



# SESAR SOLUTION PJ03a-04 COST BENEFIT ANALYSIS (CBA) FOR V3

|                                |                                   |
|--------------------------------|-----------------------------------|
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# SUMO

## ENHANCED VISUAL OPERATIONS

This Cost Benefit Analysis 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 programme.



### Abstract

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This Cost Benefit Analysis document aims at providing an analysis of the benefits and costs for the deployment of equivalent visual landing and taxi operations developed under solution PJ03a-04 Enhanced Visual operations. The CBA forms part of the data pack and supports development and deploying of new technologies, Head mounded display and active sensor. The initial costs were estimated based on standard inputs and OEM and expert judgement. The benefits were in some cases successfully quantified and explained in cases where quantification was not applicable.

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# 1 Executive Summary

This document provides the Cost Benefit Analysis (CBA) for PJ03a-04 that has been focus on development of equivalent visual operation supported by Head Mounted Display (HMD) and/or active sensor.

The outcomes of the PJ03a-04 validation exercises have confirmed the V3 maturity level of HMD technology for taxi and landing operations.

Distinguishing between these two technological enablers in the document aims at providing qualitative and when possible quantitative assessment of the costs and benefits provided at ATM level on a 20-year timeframe following the introduction of each technology.

Two scenarios are considered where HMD and Active Sensor are separately fitted on a percentage of newly-built heavy business jets, which is one of the main targets for these enablers.

Although other segments (Regional or even Mainline) maybe interested by these technologies the current situation does not allow providing even imperfect figures regarding the future deployment of HMD and active sensor on these segments. Considering that EVS sensors are currently only fitted on business jets, and that only one HMD system is existing and still not yet certified, the consortium decided to provide detailed Cost Benefit Analysis on heavy business jets only, treating other segments as potential growth.

Gains in terms of reduced diversion, cancellation and delays are assessed as well as reduced number of runway incursion.

Break-even point is computed for the two technologies and a number of non-monetized benefits are also considered, including efficiency, improved awareness, reduced go-around or runway excursions, decreased number of go around or collisions.

The document concludes on the financial interest of both HMD and Active Sensor on given scenarios.

## Disclaimer

Although this document tries to provide realistic figures at ATM level, the absence of some relevant stakeholders in the project could not allow performing the required consolidation of the publicly available data used for analysis.

Whereas the benefit of these technologies is reasonably assessed and understood (although their concept of use may be refined), their cost still remains subject to uncertainty. In particular the cost and visual advantage that will actually be provided by an Active Sensor, the benefits monetisation and the selling price of a future Head Mounted Display product have still to be consolidated.

The reader is then requested to consider the results in this document with care and should be aware that the figures provided may present some degree of uncertainty.

## 2 Introduction

### 2.1 Purpose of the document

This document provides the Cost and Benefit analysis for SESAR Solution PJ03a-04. It describes how Head Mounted display and Active Sensor technology could benefit ATM system based on the outcome of the exercises performed and documented in VALP and VALR.

The CBA differentiates between the two technological enablers and their associated maturity level, reached at the end of the project.

### 2.2 Scope

This document limits the detailed analysis of the introduction of HMD and active sensor to heavy business aviation only. This segment is indeed the main target of these new technologies as it is the only one performing EFVS/CVS operations for the moment.

The consortium is aware that Regional and even Commercial transport could be interested in the future by these technologies. Nevertheless, the lack of available concrete data and the absence of representative of these segments into the project have conducted the consortium to only consider them as a potential growth with regard to the consolidated heavy jet baseline.

### 2.3 Intended readership

#### 2.3.1 SESAR readership

The intended audience for this Validation Plan document is represented by the following solutions:

- 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.
- PJ.18-04a (Management and sharing of data used in trajectory (AIM, METEO)) as provider of aeronautical data necessary via AIXM format for aircraft vision system using active sensor

- AAL2 (Augmented Approaches to Land 2) project addresses increased access to airports for low visibility 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).

### 2.3.2 Other readership

Additional intended readership includes members of EUROCAE WG-79 and RTCA SC-213, which are in charge of the Enhanced Flight Visions Systems/Synthetic Vision Systems (EFVS/SVS).

## 2.4 Structure of the document

The document follows the template provided by SJU, by describing:

- An overview and reminder of the project objectives.
- The foreseen benefits of the two technology at ATM level
- The expected costs for the ATM stakeholders as defined in EATMA.
- The CBA model used by the partners
- The CBA results as well as a description of their significance and limitations

## 2.5 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”

**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).

**WP09.28:** The goal of the project 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 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 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 technological enablers, using a HMD instead of HDD/HUD classic avionics displays and active sensor instead of passive sensor, increasing cost benefits in operations and improving availability of the operation.

## 2.6 Glossary of terms

| Term        | Definition                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | Source of the definition |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| <b>CVS</b>  | Combined vision systems (CVSs) combine a real-time imaging sensor and display with a synthetic image generated using a terrain and obstacle database utilising a precision navigation position.                                                                                                                                                                                                                                                                                                                                                                                                                                                | EASA NPA 2018-06 AWO     |
| <b>EFVS</b> | <p>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.</p> <p>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</p> | EASA NPA 2018-06 AWO     |

|                          |                                                                                                                                                                      |                     |
|--------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------|
|                          | only for improved situational awareness (see definitions in Annex I).                                                                                                |                     |
| <b>EVS sensor</b>        | Imaging sensors, including but not limited to forward-looking infrared, millimeter wave radiometry, millimeter wave radar, or low-light level image intensification. | FAR_91.176          |
| <b>Net Present Value</b> | Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.                                                       | <i>Investopedia</i> |

## 2.7 List of Acronyms

| Term    | Definition                                          |
|---------|-----------------------------------------------------|
| ADD     | Architecture Definition Document                    |
| AIM     | Aeronautical Information Manual                     |
| AN      | Availability Note                                   |
| ANSP    | Air Navigation Service Provider                     |
| ATC     | Air Traffic Control                                 |
| ATM     | Air Traffic Management                              |
| ATM MP  | Air Traffic Management Master Plan                  |
| BA      | Business Aircraft                                   |
| CBA     | Cost and Benefit Analysis                           |
| CVS     | Combined Vision Systems                             |
| EATMA   | European ATM Architecture                           |
| E-ATMS  | European Air Traffic Management System              |
| E-OCVM  | European Operational Concept Validation Methodology |
| EASA    | European Aviation Safety Agency                     |
| EBAA    | European Business Aviation Association              |
| EFVS    | Enhanced Flight Vision System                       |
| EUROCAE | European Organisation for Civil Aviation Equipment  |
| FAA     | Federal Aviation Administration                     |

|         |                                                |
|---------|------------------------------------------------|
| FOC     | Full Operational Capability                    |
| GBAS    | Ground Based Augmentation System               |
| GNSS    | Global Navigation Satellite System             |
| HDD     | Head Down Display                              |
| HMD     | Head Mounted Display                           |
| HUD     | Head Up Display                                |
| IBP     | Industrial Based Platform                      |
| ICAO    | International Civil Aviation Organization      |
| IOC     | Initial Operational Capability                 |
| IR      | Infra-Red                                      |
| IRS     | Interface Requirements Specification           |
| INTEROP | Interoperability Requirements                  |
| KPA     | Key Performance Area                           |
| KPI     | Key Performance Indicator                      |
| LVP     | Low Visibility Procedure                       |
| LVC     | Low Visibility Conditions                      |
| MCMF    | Multi-Constellation / Multi-Frequency          |
| NPV     | Net Present Value                              |
| OSED    | Operational Service and Environment Definition |
| PIRM    | Programme Information Reference Model          |
| RTCA    | Radio Technical Commission for Aeronautics     |
| RVR     | Runway Visual Range                            |
| SBAS    | Satellite-Based Augmentation System            |
| SESAR   | Single European Sky ATM Research Programme     |
| SJU     | SESAR Joint Undertaking                        |
| SPR     | Safety and Performance Requirements            |
| SUT     | System Under Test                              |

|      |                                  |
|------|----------------------------------|
| SVGS | Synthetic Vision Guidance System |
| SWIM | System Wide Information Model    |
| TRL  | Technology Readiness Level       |
| TS   | Technical Specification          |
| UC   | Use Case                         |
| VALP | Validation Plan                  |
| VALR | Validation Report                |
| VALS | Validation Strategy              |

## 3 Objectives and scope of the CBA

### 3.1 Problem addressed by the solution

PJ03a-04 aims at assessing the interest at ATM level of new technology enabling more efficient EFVS/CVS approaches and taxi guidance.

