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SUMO

ENHANCED VISUAL OPERATIONS

This TS/IRS document is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 734153 under European Union's Horizon 2020 research and innovation program.



Abstract

This document is the final version of the V3 Technical Specification (TS/IRS) for the “Enhanced Visual Operations” solution (PJ.03a-04). It collects and describes the functional, non-functional and interface requirements for a Head Mounted Display (HMD) prototype capable of providing operational benefits for Enhanced Flight Vision System (EFVS) and surface guidance.

Additionally the use of Active Sensors as a complement or replacement of traditional passive Infra-Red (IR) sensors is investigated to improve runway detection during EFVS operations. Active sensor work is however not included in the scope of the V3 maturity assessment.

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1 Executive summary

This final version of the V3 Technical Specification (TS/IRS) for the “Enhanced Visual Operations” solution (PJ.03a-04) details the Technical System Requirements (functional, non-functional and interface) which shall guide the development and implementation of a prototype for assessing the benefits of Head Mounted displays (HMD) technology.

The use of HMD augmented with Combined Vision System (CVS) aims at increasing access to secondary airports (by performing affordable low-visibility EFVS operations) as well as improving human performance during surface navigation management in adverse weather conditions. The advantage of HMD compared to conventional Head-Up Displays is the 360° field of view as well as the color display capability. System requirements are derived from the Operational Requirements defined in the PJ03a-04 SPR/INTEROP/OSED [31].

Additionally the use of CVS using active sensors is investigated and translated into requirements, although not comprised in the V3 maturity assessment scope of the solution. Active sensors based on millimeter wave radar (MMWR) will have less dependency to adverse weather conditions than existing legacy Infra-Red sensors and should allow more reliable operations in “all weather” conditions to provide EFVS operational credit on published minima.

HMD and active sensor technologies aim at complementing or replacing current systems based on Head-Up Displays (HUD) and Infra-Red sensors which are considered as the reference baseline and were operationally assessed for landing operations in the frame of Solution #117. A comprehensive description of these legacy and novel technologies is provided in §5.

This final document has been updated along with OSED/SPR/INTEROP with the results of the PJ03a-04 validation exercises.

The outcomes of the validation exercises have confirmed the V3 maturity level of HMD technology during taxi and landing operations despite some non-blocking limitations observed during EFVS flight trials. The validation exercise for active sensor in landing operations has not confirmed V3 maturity level, as expected during project timeframe, because of low sensor maturity.

2 Introduction

In response to the forecast increase in air traffic over the next decades and following safety recommendations issued from regulation authorities (FAA/EASA) [64], [38], a number of advanced technologies are currently under development and operational assessment, among which Equivalent Visual Operations (such as EFVS, SVGS) based on embedded Vision Systems (Head-Up Display, synthetic vision, infrared imagery, etc..).

The main goals of those new operations are to:

- ✓ Improve traffic and access to secondary aerodromes in degraded weather conditions
- ✓ Increase the traffic capacity on main airports (for Active Sensor)

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. Concepts based on the use of solutions such as Head Up Display (HUD) or Helmet Mounted Display (HMD) along with Combined Vision System (CVS) aiming at providing to pilots a realistic view of external environment in bad weather conditions are studied and tested since few years with the goal to achieve the level of taxi performance normally seen VMC in IMC.

With respect to landing operations in low visibility conditions at other than CATII/III aerodromes, the European PBN regulation (EU) 2018/1048 requires the publication of LNAV, LNAV/VNAV and LPV minima by 2020 at runways served by non-precision approaches, and by 2024 at other runways. EFVS operation will fully supports and will complement this PBN strategy expanding access at all airports.

Although EFVS concepts already exist (possibly combined with SVS), the technology on which sensors are based shows variable and unpredictable performances. The use of advanced active sensor at affordable cost is studied with the goal to increase the performances and improve the reliability of the EFVS landing operations to make EFVS “all weather operations” concepts a reality. Relevant requirements and implementation options for this technology are described in Appendix A because is not part of OI aiming at V3 as solution itself.

2.1 Purpose of the document

This document provides the requirements specification covering functional, non-functional and interfaces requirements related to SESAR Solution PJ.03a-04 which addresses Enhanced Visual Operation based on Enhances Vision Systems (EVS) and Synthetic Vision Systems (SVS) to enable more efficient taxi, approach and landing operations in low visibility conditions.

The main goals of the SESAR2020 PJ03a-04 are to assess:

- ✓ The feasibility and benefits of EFVS approach operation using CVS in a colored and monocular HMD, adding terrain, obstacles and runway information to current sensor images.
- ✓ The benefits of CVS fed with surface traffic and ATC clearance information in a colored and monocular HMD for taxi operations in LVC (V3 maturity assessment).

The secondary goal of solution is to initially assess:

- ✓ The feasibility and benefits of active sensors for EFVS approach operation using CVS as combination of SVS and EFVS

Those new features are supposed to improve situational awareness and performances in all weather conditions by adding CVS using HMD and active sensors. The introduction and use of HMD (which is expected to be financially more attractive than HUD as detailed in [32]) is also supposed to enlarge to more aircraft types the accessibility of Head-Up based operations (EFVS) and benefits. The active sensor used is supposed to improve availability of intended CVS approach operation due to various weather conditions.

For more details on operational environment, technical characteristics and technologies involved please refer to section 3.2 of PJ03a-04 SPR/INTEROP/OSED document [31].

The figure below defines the relations of the PJ.03a-04 solution with other SESAR elements as currently defined through EATMA model:

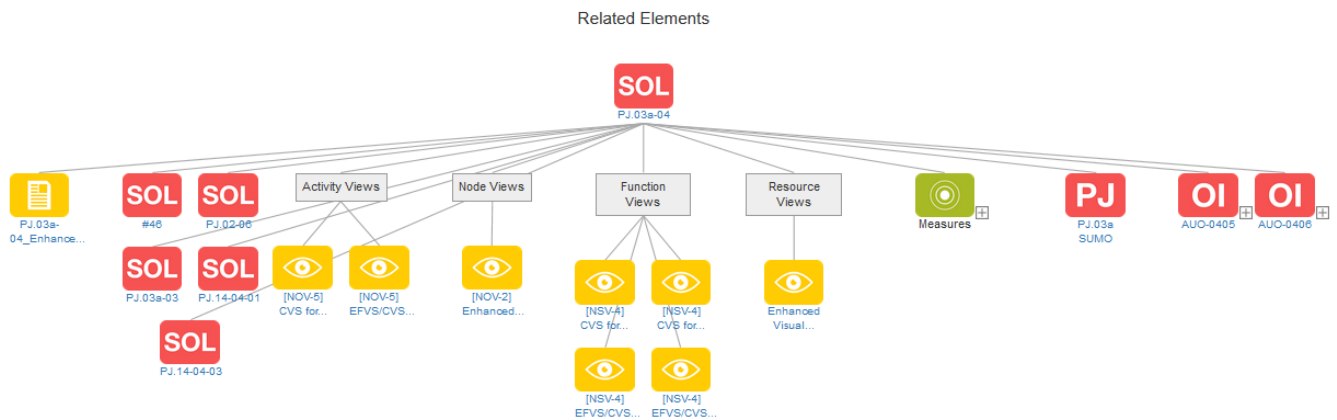


Figure 1: EATMA solution PJ03a-04 context and related elements

2.2 Scope

The scope of this TS/IRS document for SESAR solution PJ03a-04 is to provide:

- The functional description of the technical implementation of the A/C-23b1 and A/C-23b2 enablers (see hereunder §3.2 table 5 for enablers detailed description) over airborne avionics components defined per EATMA model,
- The specification of functional, non-functional and interface requirements allocated to the different architecture components supporting the different expected operational improvements from the implementation of A/C-23b1 and A/C-23b2 enablers.

2.3 Intended readership

This document is intended for various stakeholders in the SESAR Program:

The intended audience for this TS/IRS document is represented by the main Solutions and Projects related to the Solution PJ03-SUMO (Surface management Operation):

- PJ03a-04 for prototype development, V3 Validation Plan and trials
- PJ19 (Content Integration) responsible for managing the content integration process to ensure the needed coherency (in terms of operational concept, architecture) between the different SESAR 2020 projects.
- PJ20 (Master Plan Maintenance) responsible for ATM Master Plan maintenance.
- PJ22 (Validation and demonstration engineering project) responsible for requirements management
- PJ02-05 (Independent Rotorcraft operations at the Airport) responsible for development of Independent Rotorcraft (RC) operations at the airport refer to RC specific approach procedures and SBAS-based point-in-space (PinS), which aim to improve access to secondary airports in Low Visibility Conditions (LVC).
- PJ02-06 (Improved access into secondary airports in low visibility conditions) for supporting the development of OSED/SPR-INTEROP from operational point of view and of secondary airports infrastructure, services and procedures proposed for low visibility operations.
- PJ15 (Common Services) The Common Service approach, if it is proved to be successful, could be viewed as an essential means to improve the overall cost effectiveness of the ATM business in Europe. PJ15 encompasses air navigation service providers and ground industry covering both provider and consumer perspectives. PJ15-10 and PJ15-11 could bring accurate and up-to date airport map in order to fulfil the database needs required for taxi guidance with HMD.
- PJ.18-04a (Management and sharing of data used in trajectory (AIM)) is a provider of aeronautical data necessary via AIXM format for aircraft vision system using active sensor. In addition PJ18-04a could contribute to enhance the predictability of successful approach by providing accurate weather data on destination airport, allowing the crew to decide whether the RVR will permit EFVS 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.

2.4 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 (LIDAR) and MMW radar, although LIDAR has been demonstrated to perform poorly in adverse weather conditions.

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.

Solution 117 : Solution 117 has been introduced in SESAR in 2018 to reflect the existing capability of aircraft equipped with EFVS technology to access to non CATII/III airport in degraded weather conditions. Although a significant part of jets are certified for EFVS operation as per (UE) n° 965/2012 regulation since 2010, SESAR projects were set up either to address ATM/ ATC/ aerodrome aspects (AAL1 and AAL2) to support regulation improvement and speed up large deployment of current EVS and future EFVS to land operations, or to continue research on new sensor technologies for enhance performances (PJ03a-04), or even to assess the potential of HMD as an alternative to HUD in the perspective to have more aircraft/ users capable of that EFVS operation (PJ03a-04).

