environmental/Fuel efficiency, Human Performance, Airport Capacity and Cost-effectiveness were rated OK based on the achieved results. Please refer to section below for full explanation of the aspects and recommendations.

Safety:

- The **horizontal flight accuracy** (TSE) results were well within the CTQ value of ±1 dot. The deviation for the lateral direction was **always within ±0.4 dot**.
- For **vertical flight accuracy**, the flights were **within the requirements of** ±1 dot for the vertical direction within **usually within ±0.4 dot and maximum within ±0.7 dot**. Larger deviations were usually caused by various environmental conditions (wind, etc.) and were usually manually flown.
- With respect to the **landing performance**, all landings were well within defined CTQ value, i.e. **inside the touchdown zone of particular runway (the first third of the runway).**

Environment/Fuel Efficiency:

- **Reduction of number of diversions and delay**: Results based on analysis and simulations using data from five airports with predominant regional and business traffic, showed that the combination of SVGS and EFVS helps to **increase the number of on-time arrivals in LVC (4.84% of time) compared to ILS by at least 33%, and saves 127 kg of the fuel and 401 kg of CO_2 emission per flight in LVC.**

Airport Capacity:

- Within the airport Eligibility Assessment, it was concluded that the number of airports in the Czech Republic and Slovakia with **instrument 3D approaches** that are **eligible to SVGS operation is 100%**.

Human Performance:

- The demonstration **confirmed the feasibility of the SVGS approach** as evidenced by the modified Cooper-Harper ratings from pilot perspective. The CTQ value, which was set to 95% of approaches are feasible based on feedback form pilots, was met.

Cost-effectiveness

- Crew qualification cost can be reduced by the SVGS utilization since CAT II training is not foreseen when using SVGS (it is envisioned that some initial SVGS training would be required). Assuming 10 years of SVGS usage, total cost for CAT II training is $25,000 and for

SVGS $12,000. **This represents 52% cost savings ($13,000)** which is well above the CTQ (20%).

Procedures Design and Safety Assessment

Procedure design for SVGS demonstrations had not to be changed as all required procedures were published and no special charts were necessary for experimental flights, as a guidance from ANS CR. Proposal of charting was implemented into documentation of the project (but not published in the Czech AIP) as not seen necessary. Safety assessment was finished early-September 2015 and test flights were approved by the Czech CAA, also for approaches in low visibility conditions. No hazards were seen from ATC perspective. Overall it may be concluded that demonstrations were successful and showed benefits of SVGS technology and also feasibility from operational perspective in a real environment.

Summary of Demonstration Flights

In total 74 approaches were flown with Honeywell experimental F900EX, 23 in Ostrava (LKMT), 40 in Brno (LKTB) and 11 in Karlovy Vary (LKKV), all successful. In Ostrava only ILS approaches were flown, in Brno and Karlovy Vary both, ILS and LPV procedures were demonstrated. In total 45 ILS 200’-50’DH and 29 LPV 250’-50’VTH approaches were performed. Some approaches were flown with autopilot coupled and some were flown manually.

Performance

Observed accuracy performance (horizontal and vertical TSE) was well within the CTQ value of ±1 dot. The deviation for the lateral direction was always within ±0.4 dot; and for the vertical direction within usually within ±0.4 dot and maximum within ±0.7 dot. Larger deviations were usually caused by various environmental conditions (wind, etc.) and were usually manually flown. Comparison of horizontal and vertical TSE performance of SVGS approaches with ILS and LPV separately confirmed the assumption that that GNSS based performance is better than ILS based (nevertheless, for both cases the performance was within the CTQ limit). Another example of benefits of GNSS based navigation compared to conventional ILS was observed in Ostrava, where the ILS signal seems to be deformed by a hilly terrain which is located before runway (i.e. aircraft flies through a "valley"). This data confirms that GNSS based systems are not susceptible to the terrain distortion and navigation is smoother. Evaluating the landing performance, all landings were well within defined CTQ value, i.e. inside the touchdown zone of particular runway (the first third of the runway).

Feasibility from Pilots’ Perspective

The perceived level of feasibility was evaluated for SVGS procedures performed with ILS (200’) and LPV (250’). At the end of each approach, where subjective human performance analysis was conducted, the pilot completed a NASA Task Load Index (TLX) workload rating scale and a Modified Cooper-Harper (MCH) scale for the adequacy of the SVGS display to support intended functions (assigned to an execution of the SVGS approach DH-50ft on ILS 200’ or VTH-50ft on LPV 250’) during demonstration flights. The results indicated an acceptable level of workload in all measured aspects experienced by pilots within ILS and within LVP approaches. No specific issues were identified by participants regarding the workload relative to the SVGS approach. The acceptable level of display support for the ILS and LVP approaches was indicated by results in the conditions tested. The MCH rating corresponded to the scale response of “Very minor issues not hindering performance”. Results were balanced and the workload level can be considered to be acceptable also from the perspective of meeting the system’s intended functions. Summarizing, the pilots flying the SVGS approach reported low workload scores during the approach and landing phase. The subjective data collected during the demonstration confirmed the feasibility of the SVGS approach as evidenced by the modified Cooper-Harper ratings. The CTQ value, which was set to 95% of approaches are feasible based on feedback form pilots, was met.