Active sensor and Head Mounted Display (HMD) are separately assessed as promising enablers to leverage the number of EFVS/CVS operations worldwide and as possible alternative to increase safety during taxi phase.

For PJ03a-04, a long term investment is planned with revenue in the following years. A relatively large number of airports without ground equipment supporting CAT II/III operations might be affected by LVC conditions. The probability of LVC condition is assumed to range from 0.2% to 2.8% (data from SESAR LSD02.02 AAL1 [55]) per analysis on 11 different CATI airports in 2014, assuming only airport opening hours. This corresponds to a total volume of 15h to 160h and has affected from 10 to 63 different days over 2014. When LVC arise at an airport without sufficient equipment for CAT II/III operations, all arriving aircrafts without sufficient equipment are affected (delayed, diverted or cancelled). The impact on each flight depends usually on the characteristics of the adverse weather, e.g. duration.

### 3.2 SESAR Solution description

The concept proposed in SESAR consists in taking credit of emerging visual based technologies such as EFVS and SVS combined through CVS and displayed in coloured HMD in order to increase the operational efficiency in both taxi and landing while significantly improving situational awareness. Furthermore, an using of active sensor can increase performance of the Vision Systems and thereby reduce number of missed approaches due to adverse weather conditions.

A unique advantage of the solution is that it is mainly supported by the aircraft system instead of airports and the need of complex and costly ground infrastructures.

From a global ATM network standpoint, the vision systems will increase accessibility at most of secondary aerodromes providing operational credit at most of runways end with precision or non-precision landing minima (LPV, LNAV/ VNAV, ILS CAT1...).

In addition, as Vision Systems provide the crew with a simple and comprehensive image of the situation, they require less mental effort and potentially allow for alleviated crew training and reduced operator constraints.

These advantages will make the Vision Systems a key operational capability especially for the business aviation community that is mainly composed of small/ medium operators with limited resources and operating frequently at small/medium airports. The Vision Systems are beneficial also for other types of aircrafts operating at small/medium airports.

Beyond operational credit, the Vision Systems will boost situational awareness in all weather conditions for all operators at all airports contributing to increase safety margin all the time.

| SESAR Solution ID | OI Steps ref. (coming from the Integrated Roadmap) | OI Steps definition (coming from the Integrated Roadmap)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | OI step coverage | Comments on the OI step title / definition |
|-------------------|----------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|--------------------------------------------|
| PJ03a-04          | AUO-0405                                           | <b>Equivalent Visual Landing operations in Low Visibility Conditions with Head Mounted Display</b><br>The ability for Flight Crew to land in low visibility/ceiling conditions is improved with new on-board feature that provides advanced vision (e.g. Combined Vision System, mixing Enhanced Vision System and Synthetic Vision System) in order to improve human performance. Due to those advanced on-board avionics, airport access is maintained in low visibility/ceiling conditions. The use of Head Mounted Display (HMD) may further improve crew performance and environmental awareness. | Fully            | OI enabled by HMD                          |
| PJ03a-04          | AUO-0406                                           | <b>Equivalent Visual Taxi operations in Low Visibility Conditions</b><br>The ability for Flight Crew to taxi in low visibility conditions is improved with new on-board feature that provides advanced vision (e.g. Combined Vision System, mixing Enhanced Vision System and Synthetic Vision System) in order to improve human performance. Due to on-board avionics the aircraft will be less dependent on ground based infrastructure at the airport while conducting taxi operations. In addition, the Flight Crew will be able to maintain an awareness of taxiway centreline                    | Fully            | OI enabled by HMD                          |
| PJ03a-04          | AUO-0410 (not in DS19, in pipeline)                | <b>Equivalent Visual Approach and Landing operations providing improved resilience to LVC</b><br>Equivalent visual approach and landing operation enabled by vision system (e.g. Combined Vision System, mixing Enhanced Vision System with Synthetic Vision System                                                                                                                                                                                                                                                                                                                                    | N/A              | OI enabled by active sensor (not V3)       |

|  |  |                                                                                                                                                                                                                                                                           |  |  |
|--|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|
|  |  | and possibly Synthetic Vision Guidance System relying on Synthetic Vision System and additional monitoring to reduce minima) using new on-board features providing improved resilience to low visibility conditions on small and medium airports (e.g. runway ILS CAT I). |  |  |
|--|--|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|

**Table 1: SESAR Solution PJ03a-04 Scope and related OI steps**

| OI Steps ref.       | Enable r <sup>1</sup> ref. | Enabler definition                                                                                                                                                                                                                                                                                                                                   | Enable r coverage | Applicable stakeholder | Comments on the Enabler / definition |
|---------------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------|------------------------|--------------------------------------|
| AUO-0405            | A/C-23b1                   | Combined Vision for Equivalent Visual Landing operations in LVC with HMD<br><br>Combined Vision for Equivalent Visual Landing operations in Low Visibility Conditions: the additional operational credit is provided by enhancing awareness and lowering approaching limits by the equivalent visual operation through a Head Mounted Display (HMD). | Fully             | Airspace Users         | HMD                                  |
| AUO-0406            | A/C-23b2                   | Combined Vision for Equivalent Visual Taxi operations in LVC<br><br>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, providing improved taxi time efficiency and increasing safety margins          | Fully             | Airspace Users         | HMD                                  |
| AUO-0410<br>(not in | A/C-23b4                   | Combined Vision for Equivalent Visual Approach operations using active sensor                                                                                                                                                                                                                                                                        | Partial           | Airspace Users         | Active sensor                        |

<sup>1</sup> This includes System, Procedural, Human, Standardisation and Regulation Enablers

|                     |  |                                                                                                                                                 |  |  |          |
|---------------------|--|-------------------------------------------------------------------------------------------------------------------------------------------------|--|--|----------|
| DS19, in pipeline ) |  | Improved performance of Combined Vision System in low visibility conditions for equivalent visual approach operation to 100ft by active sensor. |  |  | (not V3) |
|---------------------|--|-------------------------------------------------------------------------------------------------------------------------------------------------|--|--|----------|

**Table 2: OI steps and related Enablers**

### 3.3 Objectives of the CBA

This CBA analyses the costs and benefits of these two technologies considered separately then together.

### 3.4 Stakeholders<sup>2</sup> identification

| Stakeholder                                | The type of stakeholder and/or applicable sub-OE | Type of Impact                                                                                               | Involvement in the analysis | Quantitative results available in the current CBA version |
|--------------------------------------------|--------------------------------------------------|--------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------------------------------------|
| ANSP                                       |                                                  | Increase access to small and medium airports in LVC                                                          | No                          | No                                                        |
| Airport Operators                          | LVC only                                         | Increased operator workload due to increased traffic in LVC caused by aircraft resilience to adverse weather | No                          | No                                                        |
| Network Manager                            | N/A                                              | N/A                                                                                                          | N/A                         | N/A                                                       |
| Scheduled Airlines (Mainline and Regional) | Approach                                         | Reduce number of delayed, diverted and cancelled flights                                                     | No                          | No                                                        |
| Business Aviation                          | Approach                                         | Reduce number of delayed, diverted and cancelled flights                                                     | Yes                         | Yes                                                       |
| Rotorcraft                                 | N/A                                              | N/A                                                                                                          | N/A                         | N/A                                                       |
| General Aviation IFR                       | N/A                                              | N/A                                                                                                          | N/A                         | N/A                                                       |
| General Aviation VFR                       | N/A                                              | N/A                                                                                                          | N/A                         | N/A                                                       |
| Military – Airborne                        | N/A                                              | N/A                                                                                                          | N/A                         | N/A                                                       |
| Military – Ground                          | N/A                                              | N/A                                                                                                          | N/A                         | N/A                                                       |
| Other impacted stakeholders                | EASA                                             | Certification process for HMD and active sensor                                                              | N/A                         | N/A                                                       |

|                                                               |  |                |  |  |
|---------------------------------------------------------------|--|----------------|--|--|
| (ground handling, weather forecast service provider, NSA....) |  | based EFVS/CVS |  |  |
|---------------------------------------------------------------|--|----------------|--|--|

Table 3: SESAR Solution 03a-04 CBA Stakeholders and impacts

### 3.5 CBA Scenarios and Assumptions

As the future is uncertain with regard to technology performances or deployment rate the consortium has considered two different scenarios, each of them being attached to a specific reference scenario.