2.5 Structure of the document

The structure of this document is as follows:

- **Section 1 – Executive summary:** It describes the scope and purpose of the Solution PJ03a-04 as well as a summary of results, conclusions and recommendations.
- **Section 2 – Introduction:** It details the purpose and the scope of the document. This section is also intended to provide an overview of previous activities relevant for SESAR Solution PJ03a-04 and all the Solutions and Projects that could be interested in reading this document.
- **Section 3 – SESAR Solution Impacts on Architecture:** It describes the Functional Blocks included in the Solution as well as the Capability Configurations and the changes from the architecture in EATMA, if needed.
- **Section 4 – Technical Specifications:** It describes the function needed to realize the Solution, provides a functional view of how the technical system participates in realizing the operational needs and lists the function technical requirements.
- **Section 5 – Implementation Options:** It describes the options, if available, that can be chosen when implementing the solution using capability configurations and sub-operating environments.
- **Section 6 – Assumptions:** It covers any assumption made about impacts on the technical specifications described in Section 4.
- **Appendix A – Active Sensor:** Active sensor relevant requirements

2.6 Glossary of terms

Term	Definition	Source of the definition
EFVS	An Enhanced Flight Vision System is an electronic means to provide the flight crew with a real-time sensor-derived or enhanced display of the external scene topography (the natural or manmade features of a place or region especially in a way to show their relative positions and elevation) through the use of imaging sensors; an EFVS is integrated with a flight guidance system and is implemented on a head-up display or an equivalent display system. The term EFVS is introduced in RMT0379 to describe a system that can be used for operational credits as opposed to ‘EVS’, which refers to a system to be used only for improved situational awareness (see definitions in Annex I).	EASA NPA 2018-06 (RMT0379)
HUD	An head-up display (HUD) or equivalent display system’ means a display system which presents flight information to the pilot’s forward external field of view and which does not significantly restrict the external view	EASA NPA 2018-06 (RMT0379)
CVS	Combined Vision Systems (CVS) combine a real-time imaging sensor and display with a synthetic image generated using a terrain and obstacle database using	EASA NPA 2018-06 (RMT0379)

	a precision navigation position. Where EFVS is part of a CVS, it is only the EFVS element that should provide the operational credits. The other part of the CVS, the SVS, should not provide operational credits	
HWD / HMD	An HMD (Head Mounted Display) also called HWD (Head-Worn Display) is a display system worn on the pilot's head that projects primary flight information (e.g. attitude, air data, and guidance) in alphanumeric and/or symbolic form to one or both pilot's eyes on a transparent screen (i.e., visor) along the pilot's dynamically changing line of sight. An HWD/HMD might also display vision system imagery. An HWD/HMD that is to be used as a HUD equivalent includes a head tracking function (HTF) to monitor the pilot's head location and line of sight so that the display can adjust in real time with head movements and enable the effective display of information over a wide field of regard	<i>SAE ARP 6377 (draft)</i>

Table 1: Glossary

2.7 Acronyms and Terminology

Term	Definition
ADD	Architecture Description Document
AESA	Active Electronically Scanner Array
AIM	Aeronautical Information management
ATM	Air Traffic Management
CC	Capability Configuration
CVS	Combined Vision System
EATMA	European ATM Architecture
E-ATMS	European Air Traffic Management System
EFVS	Enhanced Flight Vision System
EVS	Enhanced Vision System
FAA	Federal Aviation Administration

GBAS	Ground Based Augmentation System
HMD	Head Mounted Display
HWD	Head Worn Display
IER	Information Exchange Requirement
IMC	Instrument Meteorological Conditions
INTEROP	Interoperability Requirements
IRS	Interface Requirements Specification
ISRM	Information Services Reference Model
LNAV	Lateral Navigation
LWIR	Long-wavelength infrared
MCMF	Multi Constellation Multi Frequency
MMW	Millimetre Wave
MWIR	Medium-wavelength infrared
NAF	NATO Architecture Framework
NSOV	NAF Service Oriented View
NOV	NAF Operational View
NSV	NAF System View
OSED	Operational Service and Environment Definition
PESA	Passive Electronically Scanner Array
PF	Pilot Flying
PIRM	Programme Information Reference Model
PM	Pilot Monitoring
PNF	Pilot Non Flying
QoS	Quality of Service
RADAR	Radio Detection And Ranging
RVR	Runway Visual Range
SDD	Service Description Document
SESAR	Single European Sky ATM Research Programme

SJU	SESAR Joint Undertaking
SoaML	Service Oriented Architecture Modelling Language
SPR	Safety and Performance Requirements
SVS	Synthetic Vision System
SWIM	System Wide Information Model
SWIR	Short-wavelength infrared
TDZE	Touch Down Zone
TRL	Technology Readiness Level
TS	Technical Specification
UML	Unified Modelling Language
V&V	Validation and Verification
VMC	Visual Meteorological Conditions
VNAV	Vertical Navigation
WSDL	Web Services Definition Language
XSD	XML Schema Definition

Table 2: Acronyms and terminology

3 SESAR Solution Impacts on Architecture

3.1 Target Solution Architecture

The approach part of solution was originally covered by OI AUO-0405 Equivalent Visual Landing operations in Low Visibility and Enabler A/C-23b1 Combined Vision for Equivalent Visual Landing operations in LVC. These elements didn't distinguish between different technologies Head-Mounted display and active sensor considered under the solution.

Because these technologies bring significantly various benefits and active sensor was on different maturity the solution decided to split two technologies under two different operational improvement steps and enablers. Therefore, original OI AUO-0405 and EN A/C-23b1 were updated and define HMD as supporting technology. Simultaneously, change requests CR 02774 and CR 02775 proposing a creation of OI (AUO-0410) and EN (A/C-23b4) for active sensor are in the pipeline for future development.

The taxi phase is without any changes in OI and EN and reflects only Head-Mounted display technology.

3.1.1 SESAR Solution(s) Overview

SESAR Solution ID and Title	Functional Blocks/Role impacted by the SESAR Solution (from EATMA)	Enabler ID (from EATMA)	Enabler Title (from EATMA)	Enabler coverage
PJ03a-04 Enhanced Visual Operations	Lateral and Vertical Guidance Flight Crew	A/C-23b1	Combined Vision for Equivalent Visual Landing operations in LVC with HMD	Fully
PJ03a-04 Enhanced Visual Operations	Airport Surface Navigation Flight Crew	A/C-23b2	Combined Vision for Equivalent Visual Taxi operations in LVC	Fully
PJ03a-04 Enhanced Visual Operations	Lateral and Vertical Guidance Flight Crew	A/C-23b4 (under change request)	Combined Vision for Equivalent Visual Approach operations using active sensor operations in LVC	Partially

Table 3: SESAR Solution PJ03a-04 Scope and related Functional Blocks/roles & Enablers

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

Cf §3.1, regarding split of enablers.

3.1.1.2 Relevant Use Cases

Relevant operational use cases are detailed in OSED [31] §3.3.2.1

3.1.1.3 Applicable standards and regulations

Applicable Standards and regulations applicable to enhanced vision systems and associated operations are extracted from OSED [31] §3.2.4 and recalled hereunder for information:

EASA Regulations:

- ✓ **EASA NPA 2018-06**, 2018 (in progress under RMT0379)

The EASA NPA No 216/2008 attempts to update the All Weather Operations (AWO) rules in all aviation domains, as regards possibility of applying safety performance principle in redrafting of current rules with the aim of allowing a better integration of **new and future technologies** supporting AWOs, as e.g. enhanced flight vision systems (EFVSs), synthetic vision systems (SVSs), synthetic vision guidance systems (SVGs), combined vision systems (CVSs), and head-up displays (HUDs).

In the context of the RMT0379 in charge of the NPA, the operations with **EFVS/CVS** and the special approval (SA) CAT I operations are **primarily addressed** as operations with **operational credits**.

As a result of the task, the European industry should be enabled to take full advantage of **safety** and **economic benefits** generated through new technologies and operational experience.

Per standard EASA rulemaking process described here below, the RMT0379 has started in 2015 and will end in **2020**.



Figure 2 EASA regulation process milestone

- ✓ EASA current Regulation (EU) 965/2012 on air operations rev 8, 2017. Will be replaced by NPA 2018-06, when published

ICAO standard documents:

- ✓ ICAO Annex 6 (Operation of Aircraft, including EFVS operations) to the Chicago Convention on International Civil Aviation, 9th Edition, July 2016
- ✓ ICAO Annex 3 (Meteorological Service for International Air Navigation) to the Chicago Convention on International Civil Aviation, 6th Edition, July 2007

- ✓ ICAO Annex 11 (Air Traffic Services) to the Chicago Convention on International Civil Aviation, 13th Edition, July 2001
- ✓ ICAO Document 9365, DOC — Manual of All-Weather Operations, 3th Edition, 2013
- ✓ ICAO Document 4444, PANS — Air Traffic Management, 15th Edition, 2007
- ✓ ICAO EUR Doc 013 — European Guidance Material On Aerodrome Operations Under Limited Visibility Conditions

RTCA/ EUROCAE standard documents (SC213/ WG79 Working group):

- ✓ EUROCAE ED-179 — Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems, 2008
- ✓ RTCA DO-315A — Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems, 2010
- ✓ RTCA DO-359 — Minimum Aviation System Performance Standard (MASPS) for Synthetic Vision Guidance Systems, 2015
- ✓ RTCA DO-341 — Minimum Aviation System Performance Standards (MASPS) for an Enhanced Flight Vision System to Enable All-Weather Approach, Landing and Roll-Out to a Safe Taxi Speed, 2012
- ✓ RTCA DO-371 — Minimum Aviation System Performance Standards (MASPS) for Aircraft State Awareness Synthetic Vision Systems, 2018

SAE International documents:

- ✓ SAE International ARP-5677 — Human Engineering Considerations for Airborne Implementation of Enhanced Synthetic Vision Systems, 2012
- ✓ SAE International ARP-5288 — Transport Category Airplane Head Up Display (HUD) Systems
- ✓ SAE International ARP 6377 - Head Worn Display (HWD) Systems
- ✓ SAE International AS 8055A - Minimum Performance Standard for Airborne Head Up Display (HUD)
- ✓ SAE International AS 5703 - Minimum Performance Standard for Enhanced Vision System

FAA documents:

- ✓ 14-CFR (§ 91.176...) Straight-in landing operations below DA/DH or MDA using an enhanced flight vision system (EFVS) under IFR, Dec 2016
- ✓ FAA Advisory circular AC 90-106A Enhanced Flight Vision Systems, 2017

- ✓ FAA Advisory circular AC 20-167A Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment, 2016

3.1.2 Capability Configurations required for the SESAR Solution

SESAR Solution ID and Title	Capability Configurations (CCs) (from EATMA)	Sub-Operating Environment(s) where the CCs operate	Capabilities (from EATMA)	Nodes (from EATMA)	Stakeholders (from EATMA)
PJ03a-04 Enhanced Visual Operations	Civil Aircraft	TMA/Airport High, Medium or Low Capacity needs	Aerodrome Operations /Airport Situational Awareness provisions/ Adverse Condition Operations Provision	Flight Deck	AU-CIV-BA-F
PJ03a-04 Enhanced Visual Operations	APP ACC	TMA/Airport High, Medium or Low Capacity needs	Arrival/Departure Routes Management	En-Route/Approach ATS	ANSP-CIV-APP
PJ03a-04 Enhanced Visual Operations	Tower	TMA/Airport High, Medium or Low Capacity needs	Aerodrome Operations /Airport Situational Awareness provisions/ Adverse Condition Operations Provision Aerodrome Operations /Surface Guidance and routing/ Surface Route management	Aerodrome ATS	ANSP-CIV-AERO

PJ03a-04 Enhanced Visual Operations	Navigation Infrastructure Satellite based.	N/A	N/A	N/A	N/A
PJ03a-04 Enhanced Visual Operations	Aerodrome ATM-MET	TMA/Airport High, Medium or Low Capacity needs	Meteorological Observation and Forecasting Provision	Meteorological Service Provision	ANSP-CIV-MET
PJ03a-04 Enhanced Visual Operations	Communication Infrastructure	N/A	Airport Operations Management	Aerodrome ATS	ANSP-CIV-CNS

Table 4: List of Capability Configuration required for the SESAR Solution

3.2 Changes imposed by the SESAR Solution on the baseline Architecture

The approach part of solution originally covered OI AUO-0405 Equivalent Visual Landing operations in Low Visibility and Enabler A/C-23b1 Combined Vision for Equivalent Visual Landing operations in LVC. These elements didn't distinguish between different technologies Head-Mounted display and active sensor considered under the solution.