Feasibility from ATCOs’ Perspective

Concerning the SVGS demonstration flight trials there are no particular comments from ATCOs’ perspective. Except the case of intentional missed approach or runway fly over during the final approach procedure, there were no deviations noticed by ATCOs compared with the standard operation. Therefore, no more workload was identified for ATCOs.

Benefit Studies

In order to support the demonstrations by evaluating the SVGS benefits three benefits studies/assessments were performed, namely studies evaluating the impact on the percentage of successful landing on destination airports in LVC when using SVGS (including also environmental aspects evaluation), airport eligibility assessment and cost assessment evaluating crew training costs savings when using SVGS advanced procedures.

Environmental Benefits Assessment

Based on the SESAR 9.29 CBA [19], this analysis considered three potential impacts of Low Visibility Conditions (LVC) for a flight - flight delay, flight diversion and cancellation of a flight. Uniform estimation has been used for the probability of LVC across all benefit models. This probability has been estimated at 4.84% of the time on the basis of 2010 meteorological data from five airports with predominant regional and business traffic aviation and broadly covering Europe, especially in the areas with a higher probability of low visibility conditions. The chosen model compared the performance of the ILS CAT I approach (baseline scenario) for the dedicated airport and runway with EFVS and combination SVGS+EFVS performance level (solution scenarios). For evaluation 2 baselines scenarios were considered – scenario EU ILS and USA ILS, when the main difference was in the approach lightening systems (ALSF1 for EU, MALSR for USA). The consumption and pollutant emissions have been also evaluated and calculated with the use of Piano X tool that uses the ICAO standard engine library.

Results showed that for both ILS baseline scenarios the combination of SVGS and EFVS helps to increase the number of on-time arrivals in LVC compared to ILS (by 33% for EU ILS scenario and by 35% for EU ILS scenario). As expected, improvements are bigger for USA ILS scenario due to higher RVR value. Also significant improvement was observed when using the combination of SVGS+EFVS compared to EFVS only usage.

Regarding the environmental impact of SVGS+EFVS implementation, there was a saving of 127 kg of the fuel and 401 kg of CO_2 emission per flight in LVC for EU ILS scenario (and saving of 136 kg of the fuel and 428 kg of CO_2 emission per flight in LVC for USA ILS scenario). Again, savings for combination of SVGS+EFVS showed to be bigger than for EFVS only usage.

*Airport Eligibility Assessmen*t

In the airport eligibility assessment, 6 IFR airports were identified with instrument 3D approaches in the Czech Republic and 5 IFR airports with instrument 3D approaches in Slovakia. For these airports the instrument 3D approach procedures (involving ILS, LPV or LNAV/VNAV) are published. SVGS may be used in conjunction with all these procedures and therefore positively impact the airport throughput in LVC by lowering the published minima by 50ft. It can be concluded that the number of airports in the Czech Republic and Slovakia with instrument 3D approaches that are eligible to SVGS operation is 100% (CTQ was determined as 80%).

Crew Qualification Cost Assessment

In the cost assessment, it was pointed out that the increase of the crew qualification costs is significant for CAT II operations due to higher demand on skilled crew (compared to CAT I). Crew qualification training comprises the initial training and the recurrent trainings. Crew qualification cost can be reduced by the SVGS utilization since CAT II training is not foreseen when using SVGS (it is envisioned that some initial SVGS training would be required). Expert evaluation was used for the crew qualification cost savings assessments. It is assumed that an initial and recurrent CAT II trainings would be contracted. In some cases the prices may be lower due to contractual conditions (e.g. discounts) and therefore the actual savings may be lower than indicated in this assessment. However, reduced prices are not taken into consideration in the assessment as they are contract dependent and therefore hardly estimable. Assuming 10 years of SVGS usage, total cost for CAT II training is $25,000 and for SVGS $12,000. This represents 52% cost savings ($13,000) which is well above the CTQ (20%).

Work with Regulatory Bodies during Project

During the project, Honeywell has worked with the Czech Aviation Authority (CAA) and ANS CR to receive approvals for the SVGS trials, as well as to receive a special waiver to fly in low visibility conditions. The waiver was granted based on Safety assessment provided to the regulator. ANS CR assessed the safety for airport operations and supplied overall documentation for approval to the CAA and supported the trials.

Work was also conducted with the FAA, mainly with respect to discussions on SVGS on LPV, assumptions on the constellation fault modes, as well as other requirements that would be applicable. The work is still ongoing.

8.2.2 Next Steps

Demonstration flights results together with real operational experience with SVGS may provide a valuable contribution to the future support of a preparation of a formal application for a European certification of this system. WP2 activity may also contribute to the future work of RTCA SC213 / EUROCAE WG79. However, at the moment, there is no ongoing SVGS activity of RTCA SC213 / EUROCAE WG79 (knowing that DO-359 defining the MASPS for SVGS 150' was published in 2015).

Further work is envisaged within S2020 and Open Calls:

Such work would include cooperation with EASA RMT 379 – to help define training requirements on crew, ground infrastructure (especially lighting, etc.), operational rules and airworthiness criteria for SVGS approval in Europe. As Honeywell is not part of this Rulemaking Task, cooperation is informal at the moment with the plan to find a more formal way in future projects.

Extending to work with additional ANSPs to cover larger scope of airports and runway configurations, as well as working on LPV200 to lower to LPV 150ft thanks to SVGS is foreseen. This will also help assess the possibility to lower DA(H) on approaches for which DA(H) is higher than 250ft.