The reference scenarios coming from solution #117. It considers EFVS or CVS using HUD as display unit and IR sensor as source data. This is current baseline in industry and reference scenarios. The solution scenarios deal with new HMD technologies and an active sensor.

#### 3.5.1 Reference Scenario for HMD

The reference scenario is based on current technology capability and expected deployment.

In this scenario, only existing HUD product is deployed.

This scenario is based on 2019 EBAA figures and segmentation as shown in the figure below.

A detailed forecast of the production of heavy jet in the coming years is provided in Table 1: Business aviation fleet evolution.

The expected target for HMD primarily being heavy jets, only this segment is considered in the reference scenario.



### 3.5.2 Solution Scenario for HMD (Scenario 1)

Aircraft equipped with IR EVS camera and HMD

In this scenario, financially attractive CVS HMD technology provides the same operational gain as conventional HUD and makes CVS operation accessible to more aircrafts. Its advantages compared to HUD (lightweight, colour, 360° FOV, expected lower acquisition cost and low cockpit installation footprint) may encourage heavy business jet operators to select this solution to equip their fleet in forward fit or retrofit.

The consortium assumes that due to the novelty of the technology only 10% of the new manufactured heavy jets will be equipped with HMD, in forward fit only.

A detailed forecast of the production of HMD-equipped heavy jet in the coming years is provided in Table 1: Business aviation fleet evolution.

As explained in 2.2 only heavy jet segment is taken into account in the reference and solution scenarios **for cost computation**.

However the consortium believes that in a very optimistic scenario, at the end of the 20-year horizon timeframe of the study a significant percentage of midsize jets, light jets, single or twin-engine turboprops, could also be potential HMD users. These segments are however not considered in the cost analysis due to a lack of input data and reliable assumptions regarding HMD deployment and use.

### 3.5.3 Reference Scenario for active sensor

Similarly, to the HMD reference scenario the active sensor reference scenario is based on current technology capability and expected deployment, and uses 2019 EBAA figures and segmentation as a baseline.

In the active sensor reference scenario, EFVS/CVS approaches are only performed by business aviation (mainly heavy jets) using available IR camera technology associated to one HUD. Neither Active Sensor nor HMD is deemed available in this scenario. The reference scenario is performed on CAT I equipped airports (ie mostly small and medium airports).

A detailed forecast of the production of heavy jet in the coming years is provided in Table 1: Business aviation fleet evolution.

### 3.5.4 Solution Scenario for active sensor (Scenario 2)

Aircraft equipped with active sensor and HUD

This scenario assumes that EFVS/CVS Active sensor and its concept of use have reached sufficient maturity. This sensor is expected to provide much better performances than IR sensor allowing a 100% probability of detecting runway visual references at DH in intended environmental conditions (compared to ~73% today with IR).

The difference compared to reference scenario is the improved operational gain of the sensor increasing the rate of successful EFVS/CVS approaches and then decreasing the number of diversion or flight cancelling because of weather.

In this scenario, active sensor may fully replace conventional IR sensors in forward fit.

Assumption is that due to the improved performance of the technology 80% of the new manufactured heavy jets will be equipped with active sensor, in forward fit only.

A detailed forecast of the production of active sensor equipped heavy jet in the coming years is provided in Table 1: Business aviation fleet evolution.

As explained in 2.2 although other segments may be interested in active sensor in the future only heavy jet segment is taken into account in the reference and solution scenarios, because they are currently the only applicants for EFVS operational credits.




**Table 1: Business aviation fleet evolution**

| BA - Fleet evolution                                                                                                    |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|-------------------------------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Year                                                                                                                    | 2024  | 2025  | 2026  | 2027  | 2028  | 2029  | 2030  | 2031  | 2032  | 2033  | 2034  | 2035  | 2036  | 2037  | 2038  | 2039  | 2040  | 2041  | 2042  | 2043  | 2044  |
| Total business aircrafts at year start                                                                                  | 3 857 | 3 895 | 3 933 | 3 972 | 4 011 | 4 051 | 4 091 | 4 131 | 4 172 | 4 213 | 4 255 | 4 297 | 4 339 | 4 382 | 4 425 | 4 469 | 4 513 | 4 513 | 4 513 | 4 513 | 4 513 |
| Aircraft growth rate                                                                                                    | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  | 1.0%  |
| Number of aircraft from growth                                                                                          | 39    | 39    | 39    | 40    | 40    | 41    | 41    | 41    | 42    | 42    | 43    | 43    | 43    | 44    | 44    | 45    | 45    | 45    | 45    | 45    | 45    |
| Annual aircraft deliveries (replacing retired aircraft and accounting for growth = 1% + 2.5%)                           | 135   | 136   | 138   | 139   | 140   | 142   | 143   | 145   | 146   | 147   | 149   | 150   | 152   | 153   | 155   | 156   | 158   | 158   | 158   | 158   | 158   |
| Number of heavy jets delivered during the year ( assuming 28% of deliveries are heavy jet (based on GAMA 2018 figures)) | 38    | 38    | 39    | 39    | 39    | 40    | 40    | 40    | 41    | 41    | 42    | 42    | 43    | 43    | 43    | 44    | 44    | 44    | 44    | 44    | 44    |
| Number of heavy jets equipped with HMD delivered during the year (=10% of delivered heavy jets)                         | 0     | 4     | 4     | 4     | 4     | 4     | 5     | 5     | 5     | 5     | 5     | 5     | 5     | 5     | 5     | 5     | 5     | 5     | 5     | 5     | 5     |
| <b>Total number of HMD equipped jets</b>                                                                                | 0     | 4     | 8     | 12    | 16    | 20    | 25    | 30    | 35    | 40    | 45    | 50    | 55    | 60    | 65    | 70    | 75    | 80    | 85    | 90    | 95    |
| Number of heavy jets equipped with active sensor delivered during the year (=80% of delivered heavy jets)               | 0     | 31    | 31    | 32    | 32    | 32    | 33    | 33    | 33    | 34    | 34    | 34    | 35    | 35    | 35    | 36    | 36    | 36    | 36    | 36    | 36    |
| <b>Total number of jets equipped with active sensor</b>                                                                 | 0     | 31    | 62    | 94    | 126   | 158   | 191   | 224   | 257   | 291   | 325   | 359   | 394   | 429   | 464   | 500   | 536   | 572   | 608   | 644   | 680   |



Founding Members



### 3.5.5 Assumptions Approach

For all scenarios, the time horizon of the CBA is 20 years following the V3 of each enabler. IOC is expected 3 years after V3. FOC is foreseen 5 years after V3. Conservative values were used in the model. A detailed list of assumptions is provided in Table 4.