Because these technologies bring significantly various benefits and active sensor was on different maturity the solution decided to split two technologies under two different operational improvement steps and enablers. Therefore, original OI AUO-0405 and EN A/C-23b1 were updated and define HMD as supporting technology. Simultaneously, change requests CR 02774 and CR 02775 proposing a creation of OI (AUO-0410) and EN (A/C-23b4) for active sensor are in the pipeline for future development.

The taxi phase is without any changes in OI and EN and reflects only Head-Mounted display technology.

Enabler ID (from EATMA)	Enabler Title (from EATMA)	Changes
A/C-23b1	Combined Vision for Equivalent Visual Landing operations in LVC with HMD	Enabler allowing the combination of EFVS (operational credit by initial required RVR reduction) and SVS (situational awareness) combination on HMD to perform approach operations in low visibility conditions in order to improve accessibility to airports in bad weather. The implementation of this capability requires: ✓ On-board installation of a HMD with conformal
	Combined Vision for Equivalent	

	Visual Landing operations in Low Visibility Conditions: the operational credit is provided by enhancing awareness and lowering approaching limits by the equivalent visual operation through a Head Mounted Display (HMD).	projection of synthetic elements (SVS, runway) and non-conformal projection of flight parameters (speed, altitude, attitudes, deviations, etc..) ✓ On-board installation of a sensor allowing detection of runway/airport visual references and conformal projection on HMD ✓ On-board installation of manual control of SVS/EFVS brightness and automatic EFVS image/SVS fusion display ✓ On-board installation of manual mean to activate/de-activate the display of CVS elements ✓ On-board terrain and runway databases ✓ On-board recording capabilities for CVS operations specific parameters
A/C-23b2	Combined Vision for Equivalent Visual Taxi operations in LVC Combined Vision for Equivalent Visual Taxi operations in Low Visibility Conditions: 'Out the window' positional awareness is improved through the application of visual enhancement technologies, with the potential for increasing taxi time efficiency and safety margins.	Enabler allowing the combination of EFVS (operational credit by RVR reduction), SVS (situational awareness) and Airport navigation specific graphical elements combination on HMD to perform taxi and navigation operation on airports in low visibility conditions. The implementation of this capability requires: Same evolutions as mentioned here above, plus: ✓ On-board conformal display of following graphical elements: ground path according to ATC clearance, signs of turn or hold indications, surrounding traffic information ✓ Specific phraseology with tower ATC for clearances on surface navigation and taxi ✓ On-board databases for introduction of specific airport features ✓ On-board recording capabilities for specific parameters
A/C-23b4	Combined Vision for Equivalent Visual Approach operations using active sensor	Enabler created to account for different maturity levels between Infra-Red (IR) and active sensor technologies for EFVS operation. While IR is only a passive system, active sensor accounts for power emission and reflection to increase the runway detection by the pilot.

	Improved performance of Combined Vision System in low visibility conditions for equivalent visual approach operation to 100ft by active sensor.	
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Table 5: List of changes due to the SESAR Solution

4 Technical Specifications

4.1 Functional architecture overview

According to use cases described in §3.1.1.2, four different functional architectures are described in this section:

- ✓ [NSV-4] CVS for taxi and airport surface navigation using HMD-CPDLC
- ✓ [NSV-4] CVS for taxi and airport surface navigation using HMD-voice
- ✓ [NSV-4] EFVS/CSV operation with HMD
- ✓ [NSV-4] EFVS/CSV operation with Active Sensor

Role	Functional Block	Function
[NSV-4] CVS for taxi and airport surface navigation using HMD-CPDLC		
	Airport Surface Navigation (PJ.03a-04)	Compute Taxi Guidance; Process Data Input;
	Combined Vision System	Head Mounted Display (HMD) Vision;
Flight Crew (PJ.03a-04)		Input Data in Airport Surface Navigation; Process Taxi Clearance; Request Taxi Clearance; Taxi Aircraft;
	Sensors and Antennas	Sensors and Antennas;
[NSV-4] CVS for taxi and airport surface navigation using HMD-voice		
	Airport Surface Navigation (PJ.03a-04)	Compute Taxi Guidance; Process Data Input;
	Combined Vision System	Head Mounted Display (HMD) Vision;
Flight Crew (PJ.03a-04)		Input Data in Airport Surface Navigation; Process Taxi Clearance; Request Taxi Clearance; Taxi Aircraft;
	Sensors and Antennas	Sensors and Antennas;
[NSV-4] EFVS/CSV operation with Active Sensor		

	Combined Vision System	Acquire required visual references by Active Sensor; Head Up display (HUD);
	Databases	Databases;
Flight Crew (PJ.03a-04)		Check Acquisition of Direct View of Runway; Detect visual cues in EFVS; Ensure Low Visibility procedures are in force; Initiate Go-Around; Process Pre-Flight Briefing; Process RVR; Request RVR;
	Sensors and Antennas	Sensors and Antennas;
[NSV-4] EFVS/CVS operation with HMD		
	Combined Vision System	Head Mounted Display (HMD) Vision;
	Databases	Databases;
Flight Crew (PJ.03a-04)		Check Acquisition of Direct View of Runway; Detect visual cues in EFVS; Ensure Low Visibility procedures are in force; Initiate Go-Around; Process Pre-Flight Briefing; Process RVR; Request RVR;
	Sensors and Antennas	Sensors and Antennas;

Table 6: SESAR Solution PJ03a-04 functional architecture overview

4.1.1 Resource Connectivity Model

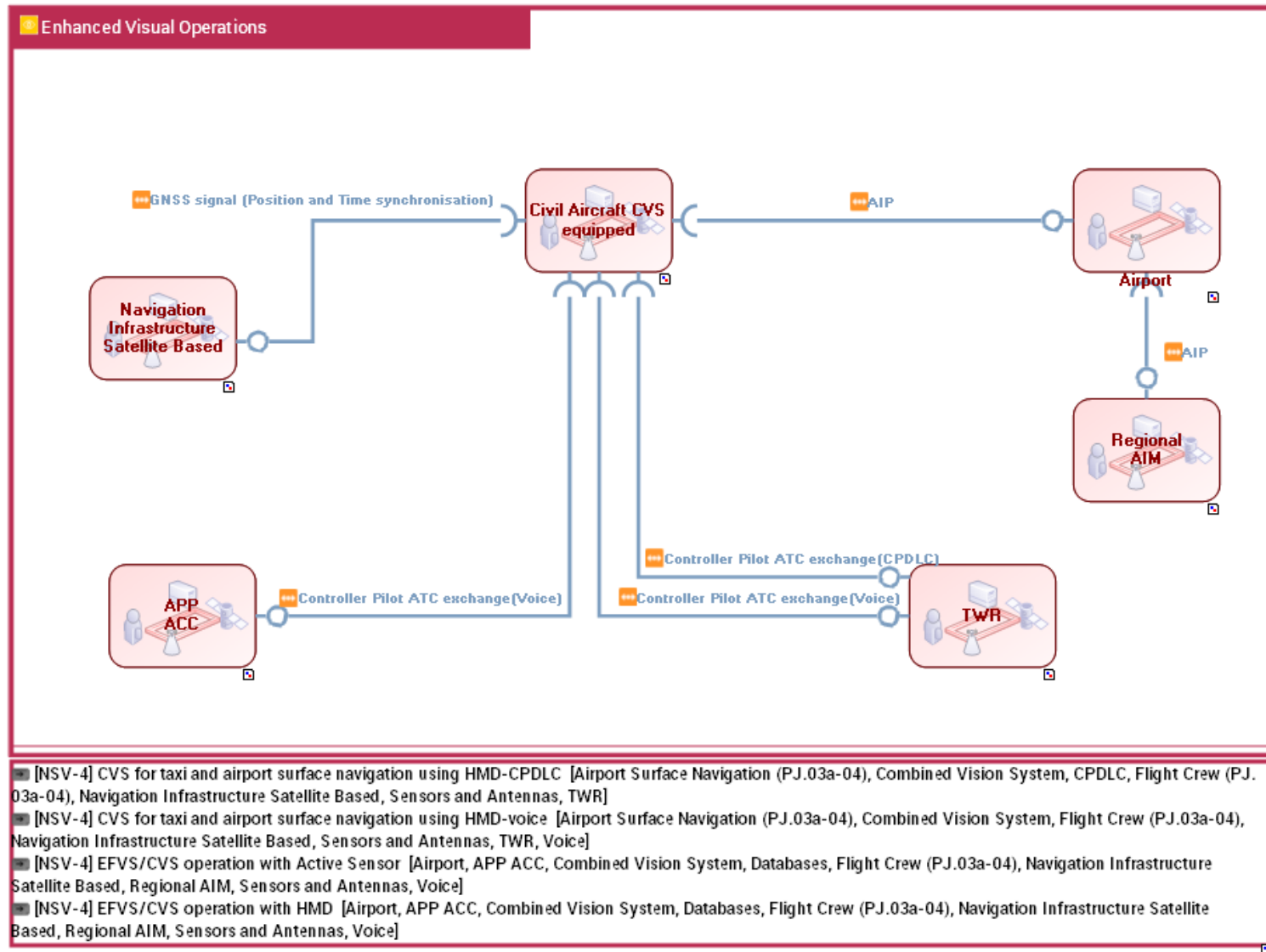


Figure 3: Resource connectivity model for enhanced visual operations

4.1.2 Resource Orchestration view

4.1.2.1 [NSV-4] CVS for taxi and airport surface navigation using HMD-voice

Use Case Environment:

The aircraft is ready for departure at the gate on a large airport with numerous runways/taxiways and dense traffic.

Assumptions:

- The aircraft is fitted with an Head-Mounted Display (HMD)
- The aircraft avionics is either:
 1. Providing a crew interface to input the taxi clearance into the system
 2. Capable of directly recovering digital taxi clearance information through CPDLC
- The aircraft is fitted with an up-to-date A816-2 compliant airport database,
- The aircraft is fitted with an ADS-B receiver capable of forwarding the surrounding traffic information to the HMD.

Pre-conditions:

- The aircraft is at the gate, ready for push-back and departure, in radio contact with ground control.
- The PF is using an HMD with taxi route guidance and traffic display capability enabled.
- A GPS position of the aircraft is available.