More EGNOS data need to be collected, review of performance of this SBAS system and its comparison to WAAS is essential.

Next steps should also ensure one consistent set of rules which is applicable for SVGS operations in the US and Europe, considering the characteristics of the two SBAS systems. As a second step, SVGS operations would be extended to other SBAS environments across the world.

8.2.3 Recommendations

Further activities, such as close work with regulatory bodies with respect to the certification framework (EASA, FAA), and subsequent demonstration activities are recommended in order to support successful industrialization and deployment of SVGS advanced procedures.

Carry out of next steps within S2020 and Open Calls.

8.2.4 View on Deployment

At the moment, the situation in European environment is the following:

EASA RMT 0379 (All Weather Operations) addressing SVGS and EFVS, the AWO project is an EASA-led working group opened to industry, supported by a panel of nominated experts.
The AWO project will publish an NPA – Notice of Proposed Amendment in October 2017, which will include the compilation of new/amended documents that need to be vetted by the European Commission. These documents will include IR (Implementing Rules) and AMC (Acceptable means of compliance) defining operational and airworthiness approval criteria. As a minimum, it is expected that these will cover SVGS ILS approaches. Publication of the IRs by the European Commission is expected in 2018/2019.

In the US:

FAA AC 20-185 (Airworthiness Approval of Synthetic Vision Guidance System) was published, and is restricted to SA CAT I ILS approaches, ops approval is still needed from Flight Standards Service. The FAA Flight Standards are working toward specific training requirements, relaxed vs. CAT II.

Bilateral Honeywell cooperation with FAA on the SVGS with LPV is ongoing, but there is no external/public activity to extend the current AC to LPV approaches.

View of ANS CR: ANS CR welcomes SVGS as another technology increasing safety of flight. Together with ILS or especially LPV procedures, it can really increase accessibility of some airports with almost no investments on airport or ATC side.

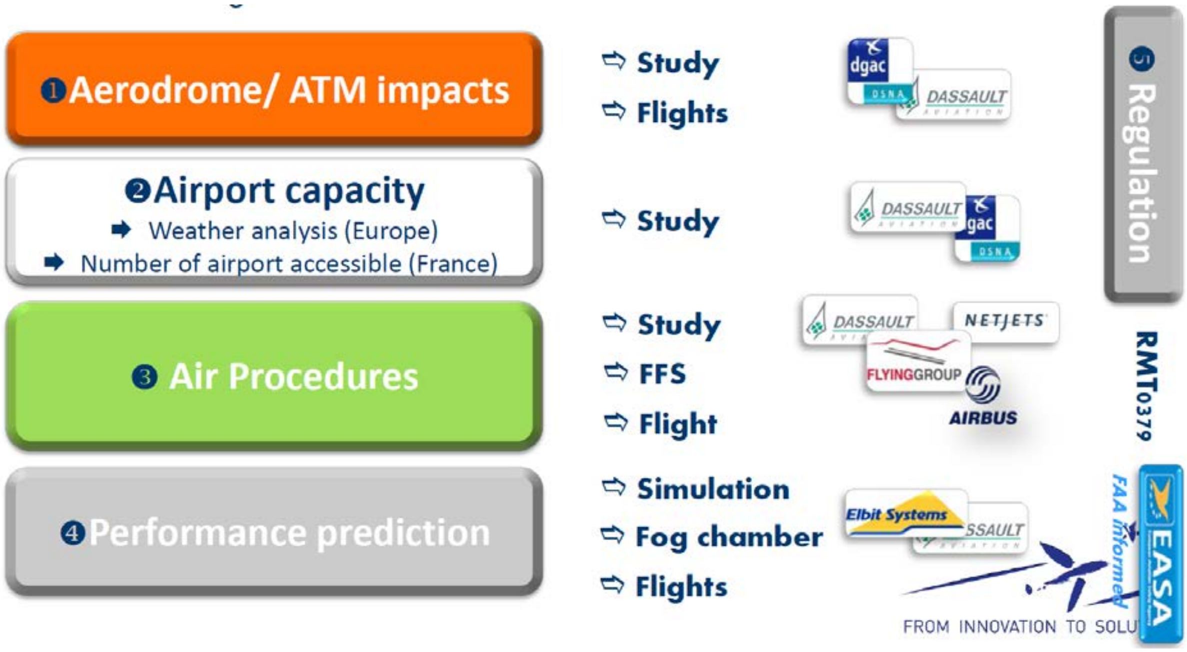
8.3 EXE_0202_300 (WP3): EFVS Advanced Procedures

Demonstrations of EFVS to land concept conducted by WP3 over the four key areas (aerodrome/ ATM impacts, increase of capacity, air procedure adequacy and performance prediction) demonstrated the overall benefit of the EFVS to land concept proposed by DASSAULT with Dual HUD, synthetic Runway and CVS compared to existing EFVS 100ft concept.

Such work is expected to further speed up deployment of this concept of operation within Europe as well as outside, for both air and ground/ATM parts.

Using data collected during demonstration activities, good accuracy as well as feasibility of EFVS to land conOPS from pilots' perspective was confirmed, even in abnormal conditions. Real trials, some of which were performed in the limit conditions, were supported by several studies illustrating the benefits and the growth potential of the EFVS to land operation, as well as aerodrome eligibility aspects. All CTQs determined in the Demonstration Plan were successfully met. Thanks to the synergy and good cooperation of stakeholders in WP3, this part of demonstrations provided a holistic view on EFVS deployment aspects. Thanks to its participation to RMT0379, EASA was kept informed of most of SESAR activities such as conOPS, aerodrome/ATM aspects or test cases to be considered for trials.

