SESAR 2020 VLD - AAL2 Demonstration Report – Appendix B

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Table of Contents

List of Tables

List of Figures

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

B.1 Summary of the Demonstration Exercise EXE-VLD-V4-200 Plan

This is an Appendix B to the SESAR 2020 AAL2 Demonstration Report for Augmented Approaches to Land 2 project. This Appendix presents the detailed analysis and assessments on the objectives involved in EXE_VLD-V4-200 performed within WP3 (EFVS-L Demonstrations). The section is structured in the following way:

- Demonstration Exercise Plan. Preparation, scope and constraints of the exercises (Section B.1)
- Deviation from the Planned Activities (Section B.2)
- Demonstration Exercise Results (Section B.3)
- Conclusion (section B.4)
- Recommendations (section B.5)

This section addresses the assessments on the following demonstration objectives:

- OBJ-VLD-V4-013 - Feasibility of EFVS to land approaches
- OBJ-VLD-V4-024 - Accuracy of EFVS to land approaches
- OBJ-VLD-V4-026 - Crew and ATC workload during EFVS to land approaches
- OBJ-VLD-V4-027 - Visual Advantage of an EFVS system
- OBJ-VLD-V4-032 - Aerodrome accessibility increase using EFVS to land operation

EFVS-L demonstrations with all ATM/ANS, ADR and air operators stakeholders properly prepared for accommodating that operation have been carried out by Dassault aviation and ATR. Some demonstrations were performed in real low visibility conditions and full OPS environment. Three of the four aerodromes initially planned in the project were covered. Two air operators participated to the flights.

It was the first time an EFVS operation is performed at a non CATII/III aerodrome approved (in the frame of SESAR) for that use.

B.1.1 Exercise description and scope

This section includes EXE-VLD-V4-200 preparation and demonstration scope description.

1. Demonstration Exercise Platforms, Data Collection and Methods

Dassault and ATR collected internal aircraft data, weather conditions (type of weather, RVR, ceiling). Also, Dassault and ATR collected questionnaires with the pilots to evaluate relevant KPAs (human performance and safety). ANSP collected questionnaires with the ATC to evaluate relevant KPAs (human performance and safety). Relevant flight data (parameters such as EFVS image, speed, autopilot, altitude, position, lateral and vertical deviation and more) were recorded through standard flight test installations. Weather information consisted in METAR report supplemented by data communicated by the ATC during the approach.

Feasibility of EFVS to land approaches using HUD or HWD

The feasibility of the operation as perceived by the crews will be captured through human factor questionnaires established in accordance with CS 25 1302 human factor process used for certification purpose.

[quantitative/qualitative]

Flight path tracking accuracy (vertical and horizontal): The precise position of aircraft will be measured by independent DGPS installation.
[quantitative]

Landing performance of EFVS to land approach:

Touchdown features of AAL2 flight demos will be recorded (i.e. Distance of Touch Down from runway threshold, offset from the runway centreline, vertical Speed at Touch Down) and be compared to Touch Down features without using EFVS. Objective is to show that these features are similar when landing with or without EFVS and that landing terminates in touchdown zone.

[quantitative/qualitative]

Crew and ATC workload:

Workload perceived by the crews will be captured through Human Factor questionnaires established in accordance with CS 25.1302 human factor process used for certification purpose. Workload perceived by the ATC will be captured through Human Factor questionnaires.

[qualitative]

Visual advantage provided by EVS during an EFVS approach in degraded weather conditions:

Visual advantage will be determined by comparing what is seen by the EVS compared to a reference camera sensitive in the visible spectrum. It will be compared to performance prediction analysis results.

[qualitative]

EFVS to land operation will retain traffic at secondary airports in degraded weather conditions

The increase of accessibility will be assessed through weather analysis. Weather data will be considered in regard to published minima and aerodrome operational constraints. The number of situations where the use of EFVS operation would have permitted landing will be determined.

[qualitative]

Measured Parameter	Tool	Data Format	Dassault	ATR	ANSP	Aerodromes
Number of successful approaches	Flight test log	paper	☑	☑		
Pilot qualitative evaluation	Questionnaire	paper	☑	☑		
ATC qualitative evaluation	Questionnaire	paper			☑	
EFVS image viewed by the pilot	Video recorder	Video	☑	☑		
External world seen from the pilot's station (natural vision)	Video recorder	Video	☑	☑		
Cockpit communication (voice + alarm)	Voice recorder	Audio	☑	☑		
Standard environmental conditions	Sensor/ data recorder	Numeric	☑	☑	☑	☑
The aircraft parameters (attitude, pilot's controls...)	Dedicated flight test data recorder	Numeric	☑	☑		
Independent aircraft trajectory monitoring	Dedicated flight test data recorder	Numeric	☑	☑		
The touchdown parameters	Dedicated flight test data recorder	Numeric	☑	☑		
Weather conditions (RVR, ceiling, Tre...)	Voice recorder/ data recorder	Audio/ numeric	☑	☑	☑	☑
Runway light/ approach lighting brightness setting	Voice recorder	Audio	☑	☑	☑	☑

Table 1: Data collection for EXE-VLD-V4-200

2. Ground preparation

As a prerequisite for demonstrations, aerodromes of the projects have been prepared for allowing EFVS-L demos.