Post-conditions Success End State:

- The PF is taxiing the aircraft along the cleared taxi route while keeping its eyes-out during all taxi

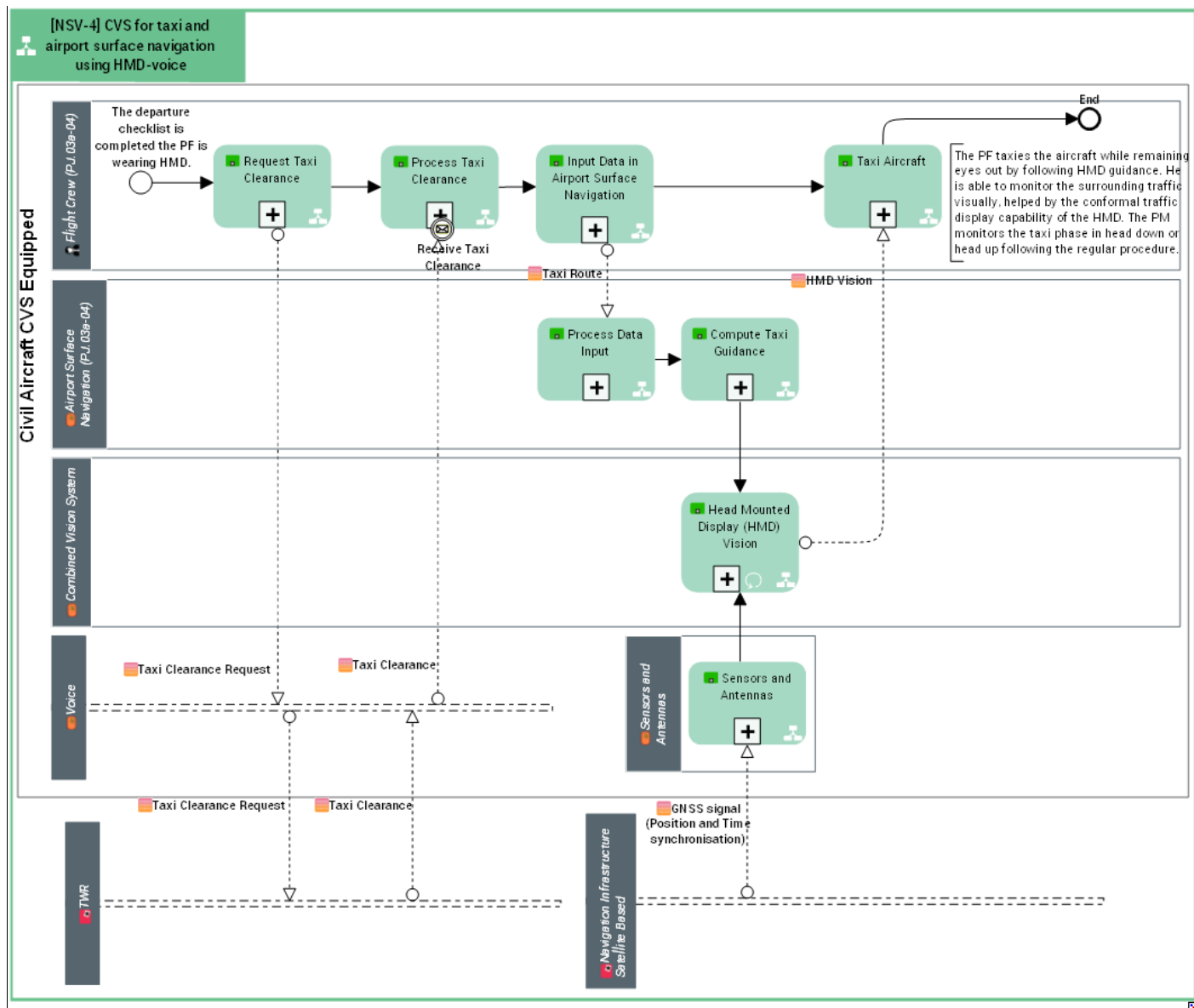


Figure 4: Resource orchestration view for “CVS for taxi and airport surface navigation using HMD-voice”

Function	Description
Compute Taxi Guidance	Based on the input taxi clearance and airport database the aircraft system computes taxi guidance based on current aircraft position
Head Mounted Display (HMD) Vision	Helmet mounted displays (HMD), although named head-worn displays (HWDs), aim at providing the crew with an unlimited Filed of View displayed symbology associated to an eyes out solution. In addition to primary flight symbology a number of different information linked to the mission may be plotted including terrain, mission targets, waypoints, IR or enhanced image.....
Input Data in Airport Surface Navigation	Flight Crew input data into Airport Surface Navigation
Process Data Input	Process inputs and update data as needed
Process Taxi Clearance	Flight Deck processes Taxi Clearance in order to input it into the avionics system
Request Taxi Clearance	Flight Crew requests Taxi Clearance
Sensors and Antennas	The function related Sensors and Antennas capabilities.
Taxi Aircraft	Flight Crew taxies the aircraft

4.1.2.2 [NSV-4] CVS for taxi and airport surface navigation using HMD-CPDLC

It is the same use case as [NSV-4] CVS for taxi and airport surface navigation using HMD, however, taxi clearance is provided through CPDLC.

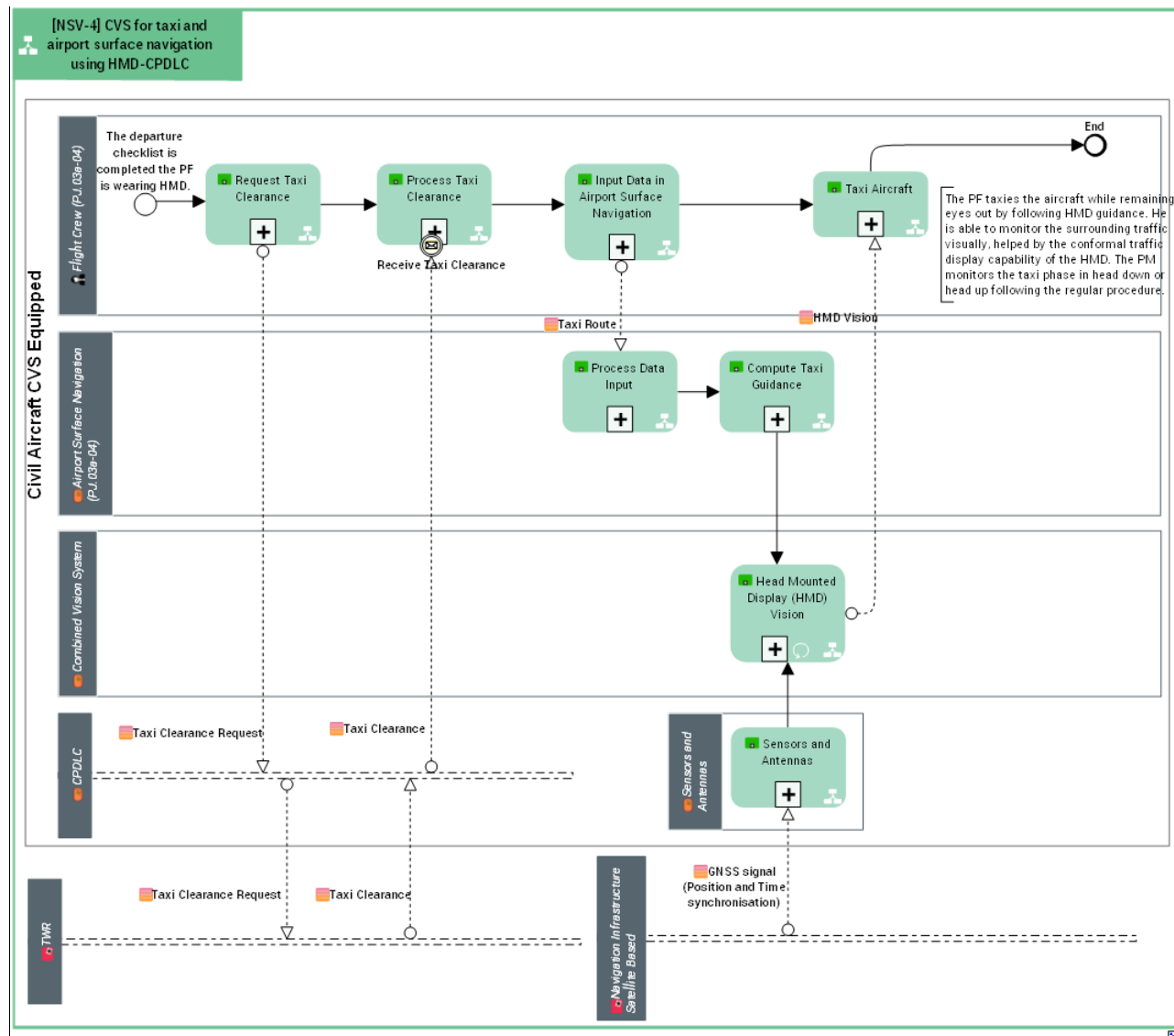


Figure 5: Resource orchestration view for “CVS for taxi and airport surface navigation using HMD-CPDLC”

Function	Description
Compute Taxi Guidance	Based on the input taxi clearance and airport database the aircraft system computes taxi guidance based on current aircraft position
Head Mounted Display (HMD) Vision	Helmet mounted displays (HMD), although named head-worn displays (HWDs), aim at providing the crew with an unlimited Filed of View displayed symbology associated to an eyes out solution. In addition to primary flight symbology a number of different information linked to the mission may be plotted including terrain, mission targets, waypoints, IR or enhanced image.....
Input Data in Airport Surface Navigation	Flight Crew input data into Airport Surface Navigation
Process Data Input	Process inputs and update data as needed
Process Taxi Clearance	Flight Deck processes Taxi Clearance in order to input it into the avionics system
Request Taxi Clearance	Flight Crew requests Taxi Clearance
Sensors and Antennas	The function related Sensors and Antennas capabilities.
Taxi Aircraft	Flight Crew taxies the aircraft

4.1.2.3 [NSV-4] EFVS/CVS operation with Active Sensor

Use Case Environment

The aircraft is in approach and ready for landing at small or medium airport taking credit of EFVS regulation. A published IAP will be selected. Continuation of the approach below the published DA/H will be achieved using EFVS with Active Sensor.

Assumptions

- The aircraft is fitted with an Active Sensor and associated controls
- The aircraft is fitted with an HUD and associated controls Pre-conditions
 - The aircraft is in the air and stabilized in final instrument segment of a published Instrument Approach Procedure
 - The PF is using the Active Sensor with EFVS/CVS and basic flight information displayed

- The airport and the Instrument Approach Procedure have been checked as suitable for the EFVS operations with operational credit (during flight preparation)
- The actual RVR measurement announced by the ATC is consistent with operational credit granted during EFVS approval

Post-conditions Success End State

- The PF is continuing the approach below published DA/H taking credit of EFVS from Active Sensor and land the aircraft