Nonetheless, SESAR AAL has clearly illustrated the some activities remain to be achieved for deployment. These activities have been identified and are proposed to be continued through the unique SESAR organization.



The following sections details the outcomes of the demonstrations of EFVS Advanced Procedures (WP3) per relevant areas.

With respect to **WP3 EFVS Advanced Procedures,** 4 KPAs were evaluated. All of these KPAs – Safety, Environmental/Fuel efficiency, Human Performance and Airport Capacity were rated OK based on the achieved results. Please refer to the sections below for full explanation of the aspects and recommendations.

<u>Safety:</u>

- **Crew workload reduction.** Results indicated the procedure is feasible even with abnormal cases and in manual. The global workload is within CTQs limits which corresponds to 70% on a Lickert adapted scale used for the tests. To alleviate workload that may remain high in manual, autopilot and autothrottle use are recommended for this low visibility operation.
- The **horizontal flight accuracy** (TSE) was well within the CTQ value of ±1 dot.
- For **vertical flight accuracy** (TSE) was well within the CTQ value of ±1 dot.

- With respect to the **successful touchdown**, all landing were safe and terminated in touchdown zone.

Environment/Fuel Efficiency:

- **Reduction of number of diversions and go around**. Considering a 2016 EFVS state of art sensor and the 2014 weather statistics in Europe, an EFVS to land concept down to RVR 300m would have permit to save 60% of the RVR < 800m or ceiling < 200ft situations that would have resulted in GO AROUND or diversion otherwise. From a concept standpoint, a full weather conditions system capable would have permit to erase 85% of the RVR<800m situations, demonstrating the big potential for such a concept in the future. In addition, SESAR AAL demonstrated that the prediction of performance is achievable for homogeneous fog with a quite good confidence level of 30%, contributing to limit the number of GO AROUND or diversion.

Airport Accessibility:

- Regarding the capacity of secondary aerodrome to accommodate EFVS to land operations in RVR lower than 550m, SESAR study conducted jointly with DSNA have proposed adequate aerodrome/ ATM recommendations that have been well received by EASA. From a deployment perspective, SESAR has demonstrated that these recommendations could be envisaged without any installation modification or significant procedure changes at the three regional/ secondary airports (Bergerac/LFBE, Bordeaux/LFBD and Périgueux/LFBX), as well as at Antwerp/EBAW airport.
- Within the airport Eligibility Assessment, it was shown that 89% of the French airports dedicated to civil aviation and having at least one IFR approach procedure are eligible EFVS to land, and this number will significantly growth in the coming years with the deployment of the PBN. More than 1/3 of the airports eligible EFVS to land are managed by AFIS.
- For the small/medium airport visibility capacity enhancement, the latest generation of IR-visual based EFVS using several sensors and advanced fusion algorithm provides optimized signal to noise ratio and enhanced performance. As an example, enhanced RVR provided by such an advanced system is at least 420m for RVR of 300m in homogeneous FOG conditions. Performance increase is expected in the coming years as new market-ready technologies will come on line.

Human Performance:

- Perceived level of feasibility of EFVS to land from pilots' perspective was successfully evaluated with RVR300m. All the abnormal cases were timely detected by the crew and resulting in an appropriate decision to go-around. No negative impact on safety and human factors was observed. Clear briefing of the operation and Training with potential deficiencies of the system is recommended. SESAR AAL exercises confirmed that the Dual HUD and CVS solutions proposed by DASSAULT were considered as valuable features for this operation by demonstrating an effective crew decision making and a far better Situation awareness than with EVS only.

8.3.1 Aerodrome/ ATM Conclusions

SESAR AAL demonstrated that EFVS to land operation should be possible:

- at CATII/III airports with no change,
- at all other controlled IFR airport or uncontrolled IFR airport with AFIS, that are compliant with the recommendation proposed jointly with DSNA in the six key domains of installation, low visibility procedure, procedure design, publication changes, phraseology and flight plan

It was demonstrated that the recommendations proposed by DSNA/ DASSAULT, reviewed by local authorities and consolidated by a demo flight could be envisaged without any installation modification or significant procedure changes at BERGERAC and PERIGUEUX secondary airports.

Recommendations were shared with EASA and used as a major input to support the ongoing rulemaking task RMT0379 dedicated to All Weather Operation, in defining the aerodrome-ATM criteria necessary for EFVS with Ops credit operations (AMC/GM of ADR part). On US side, recommendations were disseminated to both FAA certification and rulemaking offices. From an operator standpoint, recommendations were presented to FLYING GROUP and NETJET - who have considered they are acceptable and in line with current practices.

Beyond this conclusion, and to ensure that EFVS operation with operational credit can be operated the same way all over European countries, recommendations will be discussed with ANTWERP (Belgium) airport by the end of October.

Next steps:

Dassault will continue to promote the SESAR AAL aerodrome/ ATM recommendations in the EASA RMT0379, with FAA in the loop.