The most significant ones are listed below:

- Average value of BA passenger time is estimated to be 425 Euro/h
- Cancellation occurs when the flight is delayed by 3 times the average flight duration. It is expected that flights will be cancelled after a shorter period of time in SESAR flexible environment;
- Each flight affected by LVC is assumed to be cancelled, diverted or delayed.
- In case of delay, 1min of delay costs 71 EUR.
- Average duration of BA flight in Europe (1.42 hour);

In addition, the analysis has the following limitations:

- Secondary effects of flight delays/diversion/cancellation are not taken into account;
- Benefits for airport are not taken into account;
- Benefits for ATC are not taken into account;
- The benefit of a more fluid use of engine and brakes during the taxi is not taken into account;
- Reduction in passenger's expenses is taken into account - see opportunity loss.

Passenger Value of time is considered for Business Aviation passenger and it is 126 EUR [11].

| Group of Inputs | Name / Reference                                     | Value    |
|-----------------|------------------------------------------------------|----------|
| General         | Discount rate (w/o inflation) / PJ.19-04 Methodology | 8%       |
|                 | USD/EUR exchange rate / [11], p. 3                   | 1.1069   |
|                 | Start year / ATM MP, CR 03567 Update AUO-0405 V3     | 2025     |
|                 | Lifetime / N/A                                       | 20 years |
|                 | Horizon of the CBA model / N/A                       | 20 years |
| Costs           | Cost of a diverted flight [EUR] / [9], p. 18         | 7400     |
|                 | Cost of cancelled flight [EUR] / [9], p. 11          | 6220     |
|                 | Cost of delay [EUR/min] / [11], p. 14                | 71       |

|                         |                                                                    |         |
|-------------------------|--------------------------------------------------------------------|---------|
|                         | Cost of emitted CO <sub>2</sub> [EUR/ton] / <sup>1</sup>           | 26.58   |
|                         | Cost of emitted NO <sub>x</sub> [EUR/kg] / [11], p.68              | 11,519  |
|                         | Cost of fuel [USD/b] / [15]                                        | 76.3    |
|                         | Fuel consumption (Holding) [kg/min] <sup>2</sup>                   | 22.24   |
|                         | NO <sub>x</sub> production (Holding) [kg/min] <sup>3</sup>         | 0.36    |
|                         | CO <sub>2</sub> production (Holding)[kg/min] <sup>4</sup>          | 31.76   |
|                         | Installation cost [USD] / <sup>5</sup>                             | 7 50    |
|                         | Training cost (first) [EUR] / [16] p. 32                           | 21 624  |
|                         | Training cost (recovery ) [EUR/year] / [16]                        | 1 081   |
|                         | Maintenance cost [USD/year] / [16], p. 30                          | 20 000  |
|                         | HUD cost [USD] / [16], p. 30                                       | 250 000 |
|                         | HMD cost [USD] / <sup>6</sup>                                      | 125 000 |
|                         | Passenger Value of Time [EUR/hour] / [11] p. 34                    | 126     |
|                         | Opportunity loss [EUR/diverted or cancelled flight] / <sup>7</sup> | 16 152  |
|                         | Average no. of passengers per flight (BA) / <sup>8</sup>           | 8       |
| <b>Other parameters</b> | Probability of LVC (RVR below CAT I minima) / <sup>9</sup>         | 2%      |
|                         | Average delay – flight [min] / [18] p. 7                           | 13.8    |
|                         | No. of flights per aircraft per year (BA) / <sup>10</sup>          | 212     |
|                         | Average duration of Europe flight (BA) [hours] / [9], p. 27        | 1.42    |

<sup>1</sup> Market data; Environmental markets; EU Emission Allowances (EUA) – September 2019

<sup>2</sup> Based on values relevant for Bombardier 300

<sup>3</sup> Based on values relevant for Bombardier 300

<sup>4</sup> Based on values relevant for Bombardier 300

<sup>5</sup> Initial data EBAA

<sup>6</sup> Expert estimate

<sup>7</sup> Expert estimate

<sup>8</sup> Expert estimate

<sup>9</sup> Expert estimate

<sup>10</sup> Expert estimate

|  |                                                   |     |
|--|---------------------------------------------------|-----|
|  | IR camera landing improvement / <sup>11</sup>     | 62% |
|  | Active sensor landing improvement / <sup>12</sup> | 85% |

**Table 4 : Summary of inputs for CBA model (approach phase)**

#### Specific Assumptions for Active Sensor- based EFVS approaches

The weather conditions considered in the analysis are the one permitting EFVS/CVS operations, ie with an RVR below CAT I minima (usually 800 m on small and medium airports) but above 300 m (to comply with EFVS regulation).

The rate of successful approaches for IR sensor is assumed to be 73%, based on academic studies and weather statistics.

The rate of successful approaches for the active sensor is considered as 100% - it is assumed that the visual advantage will be significantly better for the intended RVR and radar will penetrate more weather conditions than IR sensors.

Another assumption is that active sensor alone provides sufficient resolution to be interpreted by the crew and that it substitutes to a regular IR sensor. This assumption should be validated in the future, as each sensor active and IR sensor has its own benefits and can be used as complementary.

### 3.5.6 Assumptions Taxi

Table below is the assumption used for taxi phase.

| Name / Reference                                                                                | Value    |
|-------------------------------------------------------------------------------------------------|----------|
| Percentage of new heavy business jets equipped with HMD from year 2020.                         | 10%      |
| Share of business aviation in the whole air traffic.                                            | 7%       |
| Horizon of the CBA model.                                                                       | 20 years |
| Percentage of runway incursions linked to pilot deviations that could be avoided thanks to HMD. | 50%      |
| Percentage of vehicle/pedestrian deviations that could be detected thanks to HMD.               | 5%       |

*Table 5 : Summary assumptions (taxi phase)*

<sup>11</sup> 85% EVS-usable LVC conditions of 73% of the successful approaches conducted with an IR sensor

<sup>12</sup> Based on estimation and weather statistics

## 4 Benefits

### 4.1 HMD benefit

| Stakeholder   | KPA             | R&D Needs                                                                                                                                                                           |
|---------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Airspace User | HP              | Increasing human performance of the crew during taxi. Unlimited FOV Eyes-Outs capability associated to conformal symbology improves pilot performances to follow the intended path. |
| Airspace User | Cost efficiency | Affordable solution than current CVS using HUD                                                                                                                                      |

Table 6: R&D Needs for HMD

The foreseen benefits of the HMD depend on the phases of flight.

#### 4.1.1 Approach phase

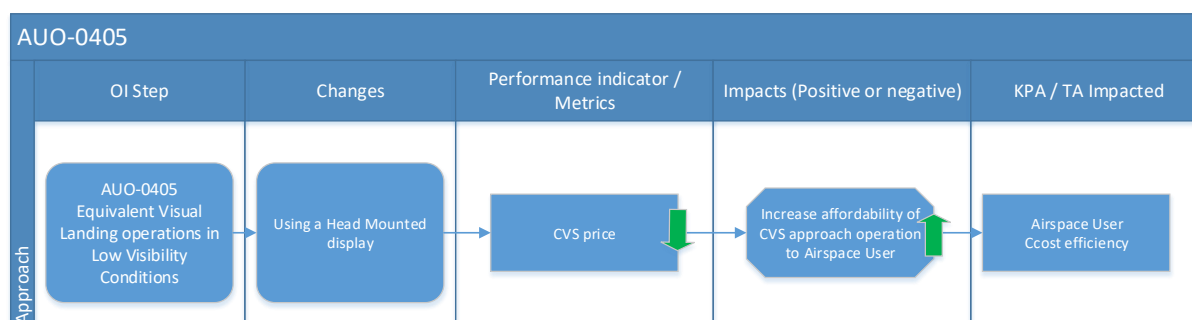


Figure 1: Benefit mechanism AUO-0405

Except from the lower purchase cost of the HMD compared to the HUD, benefits in approach phase could not be easily monetized and have only been considered from a qualitative point of view.