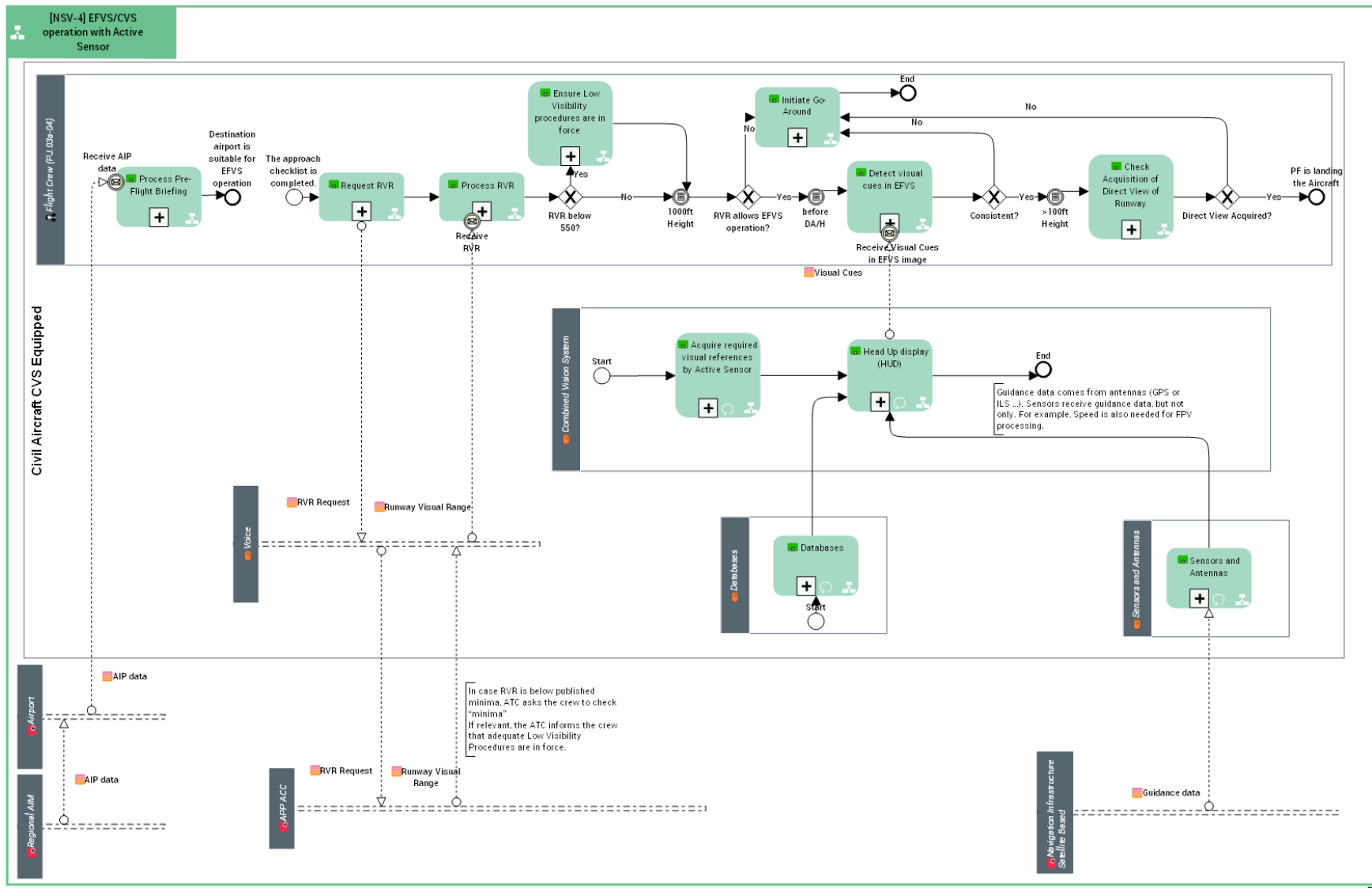


Figure 6: Resource orchestration view for "EFVS/CVS operations with active sensor"

Function	Description
Acquire required visual references by Active Sensor	The active sensor is implemented as option to all existing EFVS products in service in civil aviation which are passive. Traditional passive sensors only detect emissions from the landscape (in different wavelengths ranging from far IR to visible light). Active sensors will illuminate the scene at a variety of visible or invisible wavelengths) in order to maximize the power reflected by the different runways objects. Active sensor can use different technologies (radar, LIDAR, ..) and wavelengths. The new types of active sensor enable the EFVS/ CVS operations with help of detecting of the required visual references during approach phase. The main benefit of using active sensors as EFVS/ CVS sensors is better penetrability in adverse environment compare to passive sensors like infrared sensors. Therefore, the new active sensors are less sensitive on various external weather conditions and thereby provide better reliability of EFVS/ CVS operation. The active sensors are also able to combine multiple functionalities such as weather, object detection, runway detection, and other functions. This enables to concentrate more function supporting weather, obstacles, taxiways awareness inside the one sensor unit. This complex sensor mainly reduces costs and issues related with installation, maintaining and carrying more units at one time.
Check Acquisition of Direct View of Runway	No later than 100ft, PF checks that he has acquired a direct view of the runway without reliance to EFVS
Databases	Onboard A/C databases (e.g. airport, navigation and terrain data bases). Some may require periodic updates based on AIRAC cycle
Detect visual cues in EFVS	At DA/DH, the crew checks that visual cues are acquired through HUD in EFVS and that EFVS and HUD are consistent.
Ensure Low Visibility procedures are in force	Flight Crew ensures Low Visibility procedures are in force
	An head-up display (HUD) or equivalent display system' means a display system which presents flight information to the pilot's

Head Up display (HUD)	forward external field of view and which does not significantly restrict the external view.
Initiate Go-Around	Flight Crew initiates Go-Around manoeuvre
Process Pre-Flight Briefing	Among others, Flight Crew processes AIP data to check suitability of EVFS operation at Destination Airport data
Process RVR	Flight Crew processes Runway Visual Range
Request RVR	The crew requests from ATC the RVR.
Sensors and Antennas	The function related Sensors and Antennas capabilities.

4.1.2.4 [NSV-4] EFVS/ CVS operation with HMD

Use Case Environment

The aircraft is in approach and ready for landing at small or medium airport taking credit of EFVS regulation. A published IAP will be selected. Continuation of the approach below the published DA/H will be achieved using EFVS in HMD (equivalent HUS system).

Assumptions

- The aircraft is fitted with an Head-Mounted Display (HMD) and associated controls
- The aircraft is fitted with an EVS camera and associated controls

Pre-conditions

- The aircraft is in the air and stabilized in final instrument segment of a published Instrument Approach Procedure
- The PF is using the HMD with EFVS/ CVS and basic flight information displayed
- The airport and the Instrument Approach Procedure have been checked as suitable for the EFVS operations with operational credit (during flight preparation)
- The actual RVR measurement announced by the ATC is consistent with operational credit granted during EFVS approval

Post-conditions Success End State

- The PF is continuing the approach below published DA/H taking credit of EFVS in HMD and land the aircraft

Function	Description
Check Acquisition of Direct View of Runway	No later than 100ft, PF checks that he has acquired a direct view of the runway without reliance to EFVS
Databases	Onboard A/C databases (e.g. airport, navigation and terrain data bases). Some may require periodic updates based on AIRAC cycle
Detect visual cues in EFVS	At DA/DH, the crew checks that visual cues are acquired through HUD in EFVS and that EFVS and HUD are consistent.
Ensure Low Visibility procedures are in force	Flight Crew ensures Low Visibility procedures are in force
Head Mounted Display (HMD) Vision	Helmet mounted displays (HMD), although named head-worn displays (HWDs), aim at providing the crew with an unlimited Filed of View displayed symbology associated to an eyes out solution. In addition to primary flight symbology a number of different information linked to the mission may be plotted including terrain, mission targets, waypoints, IR or enhanced image.....
Initiate Go-Around	Flight Crew initiates Go-Around manoeuver
Process Pre-Flight Briefing	Among others, Flight Crew processess Weather at Destination Airport data
Process RVR	Flight Crew processess Runway Visual Range
Request RVR	The crew requests from ATC the RVR.
Sensors and Antennas	The function related Sensors and Antennas capabilities.

4.1.3 Infrastructure connectivity model

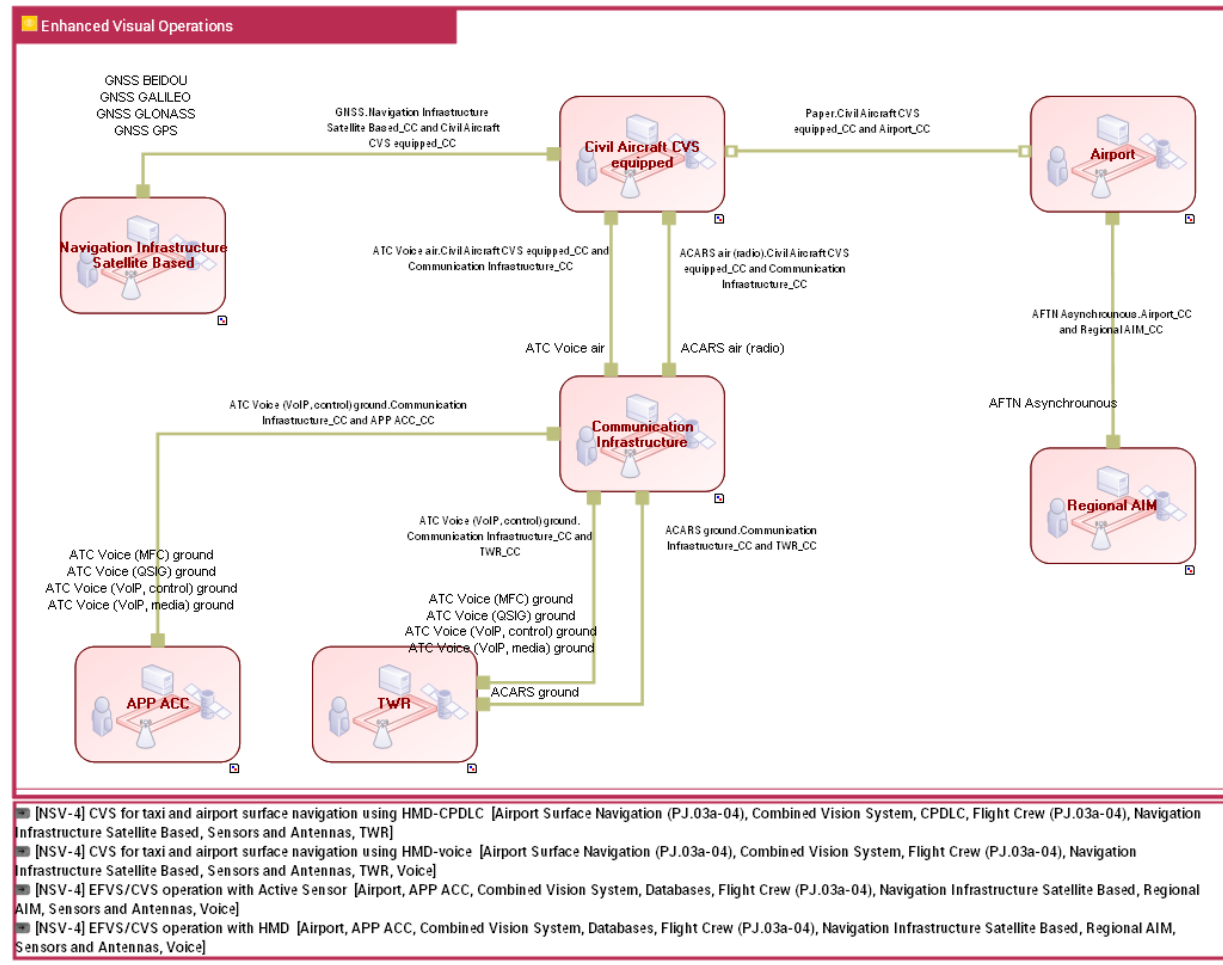


Figure 8: Infrastructure connectivity model diagram

4.1.4 Service view

4.1.4.1 Service description

No new service is required by the solution.

4.1.4.2 Service Provisioning

Interaction	Consumer CC	Consumer System	Provider CC	Provider System
AIP.Civil Aircraft CVS equipped_CC and Regional AIM_CC	Civil Aircraft CVS equipped	Aircraft;	Regional AIM	AIM;
GNSS signal (Position and Time synchronisation).Civil Aircraft CVS equipped_CC and Navigation Infrastructure Satellite Based_CC	Civil Aircraft CVS equipped	Aircraft;	Navigation Infrastructure Satellite Based	GPS (External); GALILEO (External); GLONASS (External); BEIDOU (External);
Controller Pilot ATC exchange(CPDLC).Civil Aircraft CVS equipped_CC and TWR_CC	Civil Aircraft CVS equipped	Aircraft;	TWR	
Controller Pilot ATC exchange(Voice).Civil Aircraft CVS equipped_CC and APP ACC_CC	Civil Aircraft CVS equipped	Aircraft;	APP ACC	Voice;
Controller Pilot ATC exchange(Voice).Civil Aircraft CVS equipped_CC and TWR_CC	Civil Aircraft CVS equipped	Aircraft;	TWR	Voice;

Table 7: SESAR Solution PJ03a-04 service provisioning description

4.1.4.3 Service Realization

- Interaction AirportMETForecast Service.Civil Aircraft CVS equipped_CC and Aerodrome ATM-MET_CC
- Interaction Controller Pilot ATC exchange(CPDLC).Civil Aircraft CVS equipped_CC and TWR_CC
- Interaction Controller Pilot ATC exchange(Voice).Civil Aircraft CVS equipped_CC and APP ACC_CC
- Interaction Controller Pilot ATC exchange(Voice).Civil Aircraft CVS equipped_CC and TWR_CC
- Interaction GNSS signal (Position and Time synchronisation).Civil Aircraft CVS equipped_CC and Navigation Infrastructure Satellite Based_CC

4.2 Functional and non-Functional Requirements

The chapter defines Functional, Non-Functional (ie Human Performances, Safety,...) and interface requirements for solution assessing HMD for V3. Requirements relevant to active sensor not achieving V3 maturity are in Appendix A.