Before large consideration, and as an extension of SESAR AAL, DASSAULT recommends to achieve the homologation/ approval of some controlled and AFIS aerodromes in cooperation with a CAA project leader. The work done should be then shared with more European secondary aerodromes, including for example some with remote tower. As it was done in AAL, flights “check” should be achieved in real environment and low visibility conditions for validation.

DASSAULT is proposing such activity in the frame of SESAR2020

8.3.2 Air Procedure

As of today, the 6 flight Demo performed by DASSAULT pilots in real low visibility as low as RVR300m and in real operational environment on F7X have demonstrated that EFVS to land operation is safe and feasible without any excessive difficulty. This evaluation in flight is still in progress and will continue till the end of October to cover more conditions and involve more crews.

On the other side, 60 FFS runs achieved by FLYING GROUP, AIRBUS and DASSAULT Ops Pilot on F8X in abnormal conditions and for a wide range of environmental conditions that would be either not feasible in flight or extremely difficult to get together at the same time, demonstrated that the concept remain safe and feasible even in the most severe situations.

Beyond this general statement:

The three go around gate and the basic principle consisting in flying the A/C by following guidance and using the EFVS image to verify the trajectory is validated.

An efficient collaboration between PM and PF was considered as essential for this operation. The concept based on the use of the dual HUD and CVS was found very intuitive and comfortable, providing good crew collaboration and a much better situation awareness than with EVS only, leading to an efficient decision making.

NETJET, as a reviewer of the procedure having an experience in EFVS operations, stressed that it is essential that the crew task sharing and call out used for this operation are in line with other day to day operations.

Regarding limit conditions, the abnormal cases were timely detected by the crew and resulted in an appropriate decision to go-around. None of the crew was tempted to maneuver the aircraft with the help of the image instead of following the guidance. The measured accuracy performance was still well within the limits and all landing were safe and terminated in touchdown zone. Flare cue was mentioned as a potential valuable feature and would be appreciated in some situations.

Only the workload was found high in manual and the use of autopilot and autothrottle should be encouraged for this operation.

As part of the concept, a clear briefing and training guideline related to potential deficiencies or overreliance to the system are proposed.

To date, although no negative impact on safety was observed, more flight in real operational environment with more adverse weather situations and involving more air users will be performed by end of October.

Next steps:

DASSAULT will continue to promote the SESAR AAL results in the EASA RMT0379, with FAA in the loop.

Before large consideration, and as an extension of SESAR AAL, DASSAULT recommends to achieve more flights in full configuration at more airports, in more adverse weather conditions and with more air users.

Moreover, in the perspective of the deployment of EFVS to land operation, it is proposed to define the OPS approval materials to support, ease and speed up the OPS approval of air users all over Europe.

DASSAULT is proposing such activity in the frame of SESAR2020

8.3.3 Airport Capacity Conclusions

An extensive weather analysis determining the amount of time the ceiling or the RVR are below published minima for 128 European aerodrome usually frequented by Falcon aircrafts has revealed a good potential for EFVS with OPS credit concept of operation, even for state of art sensor that are in service in 2016.

From an EFVS to land concept with RVR down to 300m standpoint, and without any sensor performance consideration, 85% of situations with RVR lower than 800m would have led to successful landing.

If a more conservative approach is considered to better reflect the state of art of EFVS sensors that are or will be still in service in the coming years, EFVS to land would have permitted to land:

- In 60% of the situations for which RVR < 800m or ceiling < 200ft.
- In 41% of the situations for which RVR < 550m or ceiling < 200ft.

This study shows that EFVS to land concept provides significant Ops credit compared to the EFVS 100ft concept. Considering for example an RVR800m minima, this study revealed that EFVS to land concept would permit to operate in twice more limit situations than for an EFVS 100ft concept.

Beyond this macroscopic view, a detailed analysis carried out for 19 of European aerodromes revealed that there are significant differences depending on airports. This lead to recommend such a detailed study is performed to assess the real potential of EFVS to land concept before its deployment at a specific aerodrome.

In the SESAR perspective of the deployment of the EFVS operation with operational credit in Europe, this study is a key input to assist all the stakeholders in their assessment of the real benefit of that new capacity (i.e. aircraft manufacturer, AIR operator and aerodrome operator).

Next steps:

It is recommended to perform such a detailed study for aerodromes where EFVS to land deployment is planned.

8.3.4 Performance Prediction

Whatever the fog chamber validation method used by ELBIT or the advanced simulation validation method used by DASSAULT, SESAR AAL demonstrated that performance prediction is achievable with a reliability of 25% for fog, provided the SVR =f(RVR) relationship is available.

The absence of relationship is well reflected in ICAO documentation and EASA regulation. Some factor resulting from studies performed in UK in the past exist but no agreed relationship is recommended. Moreover, no studies seems have been conducted for rain or snow.

Next steps:

DASSAULT and ELBIT recommend SVR= f (RVR) relationship are proposed by relevant expert for EFVS to land operation for fog, rain and snow. This activity should involve Weather office and take into consideration the previous experimentations performed for in UK and in US.

DASSAULT and ELBIT will continue to validate the EFVS performance prediction methods with a larger sample of flight data.

ELBIT will continue investigation to determine how the fog chamber must be modified to improve reliability of the measurements.

8.3.5 View on Deployment:

EASA EFVS to land regulation materials, including aerodrome part are expected to be available from end of 2017

First aerodrome homologation and approval, and full validation of EFVS to land concept is achievable in 2019, provided remaining activities are accomplished.