During approach phase the main gain of HMD will be increased situational awareness by helping the crew to keep its attention out of the cockpit. Such an head-up /eyes-out capability will help the crew to easily follow the intended path. In particular it is expected that HP and efficiency will be increased by:

- reducing possible overshoots of landing path.
- reducing the occurrence of runway overrun and underrun



- Improving brake efficiency and lifetime by providing the crew with improved awareness of runway end position.
- reducing the number of go-around linked to unstabilized approaches.

Reduction of purchase costs is shown in following table.

V

| Performance Framework KPA <sup>[1]</sup> | Focus Area                    | KPI/PI from the Performance Framework                      | Unit         | Metric for the CBA                                                                                                                                                                                                                     | Unit   | 2025      | 2030        | 2035        |
|------------------------------------------|-------------------------------|------------------------------------------------------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|-----------|-------------|-------------|
| Cost efficiency                          | Airspace User Cost efficiency | <b>AUC3</b><br>Direct operating costs for an airspace user | EUR / flight | Impact on direct costs related to the aeroplane and passengers. Examples: fuel, staff expenses, passenger service costs, maintenance and repairs, navigation charges, strategic delay, landing fees, catering (avoided-; additional +) | €/year | - 451 712 | - 2 332 124 | - 3 866 460 |

**Table 7: HMD Results of the benefits monetisation per KPA**

<sup>[1]</sup> For information, the mapping to the Performance Ambition KPAs (used in the ATM Master Plan) is available in the Appendix.

#### 4.1.2 Taxi Phase:

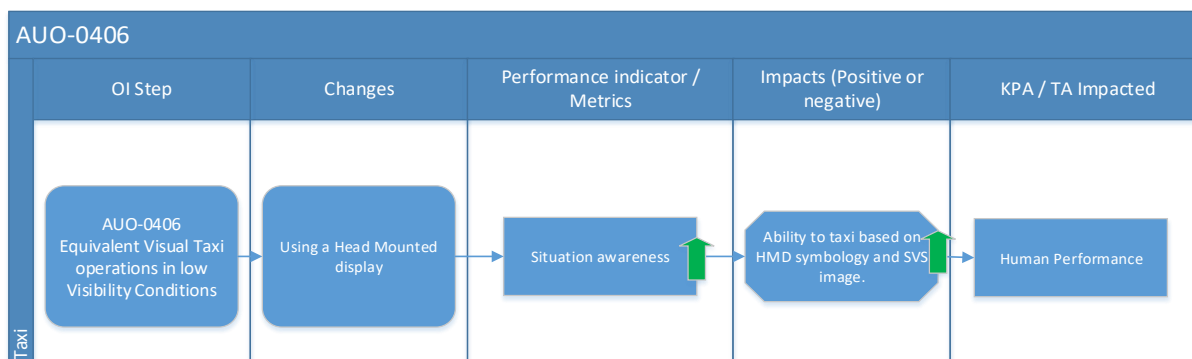


Figure 2: Benefit mechanism for AUO-0406

During taxi phase, the use of an HMD increases Crew Efficiency and HP through several contributors:

- By displaying the taxi clearance, it reduces the risk for the pilot to be lost during taxi phase which could result:
  - in a runway / taxiway incursion
  - in delay to reach its gate or the departure runway.
- By displaying the conformal traffic, it reduces the risk of ground collision with other traffic or vehicle.
- By keeping its attention out of the cockpit, the crew improves its awareness of the external world.
- By displaying the taxi clearance, it will support the pilot decision making for accepting a change of route at any time.
- By displaying the taxi clearance, it will provide better taxi routing awareness and potentially reduce ATC-crew voice communication for asking confirmation or further information

It is recognized that quantifying (and monetizing) such benefits is difficult. Therefore, the partners have decided to focus on the gain linked to the reduced percentage of runway incursions. However, this strategy has been made difficult due to the absence of any Airport Operator or ANPS in the project. Therefore, the consortium could only conduct its analysis based on data publicly available.

#### Statistics:

Runway incursions statistics are provided by ICAO, Eurocontrol, FAA or EASA.

However, the statistics do not rely on the same gathering process (some come from voluntary reports, some only relate to near accidents) nor description.

In addition, some airports or countries are more prone to declare such events than others.

It has been decided to use figures provide by EVAIR reports from Eurocontrol in [22] for Europe and by FAA for the US in [25] and to extrapolate them at European level.

### Identified causes:

In [22] Eurocontrol provides a very detailed analysis of the runway incursion causes, for events recorded through voluntary reports.

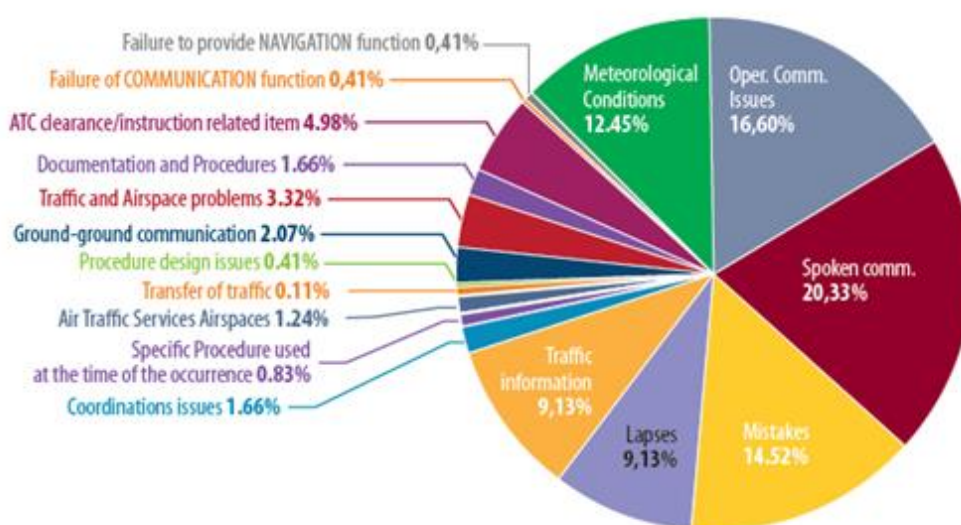


Figure 3: Runway Incursions contributory factors 2012-2016 Eurocontrol

From the above distribution one can expect a partial improvement for the following contributing factors:

- Meteorological conditions (as the HMD displays taxi route guidance in all-weather condition)
- Operational Communication Issues
- Mistakes
- Traffic information (thanks to the use of traffic display)
- Ground communications
- Coordination issues
- Traffic and airspace problem

Unfortunately, it is difficult to further analyse these categories and what actually append in each case.

The sum of all these factors however accounts for almost 60% of the cases.

Reasonably assuming that 50% of these occurrences could have been avoided by the use of an HMD (provided the aircraft is equipped with HMD, taxi guidance and traffic display capability) we come to the conclusion that 30% of the runway incursions could be avoided by HMD.

An FAA analysis is also available for the year 2014, which provides the following analysis:

2014 Runway Incursions Totals by Type

|                          | Operational Incidents | Pilot Deviations | Vehicle/ Pedestrian Deviations | Other**  | Total       | Annual RI Rate* |
|--------------------------|-----------------------|------------------|--------------------------------|----------|-------------|-----------------|
| AAL (Alaskan)            | 6                     | 30               | 17                             | 0        | 53          | 66              |
| ACE (Central)            | 6                     | 12               | 6                              | 0        | 24          | 16              |
| AEA (Eastern)            | 67                    | 59               | 31                             | 1        | 158         | 26              |
| AGL (Great Lakes)        | 37                    | 77               | 23                             | 2        | 139         | 22              |
| ANE (New England)        | 6                     | 11               | 5                              | 0        | 22          | 12              |
| ANM (Northwest Mountain) | 21                    | 68               | 21                             | 0        | 110         | 24              |
| ASO (Southern)           | 41                    | 147              | 31                             | 3        | 222         | 20              |
| ASW (Southwest)          | 25                    | 116              | 43                             | 1        | 185         | 29              |
| AWP (Western Pacific)    | 49                    | 244              | 57                             | 1        | 351         | 31              |
| <b>TOTALS</b>            | <b>258</b>            | <b>764</b>       | <b>234</b>                     | <b>8</b> | <b>1264</b> | <b>246</b>      |

\* Annual RI Rate — Calculated for all RIs. RI events per million operations.