4.2.1 General requirements

[REQ]

Identifier	REQ-03a.04-TS-GEN.0101
Title	CVS display on HMD
Requirement	The HMD shall be able to display to pilots a blended CVS (Combined Vision System) image to improve external world view whatever the meteorological conditions. This image shall be composed of: ✓ SVS (Synthetic Vision System) depicting surrounding environment ✓ EVS (Enhanced Vision System) depicting surrounding lights based on an infrared sensor installed on aircraft.
Status	<validated>
Rational	Perform EFVS operations (EVS) and improve surrounding environment awareness (SVS). This requirement is generic (no detail on specific symbology) as it addresses both landing and taxi phases.
Category	<Functional>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0001
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0002
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDT.0003
< ALLOCATED_TO >	<Enabler>	A/C23b1
< ALLOCATED_TO >	<Enabler>	A/C23b2
< ALLOCATED_TO >	<Functional Block>	Displays and Controls

[REQ]

Identifier	REQ-03a.04-TS-GEN.0102
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Founding Members

Title	Latency performance for displayed elements
Requirement	The maximum allowable latency between head motion and display of an image affected by this motion shall be compliant with pilot comfort acceptable criteria.
Status	<validated>
Rational	Acceptable retard of image display vs head motion based only on pilot feedback. Indeed the regulation (AC20-167A) states that : <i>Any lag introduced by the display system should be consistent with the aircraft control task associated with that parameter. In particular, display system lag (including the sensor) for attitude which does not exceed a first order equivalent time constant of 100 milliseconds for aircraft with conventional control system response is generally acceptable.</i> But this requirement does not specify which latency due to head tracking is acceptable (and no regulation does), so pilot comfort (including absence of headache, nausea or disorientation after several minutes of HMD usage) is the most relevant criteria.
Category	<Performance>

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDT.0003
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0002
<ALLOCATED_TO >	<Enabler>	A/C23b1
<ALLOCATED_TO >	<Enabler>	A/C23b2
<ALLOCATED_TO >	<Functional Block>	Displays and Controls

[REQ]

Identifier	REQ-03a.04-TS-GEN.0103
Title	Human performances for EFVS operations
Requirement	The HMD design with respect to human performances requirements to perform EFVS operations shall be compliant with guidance and requirements from FAA AC25-11B [65].
Status	<validated>
Rational	Human performances objectives for EFVS operations based on FAA AC25-11B which addresses "HUD or equivalent" and directly applies to HMD (a dedicated appendix of AC25-11-B (Appendix H) relates to HMD).

Category	<Human performances>
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Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0002
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0003
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDT.0003
< ALLOCATED_TO >	<Enabler>	A/C23b1
< ALLOCATED_TO >	<Enabler>	A/C23b2
< ALLOCATED_TO >	<Functional Block>	Displays and Controls

4.2.2 Taxi operations using HMD specific requirements

This section provides the list of requirements allocated to HMD for airport surface navigation aid function in accordance with previous functional analysis.

The main goal of this function is to provide to pilots (when aircraft is on ground) through conformal and non-conformal symbology displayed on HMD, information improving taxi operations in reduced visibility conditions.

[REQ]

Identifier	REQ-03a.04-TS-TAXI.0201
Title	HMD interface for airport taxi operations clearance
Requirement	The HMD shall provide an interface to receive taxi clearance data either from the aircrafts avionics or manually input by the crew.
Status	<validated>
Rational	Surface navigation clearance exchange between crew and ATC
Category	<Interface>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDT.0004
< ALLOCATED_TO >	<Enabler>	A/C23b2
< ALLOCATED_TO >	<Functional Block>	Airport Surface Navigation
< ALLOCATED_TO >	<Functional Block>	Databases

< ALLOCATED_TO >	<Functional Block>	Displays and Controls
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[REQ]

Identifier	REQ-03a.04-TS-TAXI.0203
Title	Position accuracy for conformal symbols display on ground
Requirement	The positioning source horizontal accuracy and stability (variation over time) shall be compliant with a display of conformal symbols allowing a clear and non-ambiguous use by the pilots.
Status	<validated>
Rational	Consistency of conformal symbols display on ground
Category	<Performance>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDT.0003
< ALLOCATED_TO >	<Enabler>	A/C23b2
< ALLOCATED_TO >	<Functional Block>	Airport Surface Navigation
< ALLOCATED_TO >	<Functional Block>	Databases
< ALLOCATED_TO >	<Functional Block>	Displays and Controls

[REQ]

Identifier	REQ-03a.04-TS-TAXI.0204
Title	Loss of function safety level for Taxi operations
Requirement	The safety level associated with loss of required elements to perform taxi operations on airport surface shall be classified "MINOR" with a quantitative objective of 10-3/FH.
Status	<validated>
Rational	Pilot reverts to traditional clearance and navigation means
Category	<Safety>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDT.0002
< ALLOCATED_TO >	<Enabler>	A/C23b2
< ALLOCATED_TO >	<Functional Block>	Airport Surface Navigation
< ALLOCATED_TO >	<Functional Block>	Databases
< ALLOCATED_TO >	<Functional Block>	Displays and Controls

[REQ]

Identifier	REQ-03a.04-TS-TAXI.0205
Title	Misleading information safety level for taxi operations
Requirement	The safety level associated with misleading information on required elements to perform taxi operation on airport surface, shall be classified no less than MAJOR with a quantitative objective of 10^{-5}/FH. Note: Aids displayed on HMD are only awareness. The mitigation crew procedures to avoid misleading guidance shall still be applicable.
Status	<validated>
Rational	Equivalent to misleading information safety level for legacy taxi operations
Category	<Safety>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDT.0002
< ALLOCATED_TO >	<Enabler>	A/C23b2
< ALLOCATED_TO >	<Functional Block>	Airport Surface Navigation
< ALLOCATED_TO >	<Functional Block>	Databases
< ALLOCATED_TO >	<Functional Block>	Displays and Controls

[REQ]

Identifier	REQ-03a.04-TS-TAXI.0206
Title	Obstruction of pilot view through HMD
Requirement	The safety level associated with obstruction of pilot's view through HMD shall be classified no less than MAJOR with a quantitative objective of 10^{-5} /FH.

	Note: Same objective as for EFVS to 100ft
Status	<validated>
Rational	Pilot takes appropriate action to put aside HMD information. Same level as in approach phase (but less critical as pilot has time to remove HMD and revert to classic surface navigation).
Category	<Safety>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDT.0002
< ALLOCATED_TO >	<Enabler>	A/C23b2
< ALLOCATED_TO >	<Functional Block>	Airport Surface Navigation
< ALLOCATED_TO >	<Functional Block>	Databases
< ALLOCATED_TO >	<Functional Block>	Displays and Controls

4.2.3 CVS approach operation requirements

This section provides the list of requirements allocated to HMD for approach and landing function in accordance with previous functional analysis.

As described through use cases detailed in OSED [31] and reminded here above in section 0, the targeted operational environment includes EFVS operations to 100ft and to land/rollout using CVS on HMD.

No changes are forecast as regard current EFVS operation using HUD and infrared sensors from an operational point of view.

The below requirements are similar to current HUD EFVS approach operations

[REQ]

Identifier	REQ-03a.04-TS-APP.0303
Title	CVS display
Requirement	The CVS shall be able to provide the CVS imagery, required aircraft flight information and flight symbology (speed tape, altitude tape, attitude indications, vertical speed information, Flight Path Vector, Flight director, Flight Path Angle Reference Cue, boresight) on HMD.
Status	<validated>

Founding Members

Rational	Display mandatory elements to perform EFVS operations
Category	<Functional>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0002
< ALLOCATED_TO >	<Enabler>	A/C23b1
< ALLOCATED_TO >	<Functional Block>	Displays and Controls

[REQ]

Identifier	REQ-03a.04-TS-APP.0308
Title	Loss of function safety level
Requirement	According to AC20-167A [62], the safety level associated with loss of required elements to perform EFVS to 100ft_operations (imagery, symbology on HMD or loss of HMD), shall be classified “MINOR” with a quantitative objective of 10-3/FH.
Status	<validated>
Rational	Pilot revert to another approach if above 1000ft or perform GA if under
Category	<Safety>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0001
< ALLOCATED_TO >	<Enabler>	A/C23b1
< ALLOCATED_TO >	<Functional Block>	Displays and Controls

[REQ]

Identifier	REQ-03a.04-TS-APP.0309
Title	Misleading information safety level
Requirement	According to AC20-167A [62], the safety level associated with misleading information on required elements to perform EFVS to 100ft operations

	(imagery and symbology), shall be classified no less than MAJOR with a quantitative objective of 10-5/FH.
Status	<validated>
Rational	Safety level for Misleading information
Category	<Safety>

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0001
<ALLOCATED_TO >	<Enabler>	A/C23b1
<ALLOCATED_TO >	<Functional Block>	Displays and Controls

[REQ]

Identifier	REQ-03a.04-TS-APP.0310
Title	Obstruction of pilot view through HMD
Requirement	According to AC20-167A [62], the safety level associated with obstruction of pilot's view through the HMD during EFVS to 100ft operations, shall be classified no less than MAJOR with a quantitative objective of 10-5/FH.
Status	<validated>
Rational	Safety level for obstruction of pilot's view
Category	<Safety>

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0001
<ALLOCATED_TO >	<Enabler>	A/C23b1
<ALLOCATED_TO >	<Functional Block>	Displays and Controls

5 Implementation Options

This section aims at describing implementation technological options for the solution.

5.1 Sensors used to detect external environment

5.1.1 Passive sensors

All existing EFVS products in service in civil aviation are **passive**. Most passive sensors are only sensitive to IR spectral band. The latest EFVS are **multisensors**, **multispectral** (several IR and visual spectral bands) and embed **fusion** algorithms. They are capable of LED lighting detection.

All EFVS sensors are well sensitive to **lights** (approach, runway, taxiway) and **markings** (runway, taxiway). **Terrain** and surrounding environment (vehicles, persons, animals, obstacles, manmade feature, fields...) may also be detected in less extreme weather conditions (mist, haze).

Some of sensors do not detect LED lights.

EFVS existing sensor have sensitivity enabling an aircraft to see approach lights in approach at **200ft** with RVR as low as **300m** in **fog** conditions.

Higher detection performance is observed for more favourable situations.

Performance of existing EFVS sensors can **vary** with weather conditions encountered, depending on atmospheric conditions and the strength of energy emitted and/or reflected from the scene in the spectral band(s) of the sensor(s).

Performance may be difficult to predict in some conditions, especially in case of inhomogeneous atmosphere.

5.1.2 Active sensor

Active sensor requires a certain amount of energy intentionally transmitted for the purpose of target detection. Contrary to passive sensors, the performance of active sensors is typically far better, due to larger power received in the echo and due to possibility to control various parameters, e.g. the direction of the energy. Considering the aircraft approach scenario, when the distance to runway is in the order of hundreds meters up to kilometres, RADAR technology is a good candidate when comparing various types of active sensors, which can be chosen to support the operation.

Radar detect target's angle, velocity, range and is capable to "see" in dark, in a sandstorm or through the rain and clouds. All these conditions must be assumed when designing an EFVS system. Primary application of radar technology at aircraft is weather detection and altitude measuring but modern radars today are capable to provide other functionalities as well, such as runway detection.

Radars can be divided based on carrier frequency, design (e.g. PESA, AESA) etc. Typical examples of weather and multifunctional radars provided by Honeywell are given below:

Honeywell IntuVue® RDR-4000 3D Weather Radar System

The RDR-4000 is a certified aircraft weather radar operating at X-band frequency. The radar scans the sky at 17 tilt angles and delivers a 3D view of the weather. The RDR-4000's 3D Volumetric Buffer continuously captures all weather and terrain in the entire airspace ahead of the aircraft, from -80 to +80 degrees in front of the aircraft, from 0 to 60,000 ft and up to 320nm ahead. The 3D buffer is continuously updated with reflectivity data from new scans, and data is shifted to account for aircraft movement, speed, heading and altitude. The RDR-4000 includes internal terrain database, which enables ground returns to be extracted without reducing the intensity of weather returns. This functionality operates on take-off and approach in addition to cruise.



Figure 9 : Honeywell IntuVue® RDR-4000 3D Weather Radar System

Honeywell IntuVue™ RDR-84K Band Radar System

The RDR-84K uses multiple beams to “see” more things at the same time. In addition to detecting weather, the system can simultaneously scan and receive radar returns from aircraft, ground vehicles, buildings and even people. It uses a unique phased-array design with electronically steered beams rather than mechanical antennas, reducing size, weight, power consumption and complexity. The radar is software adaptable so users can easily change and customize the system's operation and performance parameters. For example, they can adjust the radar's range to meet their specific needs or focus on certain types of objects. The radar is capable of telling the difference between different types of objects.

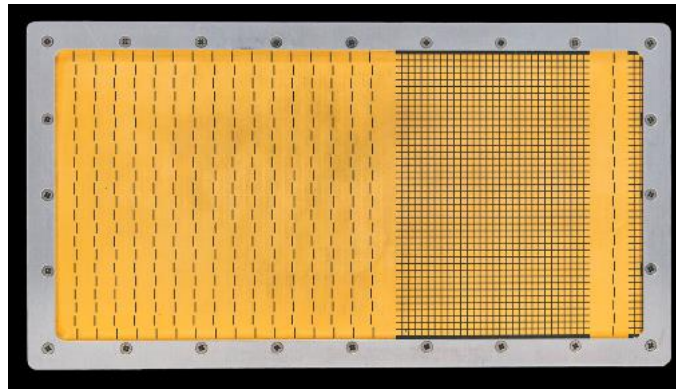


Figure 10: Honeywell IntuVue™ RDR-84K Band Radar System

5.2 Display system

5.2.1 HMD

Modern HMD have been used in military aviation since 1990th where they provide great benefit. From fixed wings aircraft needing to spot or designate moving targets to rotorcrafts flying into terrain HMD are currently equipping several thousands of carriers. Now, due to miniaturization and maturation improvements, lightweight HMD are about to enter the civil aviation market where the expected gains will be adapted to civil operations. Helmet mounted displays (HMD), although named head-worn displays (HWDs), aim at providing the crew with an unlimited Filed of View displayed symbology associated to an eyes out solution. In addition to primary flight symbology a number of different information linked to the mission may be plotted including terrain, mission targets, waypoints, IR or enhanced image...

HMD are not only targeting to provide the same benefits/credits as the HUDs for a **lower price and installation complexity**, but they also plan to provide **increased awareness**. Compared to the all-green limited FOV legacy HUD solutions the crew will benefit from a **SVS/ CVS terrain** and **traffic** information displayed on an **unlimited FOV**. When it comes to HMD technology a number of new constraints / trade-offs have to be considered compared to traditional HUD solutions.

Several ways exist for displaying the information to the pilot eyes: **monocular**, **binocular** and **biocular** as reminded in the following extract of App HH of AC-25-11B §3.3.2.1.1.1.1.1.

An exact positioning of the **conformal** symbology on the helmet display is a real challenge since it requires an accurate knowledge of the helmet localisation and orientation inside the cockpit, as well as aircraft attitude parameters. As an example a 2° projection error (corresponding to an AHRS heading standard error) will look totally unacceptable to the crew.

Several technologies may be used to provide accurate head tracking, based on embedded IMUs, magnetic field or optical trackers.

Head-Mounted display provides an easier and more intuitive way of displaying flight symbology, SVS and EVS to the pilot than aircraft non-equipped with Head-up solutions.

By supporting the eyes-out concept, the Head Mounted Display increases the total available Field of Regard (FOR) compared to a head down display or a traditional HUD allowing to display only a fixed Field of View (FOV).



Figure 11: Thales Head Mounted display

The projection of conformal symbology must also be studied to prevent **overlapping** with non-conformal symbology or interfering with **head-down** or overhead panel.

In addition HMD design must account for **ergonomics issues**, for example allowing the crew to wear **glasses**, to use colour or to don its oxygen mask without impairing the flight safety.

5.3 CVS

CVS (Combined Vision System) depicts EFVS and SVS at the same time in head up display. Currently this technology is in service on Business jet aircrafts. Design has been optimized to have a complementary blending of EFVS and SVS, without masking or presence of interferences between the two layers of information.

When in CVS mode, **EFVS Operational credit** is only provided by the EFVS that is displayed on **Head up display**.

Other CVS concepts based on fusion of EFVS and SVS images (either in Head up or in Head down) are still under study.

Dynamic **compensation mechanisms** are usually necessary to be implemented to limit latency for having SVS scaled and aligned with external scene.

6 References and Applicable Documents

6.1 Applicable Documents

Content Integration

- [1] PJ19 D5.1 EATMA Guidance Material Version 2018
- [2] EATMA Community pages
- [3] SESAR ATM Lexicon

Content Development

- [4] SESAR2020 PJ19-02 D2.5 Concept of Operations Edition 2019 – ed.00.01.00 - July 2019

System and Service Development

- [5] 08.01.01 D52: SWIM Foundation v2
- [6] 08.01.01 D49: SWIM Compliance Criteria
- [7] 08.01.03 D47: AIRM v4.1.0
- [8] 08.03.10 D45: ISRM Foundation v00.08.00
- [9] PJ19 ADD 2018
- [10] B.04.05 Common Service Foundation Method

Performance Management

- [11] PJ19-04 D4.4 Performance Framework (2018) ed.01.00.00 – 24/08/2018
- [12] 16.06.06-D68 Part 1 –SESAR Cost Benefit Analysis – Integrated Model
- [13] 16.06.06-D51-SESAR_1 Business Case Consolidated_Deliverable-00.01.00 and CBA
- [14] 16.06.06 D26 [Method to assess cost of European ATM improvements and technologies, EUROCONTROL \(2014\)](#) ATM Cost Breakdown Structure_ed02_2014
- [15] Standard Inputs for EUROCONTROL Cost Benefit Analyses
- [16] 16.06.06_D26-08 ATM CBA Quality Checklist
- [17] 16.06.06_D26_04_Guidelines_for_Producing_Benefit_and_Impact_Mechanisms

Validation

- [18] D3.6 PJ22 Updated platform development methodology

- [19] Transition VALS SESAR 2020 - Consolidated deliverable with contribution from Operational Federating Projects
- [20] PJ19.02 D2.4 - PJ19: VALS (2018)
- [21] European Operational Concept Validation Methodology (E-OCVM) - 3.0 [February 2010]
- [22] PJ19-04 D4.8 Validation Targets (2019) – ed.00.01.00 – 09/04/2019

System Engineering

- [23] SESAR Requirements and V&V guidelines

Safety

- [24] SESAR, Safety Reference Material, V00.04.01, December 2018
- [25] SESAR, Guidance to Apply the Safety Reference Material, Edition 3.1, December 2018
- [26] SESAR, Resilience Engineering Guidance, May 2016

Human Performance

- [27] PJ19HP HP Guidance Reference Material , V00.02.00, April 2018

Environment Assessment

- [28] SESAR, Environment Reference Material, alias, “Environmental impact assessment as part of the global SESAR validation”, Project 16.06.03, Deliverable D27,2016

Security

- [29] PJ 19-03 Security Prioritisation CST FEB 2019

Dataset

- [30] European ATM Master Plan Portal, <https://www.atmmasterplan.eu/>

6.2 Reference Documents

- [31]D4.010: SESAR Solution PJ03a-04 SPR-INTEROP/OSED for V3 – Part I
- [32]D4.070: SESAR Solution PJ03a-04 Cost Benefit Analysis for V3
- [33]D4.030: SESAR Solution PJ03a-04 VALP for V3
- [34]D4.060: SESAR Solution PJ03a-04 VALR for V3

[35]A-SMGCS Services, Procedures, and Operational Requirements (SPOR) EMMA2 2-D1.1.1 SPOR

6.3 Regulatory documents

EASA documents:

- [36]EASA NPA 2018-06, 2018 (in progress under RMT0379)
- [37]EASA current Regulation (EU) 965/2012 on air operations rev 8, 2017
- [38]EASA MB 2018-02, Cologne, 13-14 December 2018

ICAO standard documents:

- [39]ICAO Annex 6 (Operation of Aircraft, including EFVS operations) to the Chicago Convention on International Civil Aviation, 9th Edition, July 2016
- [40]ICAO Annex 3 (Meteorological Service for International Air Navigation) to the Chicago Convention on International Civil Aviation, 6th Edition, July 2007
- [41]ICAO Annex 11 (Air Traffic Services) to the Chicago Convention on International Civil Aviation, 13th Edition, July 2001
- [42]ICAO Annex 14 Aerodromes - Aerodrome design and Operations; ICAO; 2013
- [43]ICAO Annex 15 - Aeronautical Information Services; ICAO; 2016
- [44]ICAO Document 9365, DOC — Manual of All-Weather Operations, 3th Edition, 2013
- [45]ICAO Document 4444, PANS — Air Traffic Management, 15th Edition, 2007
- [46]ICAO EUR Doc 013 — European Guidance Material On Aerodrome Operations Under Limited Visibility Conditions

RTCA/ EUROCAE standard documents (SC213/ WG79 Working group):

- [47]EUROCAE ED-179 — Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems, 2008
- [48]ED-78A GUIDELINES FOR APPROVAL OF THE PROVISION AND USE OF AIR TRAFFIC SERVICES SUPPORTED BY DATA COMMUNICATIONS
- [49]ED-120: Safety and performances requirements standard for air traffic datalink services in continental airspace (continental SPR standard)

- [50]RTCA DO-315A — Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems, 2010
- [51]RTCA DO-359 — Minimum Aviation System Performance Standard (MASPS) for Synthetic Vision Guidance Systems, 2015
- [52]RTCA DO-341 — Minimum Aviation System Performance Standards (MASPS) for an Enhanced Flight Vision System to Enable All-Weather Approach, Landing and Roll-Out to a Safe Taxi Speed, 2012
- [53]RTCA DO-371 – Minimum Aviation System Performance Standards (MASPS) for Aircraft State Awareness Synthetic Vision Systems, 2018
- [54]RTCA DO-276C; User Requirements for Terrain and Obstacle Data; RTCA, Inc.; 2015

SAE International documents:

- [55]SAE International ARP-5677 — Human Engineering Considerations for Airborne Implementation of Enhanced Synthetic Vision Systems, 2012
- [56]SAE International ARP-5288 — Transport Category Airplane Head Up Display (HUD) Systems
- [57]SAE International ARP 6377 - Head Worn Display (HWD) Systems
- [58]SAE International AS 8055A - Minimum Performance Standard for Airborne Head Up Display (HUD)
- [59]SAE International AS 5703 - Minimum Performance Standard for Enhanced Vision System

FAA documents:

- [60]14-CFR (§ 91.176...) Straight-in landing operations below DA/DH or MDA using an enhanced flight vision system (EFVS) under IFR, Dec 2016
- [61]FAA Advisory circular AC 90-106A Enhanced Flight Vision Systems, 2017
- [62]FAA Advisory circular AC 20-167A Airworthiness Approval of Enhanced Vision System, Synthetic Vision System, Combined Vision System, and Enhanced Flight Vision System Equipment, 2016
- [63]Aeronautical Information Manual; FAA; 2017
- [64]EFVS Overview presentation, Flight Technologies and Procedures Division Flight Operations Group, 10/1/2018
- [65]FAA AC25-11B: Advisory Circular Electronic Flight Displays, 2014



Appendix A Active sensor

A.1 Functional and non-Functional Requirements

A.1.1 CVS approach operation requirements

[REQ]

Identifier	REQ-03a.04-TS-APP.0302
Title	CVS sensor
Requirement	The CVS shall be able to acquire required visual references by its sensor in intended segment of operation.
Status	<in progress>
Rational	Ensure transition to visual references
Category	<Functional>

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0001
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-HMDL.0003
<ALLOCATED_TO>	<Enabler>	A/C-23b4 (in pipeline CR 02775)
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-SENS.0001

[REQ]

REQ-03a.04-TS-APP.0304	
Title	CVS sensor performance
The CVS sensor performance shall be sufficient for intended approach operation.	
Status	<in progress>
Rational	Perform EFVS operations
Category	<Performance>

Relationship	Linked Element Type	Identifier
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Founding Members

< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
< ALLOCATED_TO >	<Enabler>	A/C-23b4 (in pipeline CR 02775)
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-SENS.0001

[REQ]

Identifier	REQ-03a.04-TS-APP.0305
Title	CVS sensor penetration
Requirement	The CVS sensor shall be able to penetrate adverse weather condition and capture required data.
Status	
Rational	Perform EFVS operations
Category	<Performance>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
< ALLOCATED_TO >	<Enabler>	A/C-23b4 (in pipeline CR 02775)
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-SENS.0002

[REQ]

Identifier	REQ-03a.04-TS-APP.0307
Title	CVS display alignment
Requirement	The provided CVS imagery, required aircraft flight information and flight symbology shall be aligned with, and scaled to external scene.
Status	<in progress>
Rational	Conformal display of external information
Category	<Performance>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
< ALLOCATED_TO >	<Enabler>	A/C-23b4 (in pipeline CR 02775)

<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-SENS.0001
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[REQ]

Identifier	REQ-03a.04-TS-GEN.0104
Title	Aeronautical data
Requirement	The onboard solution using an active sensor may be able to store the aeronautical, obstacle and terrain data.
Status	<in progress>
Rational	Some implementation of EFVS/CVS can use aeronautical, obstacle and terrain data for matching with active sensor data.
Category	<Functional>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-SENS.0001
< ALLOCATED_TO >	<Enabler>	A/C-23b4 (in pipeline CR 02775)

[REQ]

Identifier	REQ-03a.04-TS-GEN.0105
Title	Dataset series request
Requirement	The onboard solution using an active sensor may be able to request the datasets concerning aeronautical, obstacle and terrain data.
Status	<in progress>
Rational	Some implementation of EFVS/CVS can use aeronautical, obstacle and terrain data for matching with active sensor data.
Category	<Functional>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-SENS.0001
< ALLOCATED_TO >	<Enabler>	A/C-23b4 (in pipeline CR 02775)

[REQ]

Founding Members

Identifier	REQ-03a.04-TS-GEN.0106
Title	Dataset series receiving
Requirement	The onboard solution using an active sensor may be able to receive the datasets concerning aeronautical, obstacle and terrain data.
Status	<in progress>
Rational	Some implementation of EFVS/CVS can use aeronautical, obstacle and terrain data for matching with active sensor data.
Category	<Functional>

Relationship	Linked Element Type	Identifier
< ALLOCATED_TO >	<SESAR Solution>	PJ03a-04
<SATISFIES>	<ATMS Requirement>	REQ-03a.04-SPRINTEROP-SENS.0001
< ALLOCATED_TO >	<Enabler>	A/C-23b4 (in pipeline CR 02775)

CVS operations with active sensor can use destination airport aeronautical data to improve runway detection in specific implementation options. These data are not required for supporting the operation itself and are only optional.

A.2 Implementation Options

A.2.1 Data acquisition

The EFVS/CVS enabling intended approach operation using active sensor can use data for target airport / runway to enable equivalent landing operation in low visibility condition. The data consist of aerodrome data containing details about important runway parameters and aerodrome surface lightings, terrain and obstacles data containing description of surface in specific area of the airport.

The system sensor requires aerodrome data for intended airport / runway to enable equivalent landing operation in low visibility condition. The implementation of the aeronautical information service is intended as one of possibilities for data acquisition required by system supporting enhanced landing operation. Another possibility for data acquisition required for the intended operation is a navigation data provider as additional service between AIS and onboard system. Both options of data acquisition are shown in figures below.

Aerodrome database contains essential data about important runway parameters and aerodrome surface lightings. These data are generally used for advanced mechanisms and methods making use of processing active radar data. Aerodrome database is intended to be stored on-board for easy access by the system. Basic data acquisition for the database can be realized by navigation data providers or via Aeronautical Information Service (AIS). Figure below illustrates data flow and data survey to onboard CVS database. Data are intended to be provided in two dataset types baseline and

update. The baseline dataset contains the latest version of complete data for all applicable airports. The update dataset contains only information reflected changes on airports and is intend to keep onboard database up to date. Any handling with aerodrome data inside the database must be appropriate and adequate to criticality of data. Update of such database is intended via above mentioned sources if any changes in data are indicated. The updates are supposed to be processed and distributed in AIRAC cycles.

Terrain and obstacle data describing appropriate areas are intended to be used by advanced mechanisms and methods for a processing active radar data. Terrain and Obstacle data are intended to be stored on-board in appropriate databases. Basic data acquisition for the database can be realized by navigation data providers or via Aeronautical Information Service (AIS). Figure below illustrates data flow and data survey to onboard CVS database. Data are intended to be provided in two dataset types baseline and update. The baseline dataset contains the latest version of complete data for all applicable airports. The update dataset contains only information reflected changes on airports and is intend to keep onboard database up to date. Any handling with aerodrome data inside the database must be appropriate and adequate to criticality of data. Update of such database is intended via above mentioned sources if any changes in data are indicated. The updates are supposed to be processed and distributed in AIRAC cycles.

Aeronautical information service (AIS) is a service with intention to support an international civil aviation. The main objective is to ensure the flow of aeronautical information/ data necessary for safety, regularity, and efficiency of international air navigation. Current AIS concept as specified by ICAO Annex 15 is provision of aeronautical information/data based on paper/electronic documentation and telex-based text messages which do not satisfy completely the needs for the ATM integrated and interoperable system. Therefore, aeronautical information services are required to transform to provide complex data-centric information supported by different methods of data provision and information management. This change assumes a transition reflecting the importance of the evolution.

Navigation data provider or service is a commercial subject that intends to support international civil aviation from a data sharing viewpoint. They are well known data providers like Jeppesen, LIDO etc.. delivering tailored documentation for specific customers.

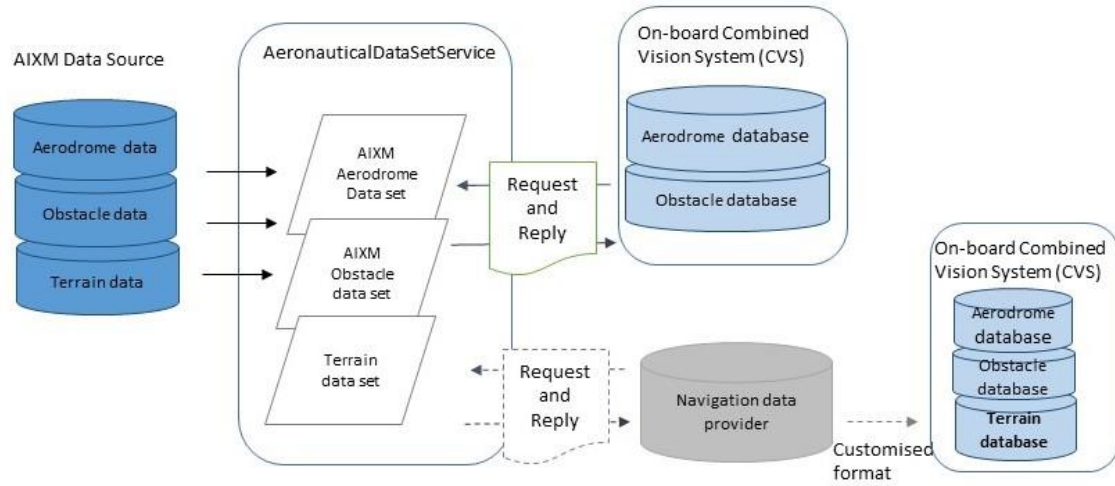


Figure 12 –Data Flow Diagram for Baseline and AIRAC updates

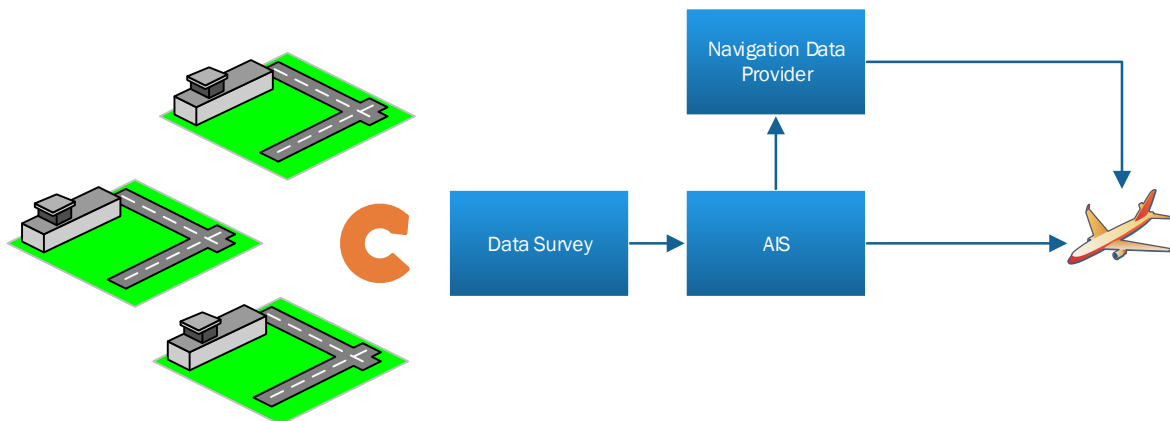


Figure 13 –Data Flow Diagram

-END OF DOCUMENT-