Considering a year test period, it is reasonable to assume a deployment of the EFVS to land operation by 2020

8.4 EXE_0202_400 (WP4): EFP&AI

The usability of EFP&AI application was successfully demonstrated.

This section details the outcomes of the demonstrations of EFP&AI application (WP4). Section 8.4.1 focuses on conclusions and Section 8.4.2 then provides the recommendations.

8.4.1 Conclusions

The flight planning system (EFP&AI) used for AAL project utilizes detailed aircraft performance data combined with the current atmospheric forecast. These inputs assure very precise calculations of flight time and fuel consumption on every flight plan created. Successful WP4 demonstrations helped to show how flight planning system brings complex tools for worldwide flight planning and to provide simple and intuitive control and to make the work of users easier and more efficient. CTQ determined in the Demonstration Plan was successfully met and positive feedback was obtained by participants during evaluations.

With respect to **WP4 Enhanced Flight Planning,** 1 KPAs were evaluated. Human performance with respect to perceived level of feasibility from Pilot's perspective was rated OK. Please refer below for full explanation of the aspects and recommendations.

Human Performance:

- Evaluation of the perceived level of feasibility of EFP&AI technology from pilots' perspective, showed positive feedback, using Osgood's semantic methodology and Likert-type scale.

Summary of Demonstrations

In this WP the benefits (e.g. relevant information successfully obtained in user-friendly format) were evaluated for EFP&AI application. Seven pilots (six male and one female) participated in the demonstration. They were testing and commercial pilots of mainline as well as of business aircraft with different level of flying experience and of different age. Flight ops dispatcher was involved as well. This big variety of people involved in the demonstrations together with realistic environment ensured good significance and quality of demonstrations results.

During evaluations, introduction to the EFP&AI was given by Flight Ops specialist and the basic functionality was demonstrated. Commented hands-on practice and tasks including typical pre-flight briefing duties were completed. All subjects tried to complete simple tasks under supervision of Flight Ops Specialist and then they went through the evaluation scenario independently. At the end of the session set of Post-exercise questionnaires were completed in order to get feedback on benefits. The CTQ value was set to 'no major issues identified' assuming 5 point Likert Scale. Osgood's semantic differential methodology using the bipolar adjective pairs was used for the assessment as well.

Feasibility from Pilots' Perspective

The analysis of general usability showed, that the application reached the rating in the positive spectrum of the bipolar scale in all measured aspects (using 7-point distance Osgood's semantic differential methodology). Additional results on usability where evaluated using 5-point Likert-type scale. All but two items reached median value 4 (1=strongly disagree, 5=strongly agree). Usability of specific flight planning tasks was evaluated as well. Median scores ranged between 2 and 4 on the Likert-type scale (1=very unsatisfied, 5=very satisfied). Very positive feedback was given while participants were commenting the tasks execution. They especially liked route selection, departure/destination selection and Trip Kit. In general, the usability of the application was considered to be good. Lower ratings on intuitiveness and confidence in application use are likely related to the fact that five of seven participants were novice users. The application was originally developed for the US market and these demonstrations helped to identify the customization features for European users' needs.

Summarizing, during evaluation of the perceived level of feasibility of EFP&AI technology from pilots' perspective, positive feedback was obtained by participants.

8.4.2 Recommendations

Further customization of EFP&AI application for European users is recommended. Also, further activities, such as subsequent demonstrations are recommended in order to support the successful deployment of EFP&AI technology.

9 References

9.1 Applicable Documents

The documents mentioned in the template are examples that can be removed

[1] EUROCONTROL ATM Lexicon
https://extranet.eurocontrol.int/http://atmlexicon.eurocontrol.int/en/index.php/SESAR

9.2 Reference Documents

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

[1] Demonstration Design

[2] Deployment Scenario Descriptions

[3] Communication Plan

[4] AATM Master Plan
https://www.atmmasterplan.eu

[5] E-OCVM Version 3, EUROCONTROL, February 2010

[6] SESAR 9.12.D02 Qualitative & Quantitative Functional, Performance and Safety Requirements, February 2011

[7] SESAR 9.29.D05 System Definition Business Aircraft, March 2012

[8] SESAR 6.8.5.D04 Operational Service and Environment Definition (OSED) RNP transition to GLS, February 2013

[9] Koenig R., Schubert E., On the Influences of an Increased ILS Glide Slope on Noise Impact, Fuel Consumption and Landing Approach Operation, AIAC14 Fourteenth Australian International Aerospace Congress, 2010

[10] EUROCAE ED-179B: Minimum Aviation system Performance Standards (MASPS) for Enhanced Vision Systems, combined Vision systems and enhanced Flight Vision Systems.