\*\* Other — Events that meet the criteria of an RI though do not fit within the primary types (emergencies, equipment failures, etc.).

Table 8: Runway incursion by Type – FAA 2014

The different categories are defined below:

**Operational Incident:** A surface event attributed to ATC action or inaction.

**Pilot Deviation:** Action of a pilot that violates any federal aviation regulation. Example: A pilot crosses a runway without a clearance while en-route to an airport gate.

**Vehicle/Pedestrian Deviations:** Any entry or movement on the movement area or safety area by a vehicle (including aircraft operated by a non-pilot or an aircraft being towed) or pedestrian that has not been authorized by ATC.

From the above data, we can consider that HMD taxi guidance could have avoided some of the cases linked to own pilot deviations from taxi route.

The traffic display capability of the HMD could have been effective against other pilots or vehicle runway incursion in case of converging trajectory. For example, when the HMD equipped aircraft is on short final and thanks to the traffic display detects the incursion of another aircraft on the runway.

The consortium assumed that 50% of the incursions linked to pilot deviations could have been avoided.

Only 5% of vehicle/pedestrian deviations are assumed to be detectable by the use of HMD as it requires an ADS-B equipped vehicle and a converging trajectory.

It is also expected that only a small fraction of operational incidents (ie from ATC responsibility) could have been mitigated by the HMD.

The following table summarized these hypotheses.

|                                                | Operational incident | Pilot Deviations | Vehicle/ Pedestrian Deviations | Other | Total      |
|------------------------------------------------|----------------------|------------------|--------------------------------|-------|------------|
| Total number of incursions                     | 258                  | 764              | 234                            | 8     | 1264       |
| Total number of incursions avoided             | 13                   | 382              | 11                             | 0     | 406        |
| % of incursions possibly avoided thanks to HMD | 5%                   | 50%              | 5%                             | 0%    | <b>32%</b> |

As a result, provided all aircrafts are equipped with HMD, a reduction of 32% of runway incursion could be avoided.

It is assumed that such figure, based on US statistics is also relevant in Europe.

Trying to cross-check the analysis from FAA and Eurocontrol it appears that around 30% of the incursions could have been avoided by the use of HMD.

#### Total number of runway incursion avoided in Scenario 1:

To keep consistency with the CBA analysis, it is assumed that **10% of new heavy business jets are equipped with HMD in forward fit only** from year T0, and that no retrofit is considered. The production figures of HMD-equipped heavy jet in the coming years are provided in Table 1: Business aviation fleet evolution.

Eurocontrol in [27] quantifies the share of business aviation to around **7% of the total movements**.

As a conclusion  $A = 7\% \times B$  of the flights would be equipped with HMD in Scenario 1, where B represents the share of business jets equipped with HMD.

As HMD is expected to avoid 30% of the runway incursion causes, it appears that in Scenario 1 the use of HMD would have avoided  $A \times 30\%$  of the runway incursions.

The yearly results are summarized in Table 2

Table 2: Runway incursion reduction

| BA - Fleet evolution                                                                                                         |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |       |
|------------------------------------------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| Year                                                                                                                         | 2020  | 2021  | 2022  | 2023  | 2024  | 2025  | 2026  | 2027  | 2028  | 2029  | 2030  | 2031  | 2032  | 2033  | 2034  | 2035  | 2036  | 2037  | 2038  | 2039  | 2040  |
| Total business aircrafts at year start                                                                                       | 3 708 | 3 745 | 3 782 | 3 819 | 3 857 | 3 895 | 3 933 | 3 972 | 4 011 | 4 051 | 4 091 | 4 131 | 4 172 | 4 213 | 4 255 | 4 297 | 4 339 | 4 382 | 4 425 | 4 469 | 4 513 |
| Total number of HMD equipped jets                                                                                            | 0     | 4     | 8     | 12    | 16    | 20    | 24    | 28    | 32    | 36    | 40    | 45    | 50    | 55    | 60    | 65    | 70    | 75    | 80    | 85    | 90    |
| Percentage of business jets equipped with HMD                                                                                | 0     | 0.107 | 0.212 | 0.314 | 0.415 | 0.513 | 0.61  | 0.705 | 0.798 | 0.889 | 0.978 | 1.089 | 1.198 | 1.305 | 1.41  | 1.513 | 1.613 | 1.712 | 1.808 | 1.902 | 1.994 |
| Percentage of IFR flights equipped with HMD (BA flights represent 7% of total IFR traffic)                                   | 0     | 0.007 | 0.015 | 0.022 | 0.029 | 0.036 | 0.043 | 0.049 | 0.056 | 0.062 | 0.068 | 0.076 | 0.084 | 0.091 | 0.099 | 0.106 | 0.113 | 0.12  | 0.127 | 0.133 | 0.14  |
| Percentage of worldwide runway incursions avoided thanks to HMD (assuming an HMD could avoid 30% of runway incursion causes) | 0     | 0.002 | 0.004 | 0.007 | 0.009 | 0.011 | 0.013 | 0.015 | 0.017 | 0.019 | 0.021 | 0.023 | 0.025 | 0.027 | 0.03  | 0.032 | 0.034 | 0.036 | 0.038 | 0.04  | 0.042 |

Although this result does not show any real improvement at ATM level it is reminded that runway incursion reduction is only one among many benefits of the HMD. Moreover it is recalled that other segments may be interested in HMD (regional or commercial aircraft) while not quantified here, resulting in a higher percentage of runway incursion reduction. That's why this result should be considered with extreme care.

## 4.2 Active sensor benefit

| Stakeholder      | KPA             | R&D Needs                                                                              |
|------------------|-----------------|----------------------------------------------------------------------------------------|
| Airspace User    | Cost Efficiency | Reduction of aircraft operating costs related to delays, diversions and cancellations. |
| Airport Operator | Resilience      | Increasing resilience to adverse weather on small airport.                             |

Table 9: R&D Needs for active sensor

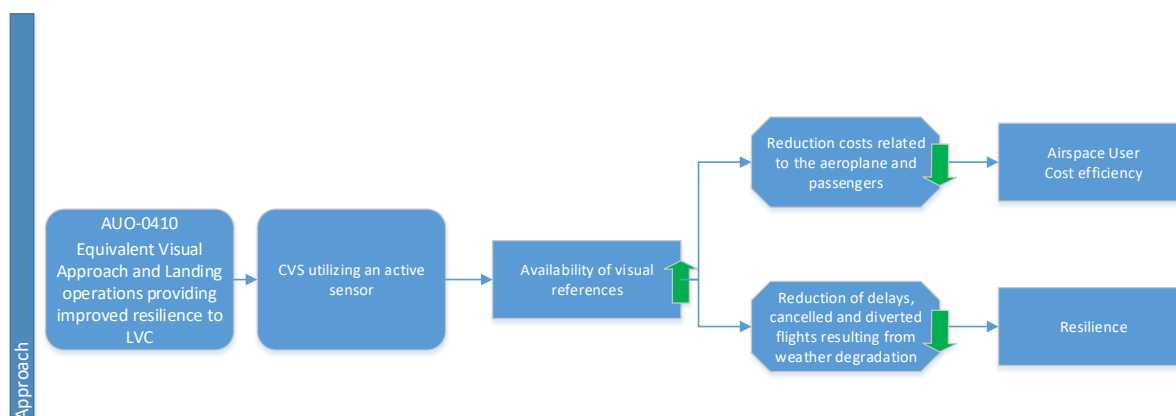


Figure 4: Benefit mechanism for AUO-0410

The main benefit of active sensor as EVS sensor supporting intended EFVS/CVS operation is the improved performance in adverse weather. It includes enhanced visual advantage which is a key element quantifying performance of EFVS/CVS.