Safety analysis was conducted for three aerodromes (Antwerp, Le Bourget and Perigueux) and covered ATM/ANS including aerodromes aspects. An experimental approval was granted by authorities for allowing EFVS-L demos (see Appendix C.2 safety). It was the first time a non CATII/III aerodrome received such authorization for EFVS operations (SESAR demos).

3. Air operator preparation

As part of the experimental approval for the demo, air operator provided justifications for issuance of a permit to fly for AAL2 Demos. In addition, they provided adequate climb gradient values for safe missed approach below DA/H (see Appendix C.2 Safety Assessment).

4. Crew preparation

In the perspective of full operational demonstration, crews from end users (Hop! for ATR and Flying Group or Zurich Insurance for Dassault) participated to AAL2 project.

They were involved at two levels in the project:

- They participated to the preparation of the demo flight by verifying the suitability check of the aerodrome/ runway for EFVS-L operation
- They were part of the crews who performed the AAL2 demos and acted as PF and PM during these demos.

As a prerequisite for the demo, each crew members were properly briefed on EFVS-L operation during ground course and they were properly trained for demo. Standard FFS equipped with EFVS was used for that purpose and crews were exposed to normal and some abnormal EFVS situations. In addition, as part of experimental approval for demos, crew members were requested to be familiar with the aerodrome environment and a familiarisation flight was performed in good weather conditions at the aerodromes of the demos.

Profile and experience of crew operators are described in the questionnaires (Appendix E). Some of them were already qualified for EFVS operation. Some others had no previous experience at all in EFVS or in HUD/ HWD. End user pilots had civil background.

5. Aircraft preparation

ATR42-600 and Falcon 8X were used for demos. ATR is a CAT B aircraft and Falcon a CAT C aircraft.

Both aircrafts were equipped with same Universal Avionics EFVS camera which is representative of the EVS technology in 2020.

On ATR 42, the Pilot Flying (PF) uses the EFVS image displayed in the very new HWD during the EFVS operation. A repeater displays the image for the PM.

Figure 1: EFVS on ATR -600

On Falcon 8X, pilots use EFVS as part of CVS in HUDs. Dual Head up display configuration is used on that aircraft.

Figure 2: EFVS on Dassault F8X

For safety purpose, and in addition to basic flight test installation, an independent positioning system (from aircraft system) has been installed on the Dassault and ATR aircrafts for allowing a monitoring of the trajectory during EFVS operation. This task was assigned to a dedicated flight test crew.

6. Aerodromes and scope of demos

Demos were intended to be achieved at the four aerodromes of the Project: Antwerp, Le Bourget, Perigueux and Payerne. The scope addressed by the demo is very large:

- Antwerp (EBAW, Belgium) is a CATI type controlled aerodrome with limited lighting infrastructure. It is very representative of the aerodromes targeted for EFVS deployment. Antwerp is an urban and small international aerodrome used for some scheduled and charter flights as well as business and general aviation flight.

Figure 3: Antwerp airport

- Perigueux (LFBX, France) is a CATI type uncontrolled aerodrome with limited infrastructures. Perigueux is a rural aerodrome.

Figure 4: Périgueux airport

- Le Bourget (LFPB, France) is dedicated to non-scheduled traffic only. It is the first airport in Europe for business aviation traffic. It is a CATI type controlled aerodrome with limited lighting infrastructure. Le Bourget is an urban aerodrome located very close to CDG HUB with which it shares some traffic regulation constraints.

Figure 5: Le Bourget airport

- Payerne (LSMP, Switzerland) is a military aerodrome recently opened to civil traffic. Payerne has a non-instrument runway fitted with ILS (and LPV).

Figure 6: Payerne airport

In accordance with the criteria defined in the EASA NPA 2018-06, following instrument approaches and associated minima were selected as suitable for EFVS-L operation for each aerodrome. In particular, approaches with offset higher than 3° and 2D only approaches were excluded from the scope of operations.

For each approach, and in accordance with the demonstrated performance of EFVS, an OPS credit of 30%-50% was considered for the Demos.