[11] ESSP – European Satellite Service Provider, http://www.essp-sas.eu/aviation

[12] ICAO DOC 8168 “Procedures for Air Navigation Services - Aircraft Operations”

[13] ICAO DOC 9613 “Performance Based Navigation (PBN) manual”

[14] ICAO 9573-AN/937: “Manual of Area Navigation (RNAV) Operations”

[15] ICAO DOC 9613 “Manual on Required Navigation Performance (RNP)”

[16] SESAR D11.1.2-1 FOC operational and performance requirements for Step 1 (Quick Wins) including the traceability of the AU comments, September 2012

[17] SESAR B4.2.D65-013 Concept of Operations Step 2, December 2013

[18] SESAR 5.06.03. D40 V3 OSED, December 2014

[19] SESAR 9.29.D03 Cost Benefit Analysis, December 2010

[20] RTCA DO-315B Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems, June 2011

[21] Simulator Report Summary EDDW #2, Airbus, 04/16/2015

[22] SESAR B4.2.D65-011 Concept of Operations Step 1, May 2012

[23] SESAR 6.8.8.D14 - INTERIM Version - Enhanced Arrival Procedures Enabled by GBAS - INTEROP Updating - V2, October 2015

[24]SESAR 6.8.8.D08 Enhanced Arrival Procedure Enabled by GBAS - VALP - V2, June 2015

[25]SESAR 6.8.8.D10 Enhanced Arrival Procedure Enabled by GBAS - VALP - V3, will be available in February 2016

[26]SESAR 5.6.3.D38 V3 SPR, September 2015

[27]SESAR LSD.02.02 Demonstration Plan 2nd Review (A2), December 2015

[28]Lissys LTD: Piano 5, Available from: <http://www.lissys.demon.co.uk/Piano5.html>.

[29]Lissys: Piano presentation to CAEP WG2 TG2, Rome 2006.

[30]DFS: Aeronautical Information publication Germany, AMDTs 07/14, 09/14, 01/15, DFS Deutsche Flugsicherung GmbH, 2014.

[31]Skyguide: Aeronautical Information Publication Switzerland, AMDT 001 2015, 2015.

[32]ICAO: ICAO Carbon Emissions Calculator, Version 3, August 2010.

[33]SESAR 16.06.05.D06-001 Human Performance Support and Coordination Function SESAR Human Performance Reference Material-Guidance, v00.01.00 , December 2010

[34]SESAR 16.6.3.D26 Environmental impact assessment as part of the global SESAR validation approach, January 2015

[35]SESAR B.04.01.D41 SESAR Performance Framework (Edition 2), November 2015

[36]SESAR Integrated Roadmap, https://www.atmmasterplan.eu/rnd/integrated-roadmap

[37]Osgood, C.E., Suci, G.J., and Tannenbaum, P.H. (1957) The measurement of meaning, University of Illinois Press, Urbana, IL

[38]FilGAPP, Filling the gap in GNSS Advanced Procedures and oPerations, D0.7 Final Project Report, FP7, July 2014

[39]eAIP France, https://www.sia.aviation-civile.gouv.fr/html/indexAIPFRANCEFr.htm

[40]Dassault Aviation: DEV106921 (internal document)

[41]Données MTO France, 2014 commande 05T74231

[42]ATM/aerodrome impact , Dassault/ DGAC, SESAR AAL, 2016

[43]ICAO Annex 3

[44]DASSAULT AVIATION: Analysis of reduced Runway Visual Range and low Ceiling regarding operational minima for European aerodromes usually frequented by Falcon aircrafts Potential benefit for EFVS concepts (Full Study), February 29th 2015

[45]ICAO Doc9613, RNP1 navigation specification and RNP1 performance of the A-RNP navigation specification

[46]Standard Inputs for EUROCONTROL Cost Benefit Analyses, Edition no.5, December 2011

[47]Standard Inputs for EUROCONTROL Cost-Benefit Analyses, Edition no.7, December 2015

[48]NOAA National Climatic Data Center (NCDC) http://www.ncdc.noaa.gov/oa/ncdc.html

[49]EUROCONTROL STATFOR Interactive Dashboard http://www.eurocontrol.int/statfor/public/standard_page/statistics_reports.html

[50]ENRI – GLS path align performance evaluation with B787 flight trials, 4-7 June 2013, 14th International GBAS Working Group, Everett, WA, USA

[51]SESAR 6.8.8. - D09 - Enhanced Arrival Procedures Enabled by GBAS - VALR - V2, November 2015

[52]The Netherlands – eAIP, http://www.ais-netherlands.nl/aim/2016-09-01-AIRAC/eAIP/html/index-en-GB.html

[53]EAD, http://ead-website.ead-it.com/publicuser/public/pu/login.jsp

[54]DIN 45643:2011-02, Measurement and assessment of aircraft sound

[55]ISO 9613-2:1996(E), Acoustics – Attenuation of sound during propagation outdoors – Part 2: General method of calculation

[56]ISO 9613-1:1993(E), Acoustics – Attenuation of sound during propagation outdoors – Part 1: Calculation of the absorption of sound by the atmosphere

Appendix A KPA Results

Demonstration results for the addressed KPAs are provided in the Table 13, Table 14, Table 15 and Table 16 in Section 5.4. Table 37 summarizes the linkage between objectives and KPAs addressed in this project and the link to the relevant Appendix containing detailed results analysis and assessment.