It is assumed that the active sensor as an EVS sensor increases the percentage of successful landings in intended RVR by 27% compared to current Infrared EVS sensors. IR sensor performance is recognized as being insufficient in all visibility conditions, limiting the actual EFVS required RVR. This number is based on a study that evaluates the percentage of successful landing in intended RVR with standard IR sensor to 73%. (Shelton, Kramer, & Ellis, 2012). This improvement has directly an impact on access/ resilience at small and medium (secondary) airports in conditions when the RVR doesn't allow standard CAT I approach and when EFVS/CVS with standard sensor is not sufficient for an approach operation. On the other hand, enhanced visual operation with active sensor enables



airspace users to reach a destination small and medium (secondary) airport in adverse weather. The resilience to adverse weather is increased for the airport influenced by LVC equipped for the CAT I procedure only. It can be interpreted as increase in runway and airport throughput in LVC.

Unfortunately, ANSP and airport operators benefits are not considered in CBA model with respect complexity of these benefits and fact that ANSP and airport operators are not part of solution Pj03a-04. Table 10 shows costs reduction compare to the reference scenario defined in chapter 3.5.3.. Therefore, the results indicate savings in direct operation costs e.g. slightly reduced acquisition costs and costs related to delays, cancellation and diversion.

| Performance Framework KPA <sup>[1]</sup> | Focus Area                    | KPI/PI from the Performance Framework                      | Unit              | Metric for the CBA                                                                                                                                                                                                                     | Unit   | 2025       | 2030           | 2035        |
|------------------------------------------|-------------------------------|------------------------------------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|------------|----------------|-------------|
| Cost efficiency                          | Airspace User Cost efficiency | <b>AUC3</b><br>Direct operating costs for an airspace user | EUR / flight      | Impact on direct costs related to the aeroplane and passengers. Examples: fuel, staff expenses, passenger service costs, maintenance and repairs, navigation charges, strategic delay, landing fees, catering (avoided-; additional +) | €/year | -2 298 229 | -18 860 085    | -39 292 735 |
| Resilience                               | Resilience                    | <b>RES4a</b><br>Minutes of delays                          | Minutes           | Tactical delay cost (avoided-; additional +)                                                                                                                                                                                           | €/year | -13 814    | -57 926-74 099 |             |
|                                          |                               | <b>RES4b</b><br>Cancellations                              | % and # movements | Cost of cancellations                                                                                                                                                                                                                  | €/year | -164 492   | -689 760       | -882 348    |
|                                          |                               | Diversions                                                 | % and # movements | Cost of diversions                                                                                                                                                                                                                     | €/year | -439 554   | -1 843 169     | -2 357 804  |

**Table 10: Active Sensor results of the benefits monetisation per KPA**

<sup>[1]</sup> For information, the mapping to the Performance Ambition KPAs (used in the ATM Master Plan) is available in the Appendix.

# 5 Cost assessment

## 5.1 ANSPs costs

### 5.1.1 ANSPs cost approach

There is a consensus within the solution team that, provided LPV are already available on the ADR, ANSP costs will not increase in the frame of PJ03a-04; no additional ground infrastructure is needed as the solution only involves airborne technological enablers.

An increase in air traffic during LVC is however foreseen (as show in [23]) following the deployment of active sensor, as more aircrafts will be capable to land because of improved performances compared to existing IR sensor.

The expected workload increase at ATC level should not be an additional cost for ANSP's as small and medium airports (which are targeted) are usually operating far from their maximum capacity. In addition, more movements managed will result in additional revenue for the ANSP.

## 5.2 Airport operators costs

There is a consensus within the solution team that, provided aerodrome has been declared as suitable for EFVS operation, Airport Operator costs will not increase in the frame of PJ03a-04; no additional ground infrastructure is needed as the solution only involves airborne technological enablers.

If aerodrome has not been checked as suitable for EFVS operation, then development of LVP and modification of ADR certificate, or publication of adequate information in AIP will be needed. Such cost is however not quantified in the document.

## 5.3 Network Manager costs

There is consensus within the solution team that Network Manager costs will not be increased in the frame of PJ03a-04. Therefore, they are not considered in the document.

## 5.4 Airspace User costs

### 5.4.1 Airspace User cost approach

As the costs for airspace users, the following aspects are considered:

Active sensor & HMD

- Installation of forward fit (initial estimated numbers)
- HUD equipment: 250 000 USD
- HMD equipment: 125 000 USD
- Legacy IR sensor: 250 000 USD
- Active sensor: 190 000 USD
- EFVS/CVS component installation: 7 500 USD

Numbers above are initial estimated numbers but final values will depend on many factors.

Additional costs linked with operation and maintenance:

- Pilots training costs 29 106 USD
- Maintenance costs 20 000 USD
- Consecutive training is 5% of the initial training costs

## 5.4.2 Airspace User cost assumptions

### 5.4.2.1 Number of investment instances (units)

|               | Business Aviation (BA) |          |
|---------------|------------------------|----------|
|               | Ground locations       | Airborne |
| HMD           | N/A                    | 95       |
| Active sensor | N/A                    | 680      |

Table 11: Number of investment instances - AUs

### 5.4.2.2 Cost per unit

| Cost category            |               | Business Aviation (BA) |                |
|--------------------------|---------------|------------------------|----------------|
|                          |               | Ground                 | Airborne       |
| Pre-Implementation Costs |               | 0                      | N/A *          |
| Implementation costs     | HMD           | 0                      | 406.5k USD     |
|                          | Active sensor | 0                      | 471.5k USD     |
| Operating costs          | HMD           | 0                      | 21k USD / year |
|                          | Active sensor | 0                      | 21k USD / year |

Table 12: Cost per unit - AUs

\* Pre-implementation costs are included in implementation costs

Implementation costs include costs related to acquisition, installation and initial training

## 5.4.3 Military costs

There is consensus within the solution team that Military costs are not impacted by the solution will not be increased in the frame of PJ03a-04. Therefore, they are not considered in the document.

## 6 CBA Model

### 6.1 Data sources

The consortium reused the CBA model that was developed for WP9.28 in the frame of SESAR1.

A fleet of 680 aircraft is considered for the Active sensor scenario.

A fleet of 95 aircraft is considered for the HMD.

In contrast to the previous SESAR CBA 9.28 analysis, new values were considered for the performance improvement of IR sensor and active sensor.

The horizon for the analysis is 20 years.

The weather condition intended for EFVS/CVS approach operation are below the CAT I minima (usually 800m for small and medium (secondary) airport).

The probability of occurrence of an RVR below CAT I minima is estimated to 2% and is called LVC probability for the purpose of this CBA. In such conditions, all unequipped flights are somehow affected by LVC / lower RVR (delayed 30%, diverted 50% or cancelled 20%).

The Bombardier Challenger 300 is considered in the analysis as being representative of the intended aircraft type for EFVS/CVS operations. At the beginning of the analysis, it is considered that no aircraft is equipped by any EFVS/CVS equipment (sensor or HMD/HUD) considered in the current CBA. A second major assumption is that all newly-manufactured aircrafts are equipped with sensor and HUD/HMD from the first year of the analysis.

The CBA model is influenced by the discount rate.

The fuel cost in EUR/min is considered for the model.

**The emissions (NOx and CO2) are also included into the costs.**

**Table 13 : CBA Fuel costs**

| Input   | Fuel cost<br>EUR/min | NOx cost EUR/min | CO2 costs<br>EUR/min | Total |
|---------|----------------------|------------------|----------------------|-------|
| Holding | 8.10                 | 4.16             | 0.84                 | 13.1  |

The probabilities of successful landing in LVC per scenarios are provided in Table 14. These values are further described in chapter 6.3.

**Table 14: IR/active sensor comparison**

| Input                                                             | Active sensor + HUD | IR+HUD |
|-------------------------------------------------------------------|---------------------|--------|
| Probability of successful landing in LVC (RVR below CAT I minima) | 85%                 | 62%    |

These are numbers further described in the text.