Runway	Approach Type	'Conventional RVR'	'Reduced RVR' (30%/ 50% OPS credits)	DA/H
Antwerp (EBAW)				
RWY 11	RNP APCH APV/BARO (LNAV/VNAV minima)	1100 m (CAT B) 1200 m (CAT C)	750 m / 550 m (CAT B) 800 m/ 600 m (CAT C)	385 ft/349 ft
	RNP APCH APV/SBAS (LPV minima)	900 m	600 m / 450 m	330 ft/294 ft
RWY 29	ILS CAT I	750 m	500 m / 400m	239 ft/200 ft
Le Bourget (LFPB)				
RWY 27	ILS CAT I	800 m	550 m / 400 m	366 ft / 200 ft
	RNAV (GNSS) LPV	800 m	550 m / 400 m	366 ft / 200 ft
	RNAV (GNSS) LNAV/VNAV	900 m	600 m / 450 m	446 ft/ 280 ft (CAT B) 456 ft / 290 ft (CAT C)
Périgueux (LFBX)				
RWY 29	RNAV (GNSS) LPV	1400 m (CAT B) 1500 m (CAT C)	900 m /700 m 1000 m / 750 m	720 ft/ 390 ft (CAT B) 730 ft/ 410 ft (CAT C)
Payerne (LSMP)				
RWY 23	ILS	1500 m	1000 m / 750 m	1955 ft/ 500ft cg 4%
	RNAV(GNSS)Z LPV CAT I	1500 m	1000 m / 750 m	1955 ft/ 500ft cg 5%

Table 2: EFVS reduced RVR

As much as possible, flight demos were performed in conditions where objectives of the projects (KPA/KPI) can be demonstrated taking into account the constraints of such demonstrations (see section here below).

For that reason, no demos were performed in Le Bourget. No appropriate weather conditions (i.e. less than published minima) allowing demonstration of OPS credit occurred in the period of demos with all other constraints satisfied. In particular, it was not accepted by Le Bourget to simulate the deployment of low visibility procedures in good weather, as it would have unacceptable effect on traffic in a normal day of operation (Le Bourget is the first aerodrome for business aviation traffic in Europe).

7. Organization of the flight and constraints of such demos

The realization of the EFVS-L demos flights in real weather conditions and in full operational context is associated to many constraints in various following domains.

a. meteo

EFVS-L demo in real low visibility conditions requires to be capable forecasting the fog conditions at an aerodrome with a reasonable delay compatible with aircraft flight test scheduling. For Demos in Antwerp we had the strong support of the skeyes weather office. This concurred to the success of the demos.

b. aircraft

Test platform aircrafts have to be properly prepared for intended Demos although they are dedicated to many activities in addition to SESAR. Therefore, the scheduling of the flights has to be done well in advance and the realization of activities depending on many short-term factors remains a challenge. In any case, aircraft activity has to be planned few weeks before the test and confirmed no later than few days before the test which is not fully compatible with weather forecast delay.

c. crew

The end user crew intended to participate to the demo shall be available in the period determined for the flight and be ready to join the aircraft with a short prior to notice (due to fog forecast delay). Pilots involved in the SESAR Demos are dedicated flight crews as they must have been trained to EFVS-L operation and be familiar with the aerodrome.

d. aerodromes/ ATC

Aerodrome shall be available the day of the Demo. No maintenance or absence of personnel shall occur and ground and ATC Personnel in position the day of the flight shall be properly briefed about demos. During AAL2, a fog event was missed due to absence of required personnel at one airport. In addition, the aerodrome must have been authorized for the Demo. This process may be long and may not match with winter periods that are more favourable for Demos. At last, as demos require activation of Low vis procedure, it may be assessed as not appropriate to simulate such procedures in good weather conditions due to significant perturbation it would cause on traffic.

Due to fog formation process, demos may occur early in the morning or late in the evening meaning at a time usually concomitants with peak of traffic.

Doing SESAR EFVS-L demos requires coordination between all stakeholders and remains a great challenge.

B.1.2 Summary of Demonstration Exercise EXE-VLD-V4-200 Demonstration Objectives and success criteria

Demonstration Objective	Demonstration Success criteria	Demonstration Exercise Plan Objectives	Demonstration Exercise Success Criteria
OBJ-VLD-V4-013	CRT-VLD-V4-013-001	EX2-OBJ- VLD-V4-013 To demonstrate feasibility of EFVS to land approaches using HUD or HWD equipment	EX2- CRT-VLD-V4-013-001 EFVS to land approaches are perceived feasible by pilot (≥7/10 on Likert scale)
OBJ-VLD-V4-024	CRT-VLD-V4-024-001	EX2-OBJ- VLD-V4-024 To demonstrate horizontal and vertical	EX2- CRT-VLD-V4-024-001 Horizontal TSE of EFVS

		path accuracy of EFVS to land approaches	to land approach is within 1 dot
	CRT-VLD-V4-024-002	EX2-OBJ- VLD-V4-024 To demonstrate horizontal and vertical path accuracy of EFVS to land approaches	EX2- CRT-VLD-V4-024-002 Vertical path of EFVS to land approach is within 1 dot
OBJ-VLD-V4-025	CRT-VLD-V4-025-001	EX2-OBJ- VLD-V4-025 To demonstrate the landing performance of EFVS to land approach	EX2- CRT-VLD-V4-025-001 Landing occurs in touchdown zone area during EFVS to land approach
OBJ-VLD-V4-026	CRT-VLD-V4-026-001	EX2-OBJ- VLD-V4-026 To demonstrate crew and ATC workload remain acceptable during EFVS to land approach	EX2- CRT-VLD-V4-026-001 Crew workload is assessed as less than 7/10 on an adapted cooper harper scale
	CRT-VLD-V4-026-002	EX2-OBJ- VLD-V4-026 To demonstrate crew and ATC workload remain acceptable during EFVS to land approach	EX2- CRT-VLD-V4-026-002 ATC workload is assessed as less than 7/10 on a adapted cooper harper scale
OBJ-VLD-V4-027	CRT-VLD-V4-027-001	EX2-OBJ- VLD-V4-027 To demonstrate Visual Advantage provided by EVS during an EFVS to land approach in degraded weather conditions	EX2- CRT-VLD-V4-027-001 Visual Advantage is at least 200m (1/3 of RVR published