Table 37: Objectives and KPA linkage and the link to relevant Appendix

OBJ	Objective Description	KPA	WP 1	WP 2	WP 3	WP 4	Appendix	Status
011	To demonstrate the feasibility of curved approaches with RNP to xLS.	**Human Performance**	x				B.2.1	OK*1)
012	To demonstrate the feasibility of GLS approaches with increased glideslopes of 3.2 deg.	**Human Performance**	x				B.2.1	OK*1)
013	To demonstrate feasibility of SVGS DH-50ft on ILS 200'.	**Human Performance**		x			C.2.1	OK
014	To demonstrate feasibility of SVGS DH-50ft on LPV 250'.	**Human Performance**		x			C.2.1	OK
015	To demonstrate feasibility of EFVS approaches.	**Human Performance**			x		D.1.1	OK
016	To demonstrate feasibility of EFP&AI (e.g. relevant information successfully obtained in user-friendly format).	**Human Performance**				x	E.1.1	OK
021	To demonstrate accuracy of advanced procedures.	**Safety**	x	x	x		B1.1, C1.1, D1.2	OK*2)
022	The operational concept of "EFVS to land" is safe and the operational credit obtained with EFVS is significant compared to exiting EFVS concepts.	**Safety**			x		D.1.3	OK
023	Reliability of EFVS to land operations in various weather conditions.	**Safety**			x		D.1.4	OK
024	To investigate the environmental impact of some advanced procedures in terms of local noise (at RNP to xLS transition and under increased glideslope).	**Environment / Fuel Eff.**	x				B.1.2	OK
025	To demonstrate fuel efficiency benefits of some advanced procedures.	**Environment / Fuel Eff.**	x				B.3.1	OK
026	To demonstrate environmental benefits of some advanced procedures in terms of CO2 emitted.	**Environment / Fuel Eff.**	x				B.3.1	OK
027	Estimate reduction of number of diversion, delay or go-around.	**Environment / Fuel Eff.**		x	x		C.3.1, D.2.1	OK
028	To evaluate the quality of flight track compared to designed (theoretical optimum) RNP to xLS approach.	**Environment / Fuel Eff.**	x				B.1.3	OK

OBJ	Objective Description	KPA	WP 1	WP 2	WP 3	WP 4	Appendix	Status
029	To estimate cost-effectiveness benefits of advanced procedures, such as cost savings for the crew qualification.	**Cost-effectiveness**		x			C.3.3	OK
030	Definition of the impacts on the small/medium airport procedures to enable EVS operations in low visibility conditions.	**Airport Capacity**			x		D.1.5	OK
031	To demonstrate airport eligibility for advanced procedures.	**Airport Capacity**		x	x		C.3.2, D.2.2	OK
041	Evaluation of the cost of publishing a SBAS LPV approach overlaid to a GBAS GLS approach.	**Airport Capacity**	x				B.4.1	OK
042	Having advanced RNP procedures to LPV (increased glideslope with the intercept RF Leg > 45deg), to describe how such an advanced procedure could facilitate independent RNP arrivals into business aviation satellite airports through complex TMAs.	**Environment / Fuel Eff.**	x				B.4.2	POK*3)

**1) NOTE: The RNP procedures were rated as feasible by both ATC and pilots. However, there were number of lessons learned and recommendations for future noted by both groups that are captured in Section 8.1.*

**2) NOTE: For WP1 only: Some of the Frankfurt mainline aircraft approaches seem to be going over the CTQ limit, but there is always an explanation provided (e.g. ATC vectoring) in Appendix B.*

**3) NOTE: Fuel efficiency slightly negative with IFR procedure RNP to LPV due to airspace and airport configuration of EDDF/EDFE. However, positive fuel efficiency results with the concept of Visual RNAV. For more details see Section 6.1.3.2.7.*

Appendix B EXE_0202_100 (WP1) Results Analysis and Assessments

This Appendix presents the detailed analysis and assessments on the objectives involved in EXE_0202_100 performed within WP1 (GBAS/SBAS Advanced Procedures).

See document "Appendix B and G to Final Demonstration Report B2".

Appendix C EXE_0202_200 (WP2) Results Analysis and Assessments

This Appendix presents the detailed analysis and assessments on the objectives involved in EXE_0202_200 performed within WP2 (SVGS Advanced Procedures).

See document "Appendix C and H to Final Demonstration Report B2".

Appendix D EXE_0202_300 (WP3) Results Analysis and Assessments

This Appendix presents the detailed analysis and assessments on the objectives involved in EXE_0202_300 performed within WP3 (EFVS Advanced Procedures).

See document “Appendix D and I to Final Demonstration Report B2”.

Appendix E EXE_0202_400 (WP4) Results Analysis and Assessments

This Appendix presents the detailed analysis and assessments on the objectives involved in EXE_0202_400 performed within WP4 (EFP&AI).

See document "Appendix E to Final Demonstration Report B2".

Appendix F Experimental Forms for the Questionnaires Used During the Demonstrations

This appendix presents the experimental forms for the questionnaires used during the demonstrations.

See document “Appendix F to Final Demonstration Report B2”.

Appendix G WP1: Approach Charts (LSZH, EDDW, EDDF)

This Appendix presents Approach Charts for airports involved in WP1 – Zurich, Frankfurt and Bremen.

See document “Appendix B and G to Final Demonstration Report B2”.

Appendix H WP2: Approach Charts (LKTB, LKMT, LKKV)

This Appendix presents Approach Charts for airports involved in WP2 – Brno, Ostrava and Karlovy Vary.

See document "Appendix C and H to Final Demonstration Report B2".

Appendix I WP3: Approach Charts (LFBE, LFBX, EHGG)

This Appendix presents Approach Charts for airports involved in WP3 – Bergerac, Perigueux and Groningen.

See document “Appendix D and I to Final Demonstration Report B2”.

Appendix J LSD.02.02 AAL Project Communication

This appendix presents project LSD.02.02 AAL communication activities evidences.

See document "Appendix J to Final Demonstration Report B2.zip".

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