Below in Table 15: CBA inputs, see the CBA model inputs overview:

**Table 15: CBA inputs**

| Input                                       | Updated value | Source                      | Note |
|---------------------------------------------|---------------|-----------------------------|------|
| Probability of LVC (RVR below CAT I minima) | 2%            | Based on weather statistics |      |
| Cost of diverted flight                     | 7400 EUR      | [11] p. 18                  |      |
| Cost of additional flight                   | 700 EUR       | [13] p. 59                  |      |
| Cost of cancelled flight                    | 6220 EUR      | [11] p. 11                  |      |

The passenger time in Table 16: CBA inputs - Passengers is taken as an input for the CBA analysis. Time of passenger (cost of the lost time) is estimated in case of delay, diversion and cancelation. The average number of passengers per aircraft is 8.

The time of passenger/hour is considered, but also the opportunity loss caused by a missed opportunity resulting from not attending an important meeting.

The opportunity loss is used as an input for the analysis only in the cases of diverted and cancelled flights - for the delayed flights, there is still a possibility that the business will occur, although delayed. The opportunity loss is then implemented in the model per flight/event. The opportunity loss is included into the analysis as the 16 152 USD/cancelled or diverted flight.

**Table 16: CBA inputs - Passengers**

| Input                                   | Updated value | Source     | Note |
|-----------------------------------------|---------------|------------|------|
| Avg. Duration of Europe flights (hours) | 1.42          | [11] p. 25 |      |
| Number of flights per 1 a/c and year    | 212           |            |      |

|                           |       |                                       |                           |
|---------------------------|-------|---------------------------------------|---------------------------|
| Avg. number of passengers | 8     | Mean value per intended aircraft type |                           |
| Time of passengers        | 126.6 | For BA multiplied factor 3 (x 42.2)   | Operational expert review |

The equipment cost presented in Table 17: Equipment costs is computed as the sum of all the costs in the first year following equipment acquisition (shipset purchase, installation cost,...) . It is assumed that all aircraft in the fleet are equipped with the equipment/scenario and no additional equipment is needed per the 20 year-life-cycle.

**Table 17: Equipment costs**

| Input     | Updated value | Source                                        | Note |
|-----------|---------------|-----------------------------------------------|------|
| HUD       | 250 000 USD   | Regulatory impact assessment AWO Project [31] |      |
| HMD       | 125 000 USD   | Expert estimate                               |      |
| IR sensor | 250 000 USD   | CBA SESAR 9.28                                |      |

The training and maintenance is considered at two levels – the 1<sup>st</sup> year (initial) and recurrent. Please, see the respective values in Table 18: Training and maintenance.

**Table 18: Training and maintenance**

| Input                         | Updated value   | Source                                                                      | Note |
|-------------------------------|-----------------|-----------------------------------------------------------------------------|------|
| Training 1 <sup>st</sup> year | 21 624 EUR      | Regulatory impact assessment AWO Project, p. 32 [31]                        |      |
| Regular training 5%           | 1081 EUR        | Consolidated thanks to regulatory impact assessment AWO Project, p. 32 [31] |      |
| Maintenance/year              | 20 000 USD/year | Regulatory impact assessment AWO Project, p. 30 [31]                        |      |

## 6.2 CBA model description

The principle of the CBA model for approach phase of flight for both HMD and Active sensor technologies includes briefly two main parts. The first part is cost side where all costs related to solution acquisition, maintenance, operation costs etc. are considered. The second part is benefit side including all benefits relevant to suggested solution under profiled conditions. The profiled conditions are determined based on historic weather statistics on appropriate airports. The model considers increasing number of aircraft (BA) equipped by appropriate technology during expected time horizon with average number of flight hours per aircraft per year combined with average flight duration. Benefits generally consist in savings generated by reduction of fuel consumption, emission, diverted and cancelled flights etc. (operational point of view) and time savings, reduction of opportunity loss etc. (passenger side). Figure 5 graphically explains model interconnections.

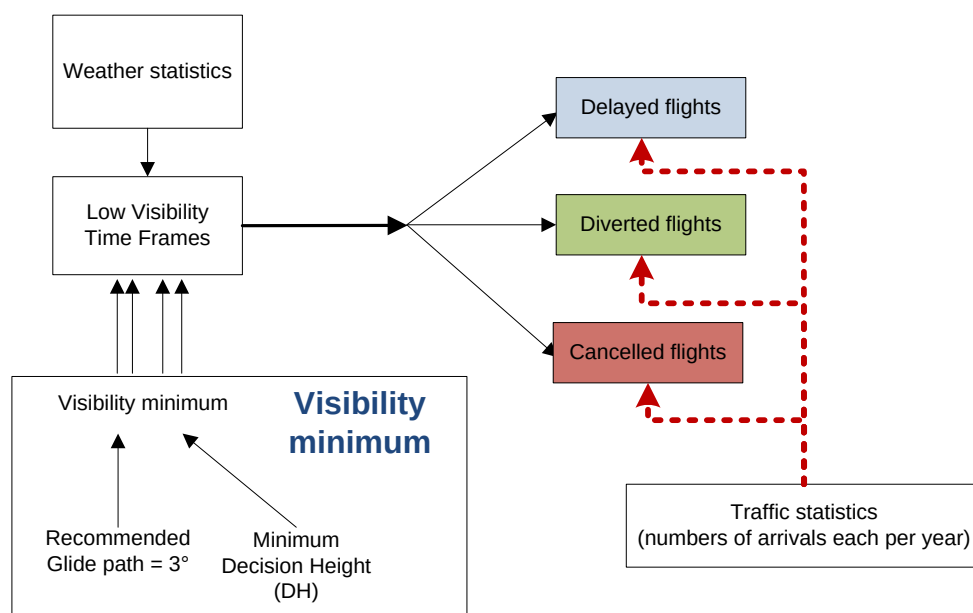


Figure 5: Approach phase Benefit Model

The model only addresses business jet segment in order to limit its complexity but also because the greatest benefits are identified for this segment which is confirmed by the strong interest shown by business jet industry.

## 6.3 CBA model differences per scenario

The following section describes the differences among the scenarios. The HMD technology is planned to achieve V3 maturity, however the active sensor will not achieve V3 at the end of Wave 1.

All scenarios are focusing on weather conditions below CAT I minima (ie usually 800m RVR for small and medium (secondary) airport). Statistics have shown that cases with RVR higher than 300m and lower than 800m (corresponding to the use-case of EFVS/CVS operations) **account for only 85%** of the total LVC time: this figure is considered as a baseline for all scenarios.

### 6.3.1 Scenario 1: Aircraft equipped with IR EVS camera and HMD

In this scenario HMD technology is planned to reach V3 and is capable of providing the exact same operational gain as conventional HUD. Its advantages compared to HUD (lightweight, colour, 360° FOV, expected lower acquisition cost). The IR camera is the currently existing EVS sensor.

The **IR EVS camera & HMD** scenario has the following inputs:

- According to the study (Shelton, Kramer, & Ellis, 2012), it is assumed, that only 73% of the approaches conducted with an IR sensor are successful, due to the limited sensor performance.
- Therefore, assuming the 85% of EFVS/CVS-usable LVC (RVR related) mentioned above, the probability of successful approaches in LVC conditions by using an EFVS IR sensor is **62%**.

### 6.3.2 Scenario 2: Aircraft equipped with active sensor and HUD

This scenario considers existing HUD and proposed active sensor as a baseline. This sensor is expected to provide much better performances than IR sensor allowing a 100% probability of detecting runway visual references at DH.

The difference compared to reference scenario is the improved operational gain of the sensor increasing the rate of successful EFVS/CVS approaches and then decreasing the number of diversion or flight cancelling because of weather.

The **active sensor & HUD** scenario has following inputs:

- According to the assumption, it is assumed, that 100% of the flown EFVS-approaches are successful when an active sensor is used.
- