



[SESAR Solution XX SPR-INTEROP/OSED Template for Vx - Part II - Safety Assessment Report]

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SUMO

[PROJECT TITLE]

This SPR-INTEROP/OSED is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No734153 under European Union's Horizon 2020 research and innovation programme.



Abstract

Solution PJ.03a-04 "ENHANCED VISUAL SYSTEMS" addresses the feasibility of the new vision based systems to increase accessibility and improve taxi to all airports in low visibility conditions and without ground infrastructure requirements. In accordance with the objective of the project, safety during TAXI using HMD and EFVS landing using HMD have been assessed from pilot point through human factor questionnaire. From SPR standpoint, as HMD is considered as a HUD equivalent solution in the EASA CS AWO.A.HUD.101 airworthiness regulation, no additional safety requirements are studied in the frame of PJ03a-04. From OSED standpoint, recommendations related to safety impacts on ATM were addressed jointly with DSN in previous SESAR AAL project. Part of the solution focusing on approach operation using EFVS/CVS and active sensor has lower maturity. Nevertheless, the active sensor is considered as a complement or replacement of traditional passive Infra-Red (IR) sensors and no additional safety requirements are studied in the solution frame.

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1 Executive Summary

This document contains the Specimen Safety Assessment for a typical application of the PJ.03a-04 Solution (Enhanced Visual Operations) and is the part II of the SPR-INTEROP/OSED deliverable.

The report presents the assurance that the Safety Requirements for the V3 phases are complete, correct and realistic, thereby providing all material to adequately inform the PJ03a-04 Solution OSED/SPR/INTEROP.

Solution PJ.03a-04 addresses the following OIs:

- AUO-0405: Equivalent Visual Landing operations in Low Visibility Conditions
- AUO-0406: Equivalent Visual Taxi operations in low Visibility Conditions
- AUO-0410 (in pipeline for W2): Equivalent Visual Approach and Landing operations providing improved resilience to LVC

This document contains the Specimen Safety Assessment for a typical application of the PJ03a-04 solution in Enhanced Visual operations.

The development of approach operation using active sensor cannot confirm V3 maturity level, as expected during project time being due to lower sensor maturity.

2 Introduction

2.1 Background

Enhanced Visual Operations has already been addressed through SESAR1 project 9.28 “Enhanced Vision Solutions (Head-Down and Head Up)” as well as project 9.29 “Enhanced and Synthetic Vision” and LSD.02.02 “Augmented approaches to land”

WP09.28: The goal of the was to develop head-up and head down Enhanced and synthetic vision systems concepts to enable more efficient approach, landing and taxi in low visibility conditions. More exactly, this work package dealt with solution analysis, mock-up development and testing in relevant environments of:

- ✓ EVS image and symbols displayed on HUD and HDD
- ✓ EVS sensors performances analysis (including a wide spectral range of passive forward-looking passive sensors, such as SWIR/MWIR/LWIR/passive MMW and active sensors such as Laser detector and ranging and MMW radar).

WP09.29: The project has worked on the development of on-board solutions combining Enhanced and Synthetic Vision Systems in order to improve pilots’ ability to conduct landing operation in low visibility conditions. To achieve these goals, the 9.29 project identified all relevant requirements, evaluated available database technologies and formats, defined a system concept, developed business and regional aircraft mock-ups, performed initial concept evaluation through modelling and simulation means and performed technical verification and validation to achieve V2 maturity level of the proposed solutions.

The benefits and feasibility analysis have only been assessed for HUD/HDD and available sensors in SESAR1. The main goal of SESAR2020 PJ 03a-04 is to complete this assessment with the introduction of HWD/HMD and active sensors as candidate solution for the cockpit display to pilot.

LSD.02.02: This project focused on a large scale demonstration of benefits (reduced environmental impact, fuel cost savings, increased traffic throughput at airports) thanks to augmented approaches to land using GBAS/SBAS/SVGS/EFVS enablers for advances procedures. Those demonstrations brought a positive impact driving to acceptance of these new technologies by the market. In this context, the SESAR2020 PJ-03a-04, aims at validate those technological enablers using a HMD instead of HDD/HUD classic avionics displays and active sensor, improving event more costs benefits in operations and availability of the operation.

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

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

AAL2 involve key relevant stakeholders such as ANSP, aerodrome operators as well as air users to conduct approvals of operations.

2.2 General Approach to Safety Assessment

See sections 3.5 and 4.1.

2.3 Scope of the Safety Assessment

This Safety Assessment Report contains the results of a safety assessment conducted according to SESAR SRM [1] up to and including V3 maturity level. This contains:

- Definition of the Safety Criteria
- Verification of key properties of the operational environment
- Safety specification at the OSED level
- Safe design consideration at SPR Level

Since the properties of the aircraft and the operational environment are crucial to the safety assessment, this process cannot be generic. The process is executed specifically for the operational environment defined in section 3.2 and consequently the term 'specimen' safety assessment should be used.

2.4 Layout of the Document

Section 2, this section, provides introduction to the document and this specific safety assessment process.

Section 3 provides safety specification at the OSED level, i.e. Safety Criteria and Safety Objectives.

Section 4 provides analysis of the solution safe design at the SPR level resulting in Safety Requirements specification.

3 Safety specifications at the OSED Level

3.1 Scope

This section deals with safety specification at OSED level for PJ03a-04 solution.

3.2 PJ03a-04 Solution Operational Environment and Key Properties

The relevant operational environment has been described in SPR-INTEROP/OSED, part I section 3.2

3.3 Airspace Users Requirements

Over the next decade, air traffic in the Europe is expected to significantly increase. In addition, according to the EASA Annual Safety Review 2017, perception/ situational awareness and decision making are among the top 5 safety issue ¹.

In response, industrials are developing a number of advanced technologies among which the Vision Systems HMD and active radar studied in PJ0a-4.

With respect to surface operations, aviation safety reports contain numerous incidents triggered by pilots becoming disoriented while taxiing under low-visibility conditions. The consequences of disorientation include deviating from the cleared route, increased interaction with ATC, and conflicts with other traffic. In extreme cases, route deviations can seriously disrupt the traffic pattern across the entire airport. For example, a misplaced aircraft forced the closing of a runway for several hours at Chicago O'Hare in US. It is clear from these incidents that surface navigation, particularly at night or under low visibility, poses a major challenge to the efficiency of terminal area operations. Concepts based on the use of solutions such as Head Up Display (HUD) or Helmet Mounted Display (HMD) equivalent display combined with Combined Vision System (CVS) that brings the pilot's eyes out the cockpit allows to achieve the level of taxi performance normally seen VMC in IMC.

With respect to landing operations in low visibility conditions using CVS systems, the use of advanced active sensor at affordable cost will increase the performances as well as improve the reliability of the EFVS landing operations due to better performance of the on-board sensor. This will increase the proportion of successful landing during EFVS operations, reduce the number of go around.

See also SPR-INTEROP/OSED, part I and VALP documents.

¹ based on the past performance of the system by counting high risk occurrences, or the number of fatalities or through the aggregated risk score.

3.4 Relevant Pre-existing Hazards

With respect to Equivalent Visual Landing operations in Low Visibility Conditions, pre-existing hazard are those already considered for existing HUD and EFVS based operation. Limited performance of existing systems based sensor and difficulties to predict performance of these sensors may lead to diversion or go around situation at low height.

With respect to Equivalent Visual Taxi operations in Low Visibility Conditions operation, pre-existing hazard are those already considered for existing HUD based operation. Limited situational awareness of the crew during taxi may induce disorientation leading to more interaction with ATC and higher risk of conflict with other aircrafts.

See also SPR-INTEROP/OSED, part I section 3.2

3.5 Safety Criteria

With respect to Equivalent Visual Landing operations in Low Visibility Conditions, the PJ03a-04 solution is only assessing the use of the monocular colour-capable HMD equipment as an acceptable alternative to HUD equipment that is already certified for EFVS 100ft operations (reference scenario of PJ03a-04). At OSED level, safety aspect associated to HUD or equivalent system and EFVS operations, i.e impacts on ATM/ aerodrome have been addressed in LSD 02.02 SESAR project (Final demonstration report (B2), 16/11/2016, ed 02.00.00) in document impact on ATM/ aerodrome produced by DGAC/DSNA and Dassault. ATM/ aerodrome recommendations produced by French ANSP and Dassault were considered by EASA for drafting the NPA 2018-06 and are being to be assessed in full Operational environment through the SESAR AAL2 (VLD) project. SESAR AAL2 project involves the full set of key relevant stakeholders that are required for achieving this task (ANSP, aerodrome operators, air users as well as the regulator). The assessment of the feasibility of the EFVS operation from a crew standpoint was achieved as part of LSD.02.02 (Final demonstration report (B2), 16/11/2016, ed 02.00.00). Results and recommendations for training and crew briefing are in simulator evaluation report.

With respect to Equivalent Visual Taxi operations in Low Visibility Conditions, according to grant agreement n° 734153 the PJ03a-04 solution is only focusing on human factor aspects associated to Head Worn Display using legacy sensors. As there is neither ANSP nor safety expert at OSED level involved in the solution, no other than qualitative information already provided in sections §3.3, 3.4 and 3.5 about safety of operation at OSED level is delivered as part of PJ03a-04 solution in this safety report.

3.6 Mitigation of the Pre-existing Risks – Normal Operations

3.6.1 Operational Services to Address the Pre-existing Hazards

With respect to Equivalent Visual Landing operations in Low Visibility Conditions the use of advanced sensor of PJ03a-04 solution with better performance and reliability than IR legacy sensors will significantly decrease with the number of go around situations. The use of advanced EFVS active sensor, with an improved penetration and a low dependence of adverse weather condition will

increase the number of successful EFVS landing operation with Operational credit, reducing the likelihood of diversion or late go around.

With respect to Equivalent Visual Taxi operations in Low Visibility Conditions, the HMD with taxi routing and traffic information will give an intuitive 360° view of the situation to the pilot and then contribute to increase safety margin during taxi. Improved situational awareness of the crew during taxi will also relieve ATC by reducing workload level in the most critical situation (high traffic density at complex airports). This is especially true at night or in low visibility conditions, at unfamiliar and/or complex airports such as CDG where the availability of an HMD displaying an intuitive and comprehensive view of the situation (composed of Enhanced Vision, Synthetic vision, guidance/clearance and traffic information) will contribute to reduce route/ flight path deviations with a significant impact on safety. The use of HMD maximize the time the pilot flying (and possibly the crew) is “head up and eyes out” avoiding to continuously scan from outside to inside and then reinforcing attentional getting, and improving decision making in critical situations.

3.6.2 Derivation of Safety Objectives (Functionality & Performance – success approach) for Normal Operations

See section 3.5.

3.6.3 Analysis of the Concept for a Typical Flight

See section 3.5.

3.7 PJ03a-04 Solution Operations under Abnormal Conditions

See section 3.5.

3.7.1 Identification of Abnormal Conditions

See section 3.5.

See also SPR-INTEROP/OSED, part I section 3.3

3.7.2 Potential Mitigations of Abnormal Conditions

See section 3.5.

3.8 Mitigation of System-generated Risks (failure approach)

See section 3.5.

3.8.1 Identification and Analysis of System-generated Hazards

See section 3.5.

3.8.2 Derivation of Safety Objectives (integrity/reliability)

See section 3.5.

3.9 Impacts of PJ03a-04 Solution operations on adjacent airspace or on neighbouring ATM Systems

See section 3.5.

3.10 Achievability of the Safety Criteria

See section 3.5.

3.11. Validation & Verification of the Safety Specification

See section 3.5.

4 Safe Design at SPR Level

4.1 Scope

With respect to Equivalent Visual Landing operations in Low Visibility Conditions using HMD and EFVS, safety aspect associated to HMD at SPR level are not different than existing one for the HUD and EFVS operation that have been already certified for many years. All European EFVS systems have been certified using the EASA CRI (Certification Review Items) standard process that proposes acceptable means of compliance for the airworthiness approval for a system. For EFVS systems, MASPS ED 179/ DO315 documentation is considered in CRI as an applicable standard for certification. With respect to safety (airworthiness), ED 179 / Do 315 produced by the RTCA SC213/ EUROCAE WG79 committee defines system safety design requirements, safety levels and safety process to be applied (Chapter 3, Appendix B and appendix C).

All mentioned above are valid also for the active sensor as a complement or replacement of traditional passive Infra-Red (IR) sensors. All related safety requirements and failure hazards are fully defined in applicable airworthiness regulation.

With respect to Equivalent Visual Taxi operations in Low Visibility Conditions using HMD, as HMD does not add operational credit at this date for that phase of flight, safety aspects to be considered are not different than those to be considered for HUD for basic phase of flight. This mainly concerns non-interference with other existing duties. This point is already addressed by the applicable airworthiness regulation CS 25 as part of basic HUD or equivalent system requirements.

During PJ03a-04 exercises, no safety related issue was raised by the pilots during EFVS operation. See SPR-INTEROP/OSD, part IV.

As a consequence, no additional safety aspect related to SPR level are given in that document.

Note: HWD/ HMD is considered as a HUD equivalent system by EASA NPA 2018-06 -CS AWO.A.HUD.101 b, AMC AWO.B.SACAT.101(a)(g)).

4.2 The PJ03a-04 Solution Functional Model

See section 4.1

4.2.1 Description of Functional Model

See section 4.1 **External Entities**

See section 4.1

4.2.1.2 Data Sources

See section 4.1

4.2.1.3 Safety functions

See section 4.1

4.2.2 Traceability

See section 4.1

4.3 The PJ03a-04 Solution SPR-level Model

See section 4.1

4.3.1 Description of SPR-level Model

See section 4.1

4.3.1.1 Aircraft Elements

See section 4.1

4.3.1.2 Ground Elements

See section 4.1

4.3.1.3 External Entities

See section 4.1

4.3.2 Task Analysis

See section 4.1

4.3.3 Derivation of Safety Requirements (Functionality and Performance – success approach)

See section 4.1

4.3.4 Traceability

4.4 See section

4.5 4.1Analysis of the SPR-level Model – Normal Operational Conditions

See section 4.1

4.5.1 Scenarios for Normal Operations

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See section 4.1

4.5.2 Thread Analysis of the SPR-level Model – Normal Operations

See section 4.1

4.5.3 Effects on Safety Nets – Normal Operational Conditions

See section 4.1

4.5.4 Dynamic Analysis of the SPR-level Model – Normal Operational Conditions

See section 4.1

4.5.5 Additional Safety Requirements (functionality and performance) – Normal Operational Conditions

See section 4.1

4.6 Analysis of the SPR-level Model – Abnormal Operational Conditions

See section 4.1

4.6.1 Scenarios for Abnormal Conditions

See section 4.1

4.6.2 Derivation of Safety Requirements (Functionality and Performance) for Abnormal Conditions

See section 4.1

4.6.3 Thread Analysis of the SPR-level Model - Abnormal Conditions

See section 4.1

4.6.4 Effects on Safety Nets – Abnormal Operational Conditions

See section 4.1

4.6.5 Dynamic Analysis of the SPR-level Model – Abnormal Operational Conditions

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See section 4.1

4.6.6 Additional Safety Requirements – Abnormal Operational Conditions

See section 4.1

4.7 Design Analysis – Case of Internal System Failures

See section 4.1

4.7.1 Causal Analysis

See section 4.1

4.7.2 Common Cause Analysis

See section 4.1

4.7.3 Formalization of Mitigations

See section 4.1

4.7.4 Safety Requirements (integrity/reliability)

See section 4.1

4.8 Achievability of the Safety Criteria

See section 4.1

4.9 Realism of the SPR-level Design

See section 4.1

4.9.1 Achievability of Safety Requirements / Assumptions

See section 4.1

4.9.2 “Testability” of Safety Requirements

See section 4.1

4.10 Validation & Verification of the Safe Design at SPR Level

See section 4.1

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5 Detailed Safe Design at Physical Level

5.1 Scope

The TopMax product will be developed according the hazard classification used for EFVS approaches and the same safety design as for existing HUD will apply (i.e internal monitoring and DAL level as described in *EASA Certification Specifications for Large Aeroplanes CS-25 and ED179/ DO315 document that is currently considered as applicable airworthiness standard by EASA in CRI for EFVS*). Similarly, PM/PF monitoring will be mandated by procedures as for approaches with HUD.

5.2 Description of the Solution Physical Model

See section 5.1

5.3 Detailed Safety Requirements for the physical System design

See section 5.1

5.3.1 Physical design of the technical system (i.e. equipment)

See section 5.1

5.3.2 Procedure Requirements

EFVS operation can be performed by the crew manually or using automatisms (Autopilot and Autothrottle). Per Dassault flight crew procedure, use of automatism is recommended to reduce workload during EFVS operations. Use of automatism is not a requirement, but a recommendation.

5.3.2.1 ATC / Flight Crew

See section 5.1

5.3.2.2 Engineering

See section 5.1

5.3.2.3 Detailed Procedural Safety Requirements

See section 5.1

5.3.3 Competence Requirements

See section 5.1

5.3.3.1 ATC / Flight Crew

See section 5.1

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5.3.3.2 Engineering

See section 5.1

5.3.3.3 Detailed Competence Safety Requirements

See section 5.1

5.4 Correct operation of the physical design

See section 5.1

5.5 Adverse, Emergent Safety Properties

See section 5.1

5.6 Proving the Safety Requirements

See section 5.1

6 Acronyms and Terminology

Term	Definition
AAL	Augmented Approach to Land
AFIS	Advisory Flight information Service
AFM	Airplane Flight Manual
AFIS	Aerodrome Flight Information Service
AHRS	Attitude and Heading Reference System
AOF	Airport Onboard Function
APV	Approach with Vertical Guidance
A/T	Autothrottle
ATC	Air Traffic Controller
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATS	Air Traffic Service
AWO	All Weather Operation
CLL	Centreline Light
CNS	Communication Navigation and Surveillance
CONOPS	Concept of Operations
CPDLC	Controller-Pilot Data Link Communication
CR	Change Request
CRI	Certification Review Item
CVS	Combined Vision System
DEM	Digital elevation Model
DH	Decision Height

EASA	European Aviation Safety Agency
EATMA	European ATM Architecture
E-ATMS	European Air Traffic Management System
EFVS	Enhanced Flight Vision System
EMM	Electronic Moving Map
EVS	Enhanced Vision System
FD	Flight Director
FLIR	Forward Looking Infra-Red
FOR	Field of Regard
FOV	Field of View
FPARC	Flight Path Angle Reference Cue
FPV	Flight Path Vector
HAT	Height Above Threshold
HDD	Head Down Display
HPAR	Human Performance Assessment Report
HMI	Human Machine Interface
HMD	Helmet Mounted Display
HUD	Head Up Display
HWD	Head Worn Display
ICAO	International Civil Aviation Organisation
ILS	Instrument Landing System
IMC	Instrumental Meteorological Conditions
IMU	Inertial Measurement Unit
INTEROP	Interoperability Requirements
IR	Infra-Red
KPA	Key Performance Area

LCD	Liquid Cristal Display
LED	Light Emitting Diode
LNAV	Lateral Navigation
LPV	Localizer Performance with Vertical Guidance
LVC	Low Visibility Conditions
LVP	Low Visibility Procedure
LSD	Large Scale demo
LWIR	Long Wavelength Infrared
METAR	MET Aviation routine Reports
MMR	MilliMetric wave Radar
MWIR	Medium Wavelength Infra-Red
NDB	Non Directional Beacon
NVG	Night Vision Google
OI	Operational Improvement
OPAR	Operational Performance Assessment Report
OSED	Operational Service and Environment Definition
PAR	Performance Assessment Report
PBN	Performance Based Navigation
PF	Pilot Flying
PFD	Primary Flight Display
PIRM	Programme Information Reference Model
PM	Pilot Monitoring
QoS	Quality of Service
RA	Radio Altimeter
RAAS	Runway Awareness Alert System
RNAV	Area Navigation

RVR	Runway Visual Range
RMT	Rulemaking Task
R/T	Radio Telephone
RTCA	Radio Technical Commission for Aeronautics
RVR	Runway Visual Range
RWSL	Runway Status Light
SAC	Safety Criteria
SAR	Safety Assessment Report
SecAR	Security Assessment Report
SESAR	Single European Sky ATM Research Programme
SMGCS	Surface Movement Guidance Control system
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SPR	Safety and Performance Requirements
SVS	Synthetic Vision system
SWIM	System Wide Information Model
SWIR	Short Wavelength Infra-Red
TAF	Terminal Aerodrome Forecast
TDZ	Touchdown Zone
TDZE	Touchdown Zone Elevation
TS	Technical Specification
VGSI	Visual Glide Slope Indicator
VNAV	Vertical Navigation
VMC	Visual Meteorological Conditions
VOR	Visual Omni Range

Table 1: Acronyms and terminology

7 References

Safety

- [1] SESAR AAL2 SESAR, Safety Reference Material, Edition 4.0, April 2016
- [2] EASA Certification Specifications for Large Aeroplanes CS-25
- [3] NPA 2016-08 CS AWO: CSs and Acceptable Means of Compliance for All-Weather Operations
- [4] ED179/ DO 315 produced by EUROCAE WG79/ RTCA SC213 committee
- [5] D4.010: SESAR PJ03a-04 SPR-INTEROP/OSED for V3 – Part I
- [6] ARP5288: Transport Category Airplane Head Up Display (HUD) Systems
- [7] ARP5677: Human Engineering Considerations for Airborne Implementation of Enhanced Synthetic Vision System



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