OBJ-VLD-V4-032	CRT-VLD-V4-032-001	EX2-OBJ- VLD-V4-032 To demonstrate EFVS to land operation will allow to retain traffic at secondary airports in limited weather conditions	EX2- CRT-VLD-V4-032-001 EFVS to land allows aerodrome to remain accessible in 60% of limited weather situations

Table 3: Summary of Demonstration Exercise EXE-VLD-V4-200

B.1.3 Summary of Validation Exercise EXE-VLD-V4-200 Demonstration scenarios

This section describes the reference and detail solution scenario.

1. Reference scenario

The reference scenario to be considered for AAL2 consists in flying a non-CAT II/III straight in instrument approach without the use of EFVS. At the outer marker (or equivalent reference point and no later than 1000 ft HAT), reported visibility must be greater than that prescribed in IAC to continue the approach. At and below DA/H, pilot must see visual reference in natural vision to continue the approach. Below DA/H, approach and landing are conducted visually.

Approach is flown out of low visibility conditions.

Aerodrome is not approved for landing in RVR conditions lower than those prescribed in published minima.

See 3.4.2.2.1.1 for reference scenario.

2. Solution scenario

The solution scenario intended to be demonstrated as part of AAL2 consist in flying a non-CAT II/III straight in instrument approach using EFVS and associated operational credit. Approach is conducted in visibility conditions such that landing would be not possible without taking credit of visual advantage of EFVS.

At the outer marker (or equivalent reference point but no later than 1 000ft HAT), reported visibility must be greater than the RVR required with EFVS-L to continue the approach. At and below DA/H, pilot must see visual reference in HUD/ EFVS (or HWD/ EFVS) and verify the consistency with other basic flight information to continue the approach safely. Below DA/H, approach and landing are conducted using EFVS in lieu of natural vision and in combination with other basic information.

Approach may be flown in low visibility conditions down to 300m depending on EFVS demonstrated performance (certification) and aerodrome demonstrated capability (presence of LVP for example).

Aerodrome has been approved for landing in RVR conditions lower than those prescribed in published minima.

See 3.4.2.2.1.2 for solution scenario.

a. Demonstrations at Antwerp Airport

IAP and minima to be considered for the Reference scenario described here above is defined in the section B.1.1.5 aerodromes and scope of demo.

With respect to solution scenario, an OPS credit of RVR of 30% was applied for Antwerp allowing operations down to RVR 500m.

Aerodrome was approved by Belgium authorities for allowing SESAR demos in these conditions.

b. Demonstrations at Le Bourget Airport

IAP and minima to be considered for the Reference scenario described here above is defined in the section B.1.1.5 aerodromes and scope of demo.

With respect to solution scenario, an ops credit of RVR up to 50% was considered for Le Bourget allowing operations down to RVR 400m.

Safety assessment conducted in Le Bourget showed that the Aerodrome is capable of RVR 400m for EFVS-L operations.

In the frame of SESAR AAL2, an experimental approval was issued for EFVS-L demos in Le Bourget aerodrome by French authorities.

c. Demonstrations at Perigueux Airport

IAP and minima to be considered for the Reference scenario described here above is defined in the section B.1.1.5 aerodromes and scope of demo.

With respect to solution scenario, an ops credit of RVR of 50% was considered for Périgueux allowing operation in these conditions.

Safety analysis conducted in Périgueux showed the aerodrome is capable of an RVR of 400m for EFVS landing operations.

a. Demonstrations at Payerne Airport

IAP and minima to be considered for the Reference scenario described here above is defined in the section B.1.1.5 aerodromes and scope of demo.

With respect to solution scenario, an ops credit of RVR of 30% was envisaged for Payerne allowing operation in these conditions.

As approval process was interrupted in Payerne, no decrease of RVR has been determined for EFVS landing operation for that aerodrome.

B.1.4 Summary of Demonstration Exercise EXE-VLD-V4-200 Demonstration Assumptions

Identifier	Title	Type of Assumption	Description	Justification	Flight Phase	KPA Impacted	Source	Value(s)	Owner	Impact on Assessment
ASS- AAL2-EXE200-1	Test aircraft	Equipment	Availability of Falcon and ATR aircraft for the demonstrations	Aircraft ready and available needed to conduct flight demonstrations	Approach	safety, human performance	Aircraft operator and aircraft manufacturer	N/A	AAL2	Medium scope of demos impacted
AAL2-EXE200-2	Aircraft operator	Aircraft operator	Aircraft operators (Flying group, Zurich Insurance and Hop!) available and properly trained for EFVS demo	Three pilots of the companies conduct demonstrations and need to have EFVS training for demo finished before start of demonstrations	Approach	safety, human performance	Aircraft operator and aircraft manufacturer	N/A	AAL2	Medium significance of results of demos impacted

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

Table 4: EXE-VLD-V4-200 demonstration assumptions overview

B.2 Deviation from the planned activities

Deviations are given in comparison with the amendment AMD_783_112-8.

First of all, the realization of the EFVS-L demos flights in real weather conditions and in full operational context is a very ambitious objective and associated to many constraints in various following domains as detailed in section B1.1.6. Such SESAR EFVS-L demos requires tight coordination between many stakeholders involved in day-to-day operations and remain a great challenge in that context.

B.2.1 Pioneer flight demos

Three demo flights were performed.

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

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

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

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

Impact is assessed as Low because other flight demos have nonetheless been conducted in weather conditions as part of the worst allowed for such operation.

B.2.2 Readiness demos

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

B.2.3 Aerodrome approval for the demos

Payerne has not received the approval following non authorization from Military authorities for demos in the period considered.

The consequence was that no demo was performed in Payerne and approval process was interrupted.

The impact is low as Payerne is a very specific aerodrome.

B.2.4 Aircraft configuration

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

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

B.3 Demonstration Exercise EXE-VLD-V4-200 Results

B.3.1 Summary of Demonstration Exercise EXE-VLD-V4-200 Demonstration Results

1. Demos results

AAL2 flight demos were achieved in two separate sessions to accommodate aircraft availability and weather periods.

10 EFVS-L approaches were performed by ATR and Dassault at Antwerp and Périgueux aerodromes.

a. Demos in Antwerp

7 approaches were performed in Antwerp in 2019.

Three of them were successfully performed in heavy fog in real low visibility conditions which are even the lowest one authorized for that kind of operation (500 meters at the time the decision to continue was taken).

These approaches were flown by either Dassault-Flying group crews or ATR-Hop! crews.

Business aviation crew requests for having EFVS aerodrome/runway/IPA/Minima capability clearly stated in the charts. For clarity reasons and sharing with ATC, he recommends the EFVS capacity is part of the flight plan.

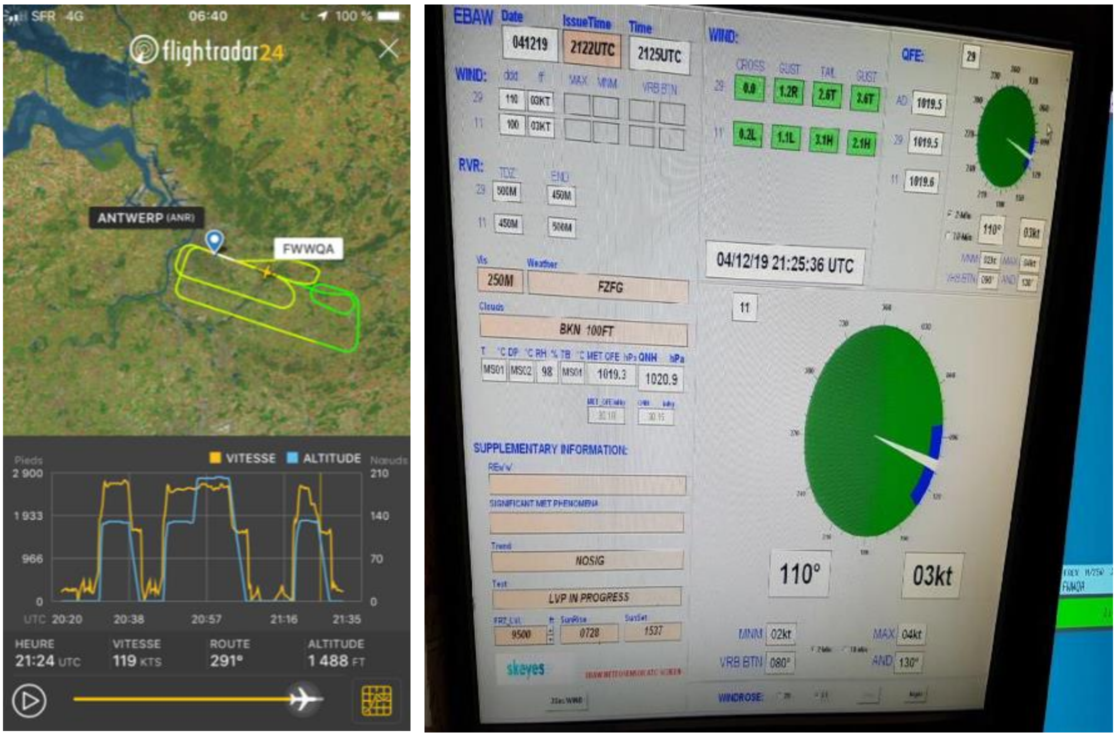

Figure 7: EFVS Business aviation Demos in Antwerp

b. Demos in Périgueux (AFIS):

3 approaches were performed in Perigueux in non-limiting weather conditions.

In order to simulate low visibility conditions as much as possible on airborne part as well as on ground part:

- an obscurant panel was placed on the windshield of the aircraft
- LVP were nevertheless fully in Force in Périgueux and partially in force in Antwerp

Figure 8: EFVS Regional aviation Demos in Périgueux

c. Demos in Le Bourget:

Weather conditions were not encountered in Le Bourget in the available period of demos satisfying all the required constraints for such demo (see B1.1.6). Due to density of traffic at Le Bourget and significant impact on traffic that would result from the deployment of LVP, DSNA Le Bourget decided not to authorize simulation of low visibility procedures in good weather conditions as it could be done for some flights in Antwerp.

No Demos were performed in Le Bourget.

d. Demos in Payerne:

As military aerodrome of Payerne has not received approval for demos, no demos were performed at this aerodrome (see B2.3).

Demonstration Objective ID	Demonstration Objective Title	Success Criterion ID	Success Criterion	Sub-operating environment	Exercise Results	Demonstration Objective Status
OBJ-VLD-V4-013	Feasibility of EFVS to land approaches	CRT-VLD-V4-013-001	EFVS to land approaches are perceived feasible by pilot (≥7/10 on Likert scale)	APT	EFVS to land operation is feasible by pilot	OK
OBJ-VLD-V4-024	Accuracy of EFVS to land approaches	CRT-VLD-V4-024-001	Horizontal TSE of EFVS to land approach is within 1 dot or equivalent in meters, when relevant	APT	TSE of EFVS to land approaches were kept within 1 dot	OK
OBJ-VLD-V4-025	Landing performance of EFVS to land	CRT-VLD-V4-024-002	Vertical path of EFVS to land approach is within 1 dot or equivalent in meters, when relevant	APT	Vertical path of EFVS to land approach was kept within one dot	OK

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

					conditions (see Appendix J.2.4)	

Table 5: Exercise EXE-VLD-V4-200 Demonstration Results

2. Results per KPA

KPA	KPI	CTQ definition	Where & how	CTQ value	results
Safety	Horizontal Flight accuracy (EFVS	Horizontal TSE for EFVS approaches is within CTQ limit.	Antwerp, Perigueux airports - experimental flights	within 1 dot	No significant deviation of trajectory Far Less than 1 dot
	Vertical Flight accuracy (EFVS)	Vertical TSE for EFVS approaches is within CTQ limit.	Antwerp, Perigueux, airports - experimental flights	within 1 dot	No significant deviation of trajectory Far Less than 1 dot
	Successful touchdown (EFVS)	Touchdown footprint for EFVS approaches is within CTQ limit.	Antwerp, Perigueux, airports - experimental flights	in touchdown zone	All touchdown occurred at the expected position within in the TDZ
	Crew and ATC workload during EFVS operation remains acceptable.	Crew and ATC workload are within CTQ limit.	Antwerp, Perigueux, airports - experimental flights & questionnaires	7/10 on Adapted Cooper Harper Scale	Dassault, ATR, Flying group, Hop! crews assessed the workload as acceptable during EFVS-L operation ATC skeyes and ATS from Perigueux (AFIS) assessed the workload is equivalent to non EFVS operation

	Significant visual advantage with EFVS.	Visual advantage compare to natural vision is greater than CTQ during EFVS approach.	Antwerp, airports - experimental flights	1/3 of actual RVR publishes	Visual advantage of more than 1/3 of published RVR was demonstrated in Antwerp.
Human Performance	Perceived level of feasibility – pilots and ATC (EFVS)	EFVS approaches are feasible based on feedback form from pilots and ATC.	Antwerp, Perigueux, airports - experimental flights & questionnaires	7/10 on Likert scale	Dassault-Fying Group crew and ATR-Hop! crews assessed the level of feasibility as improved or equivalent to normal non EFVS operations
					ATC from skeyes and ATS from Perigueux (AFIS) assessed the feasibility level as acceptable
Airport Capacity	Increased access to secondary airports in low visibility (EFVS)	EFVS operation in RVR as low as 300m (as permitted by regulation) will allow to retain access in CTQ values of observed low visibility conditions.	Weather analysis impact	60%	EFVS to land would allow to cover more than 78 % of the limited situations.

Table 6: EXE-VLD-V4-200 Results per KPA/KPI

3. Results impacting regulation and standardization initiatives

AAL2 had as objective to deploy in advance at some pioneer aerodromes the EFVS-L operation as per EASA NPA 2018-06 and to perform demos.

AAL2 had also as objective to get feedback from each stakeholder in order to convey European regulation makers (EASA, Eurocontrol, European ICAO members…) with recommendations for potential improvement of the regulatory materials.

Feedbacks have been collected through human factor questionnaires (Appendix E) for ATC/ ANSP, aerodrome operator, AIR operator, and crews. Following two recommendations resulting from questionnaires have been made.

a. Addition of the EFVS related RVR capacity in the FPL

According to regulation, EFVS OPS credit is applicable for flight planning as well as for allowing the continuation of the approach below 1 000ft HAT.

The RVR capabilities of the aircraft resulting from EFVS is recommended to be mentioned in the flight plan for traffic regulation purpose (see Le Bourget for example) and for ATC awareness purpose (see Antwerp). Field 18 has been successfully used in AAL2 demos. Field 10 could be also envisaged.

A presentation was given in that perspective to Eurocontrol specialists and to EASA rulemaking (RMTO379).

In consequence, EASA and Eurocontrol members have relayed the request in ICAO FLTOPS meeting. Topics received a preliminary positive opinion. *"Resolution of these questions and agreement as to the ultimate requirements needs to be achieved via the respective panels which currently seems to be FLTOPS, ATMOPS presumably, and ATMRPP."*

b. Promulgation of the aerodrome

According to NPA 2018-06, suitability check of the aerodrome for EFVS operation can be performed by the state of the aerodrome. In case an aerodrome/runway/procedure is not promulgated for the use of EFVS, it is up to each air operator to request approval and provide all the necessary evidence (SPA.LVO.110) to his national authority.

In case the suitability check is performed by the air operator, it was assessed as feasible with no extra complexity by major air operator of scheduled air transport which are familiar with the use of AIP information and such required computations (PANS OPS Study). However, it was assessed as too much complicated especially by business aviation operators, mainly because it requires information that may be not directly and easily accessible (AIP information is public, but aerodrome OPS manual is restricted). In addition, such process based on retrieval of information from different sources and computation is not suitable to quick assessment of EFVS capacity, as it may occur in business aviation due to the nonscheduled nature of the operations.

Due to the lack of prescriptive enough process for EFVS, one Business aviation operator even pointed out the fact "*the most difficult part today is convincing the authorities of the validity of the procedures*." Based on his experience with several authorities, he also mentioned that approvals are not standardized. More or less detailed justifications may be requested depending on the authorities.

In case suitability check is performed by the ANSP/ aerodrome (see Appendix C) and results in an approval issue by the authority, the activity has been assessed as achievable with reasonable effort (see questionnaire in Appendix E) by the leaders in charge of the AAL2 experimental approval.

According to the ANSP and the aerodrome operator who conducted the approval in Antwerp, even if "*some elements of this suitability assessment could be checked relatively easily, by consulting the information in the AIP (e.g. offset final approach track and runway centerline, available approach procedures and minima, presence of LED lights -AMC1 ADR.OPS.A.005-, etc.), some elements cannot be checked easily by the air operator (e.g. airport requirements on electrical power supply systems, serviceability levels, meteorological equipment, etc.). In particular the PANS-OPS study – in order to check the obstacle clearances – requires a detailed assessment. In principle, as long as a runway is not yet promulgated for the use of EFVS, all operators should perform this study. This is not an obvious task for an operator, as it is a specialist assessment to be performed by a certified PANS-OPS expert. In Belgium, the authorities to be involved are the Belgian Civil Aviation Authority (BCAA) and Belgian Supervisory Authority (BSA).*"

In conclusion, and with respect to business aviation that is the most equipped and therefore the main potential user of EFVS operation, results of AAL2 show that it is highly preferable the aerodromes are promulgated as suitable for EFVS operation by the state of the aerodrome in the AIP.

At this stage, Antwerp also considers that there is a lack of clear guidance material on the use of EFVS operation, in particular concerning the airports/runways/procedures that are promulgated, and which requirements should be fulfilled for all stakeholders involved (air operator, aerodrome, ANSP, etc).

The draft regulation, included in the Notice of Proposed Amendment (NPA) for All-Weather Operations (AWO), contains clear guidelines for the use of all types of EFVS operations. However, it is a very extensive document, where one easily gets lost in finding & compiling the relevant information. The list of requirements to be fulfilled should be clearly established as well as the role of each stakeholders involved in the process (ANSP, Aerodrome, air operator or regulator).

In the perspective of promulgation of aerodromes/ runways for EFVS operations, and because EFVS approval requires a joint effort/ involvement from several services (see Appendix C), skeyes took credit of the experience gained through SESAR AAL2 for preparing a comprehensive guidance manual. This document will allow to support EFVS approvals of some other potential aerodromes in Belgium.

Beyond Belgium context, the content of that manual can serve as a solid basis for providing guidelines when applying for EFVS approval at some other European aerodromes. It could be considered for improving guidance materials of regulation.

Promulgations of aerodromes for EFVS operations avoid each air operator to accomplish the same tedious and repetitive study requiring involvement of aerodrome/ ANSP. It will allow more small operators operating nonscheduled flights to have (finally) access to EFVS operations.

Compared to CAT II/III, although substantial effort needs to be done to check the suitability of airport/runways, the approval process of the aerodrome was assessed as fast and affordable compared to installing airport equipment (e.g. ILS CAT II/III).

An air operator underlined that a large part of the effort associated to the approval consists in convincing authorities of the "*validity of the procedures*". Such process is time consuming and is a brake to the development of the EFVS operation. The operator added this would be even more regrettable that AAL2 demos proved the "*validity and necessity of the Ops credit operation*".

B.3.2 Analysis of Exercises Results per Demonstration objective

Feasibility Demonstration Objective

1.EX1-OBJ-VLD-V4-013 Results

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

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

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

- The ease of the operation is improved for approach and landing and is equivalent for taxi and rollout compared to non EFVS operations.
- No difficulty was perceived. Workload is not increased except for taxi (realized in more dimensioning conditions as in reality due to the 0 visibility resulting from the obscurant panel),
- Decision making in case of aborted approach is equivalent and may be even improved by the use of EFVS,
- Crew coordination was assessed as acceptable.

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

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

See questionnaires in the Appendix E.

2.EX1-OBJ-VLD-V4-024 Results

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

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

3.EX1-OBJ-VLD-V4-025 Results

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

4.EX1-OBJ-VLD-V4-026 Results

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

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

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

5.EX1-OBJ-VLD-V4-027 Results

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

During demo in Antwerp aircrafts had to perform missed approaches at both EBAW and EBBR.

Figure 9: EFVS Landing Low Visibility Conditions

6. EX1-OBJ-VLD-V4-032 Results

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

B.3.3 Unexpected Behaviours/Results

See deviations sections in B.2.1 and B.2.2 and B.2.4.

B.3.4 Confidence in the Demonstration Results

1. Level of significance/limitations of Demonstration Exercise Results

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

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

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

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

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

Stakeholders involved in the execution of the demos provided feedbacks that have been collected through dedicated human factor questionnaires and some recommendations were made for regulation maker bodies (B3.1.3).

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

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

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

Limitations of demos have been described in B.2.

2. Quality of Demonstration Exercise Results

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

3. Significance of Demonstration Exercises Results

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

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

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

B.4 Conclusions

According to ICAO AWO manual (Chapter 6.1.3), *“the nature of all-weather operations”* –EFVS operations are part of- “*necessitates a clear presentation of the requirements of the State of the Operator and an agreed-upon means of indicating authorization and approval to achieve full utilization of facilities in international operations. There are five elements involved in the approval of an operation by the State of the Operator*.” Second element is the authorization of the use of the aerodrome AAL2 is focused on.

Moreover, NPA AWO 2018-06 requires the suitability of runways is verified for EFVS operations and stipulate that “*in case a runway has been promulgated as suitable by the State of the aerodrome (i.e. in the AIP), then no further investigation is required from each air operators*”. Proceeding this way will increase the standardization of approvals and guaranty the highest level of safety of the operation. It will give a clear and non-ambiguous indication of EFVS operation shared between all ATM stakeholders i.e. aerodrome operator, ATC, air operator.

The alternative consisting in letting each air operator to determine by its own the suitability of the runway for EFVS operation has been assessed as too long and too much complicated, especially by the air user of business aviation. Belgium ANSP who conducted the experimental approval for Antwerp confirmed that statement arguing several stakeholders must be involved in the authorisation of the aerodrome for EFVS operation (see B.3.1.3.b).

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

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

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

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

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

Figure 10: EFVS/CVS view (Falcon)

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

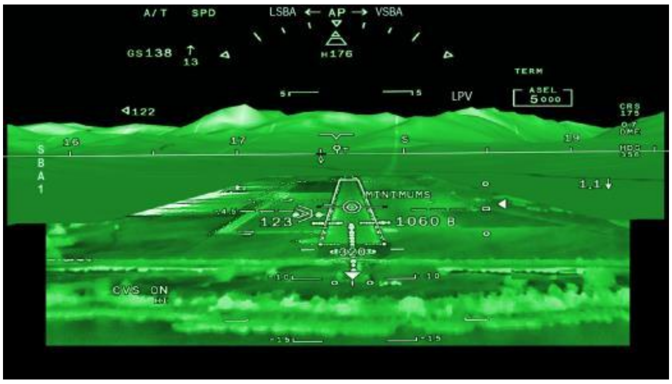

Figure 11: EFVS/CVS view (Falcon)

B.5 Recommendations

B.5.1 Recommendations for industrialization and deployment

The manual produced by skeyes for Antwerp should serve as example for states/ ANSP to establish a list of similar aerodromes authorizing the use of EFVS in the perspective of large deployment of the operation (see B4 here above and Appendix C) and as part of *promulgation of aerodrome for EFVS* activity.

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

In the perspective of the deployment of the EFVS operation in Europe, the large scope weather analysis produced in AAL2 is a key input to assist all the stakeholders in their assessment of the real benefit of that new operational capacity (i.e. States, AIR operator, aerodrome operator, ANSP).

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

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

B.5.2 Recommendations on regulation and standardisation initiatives

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

Beyond this, it will serve for supporting all types of EFVS operation including EFVS-L as soon as introduced by EASA through new AWO regulation resulting from NPA 2018-06.

See also section B.3.1.3.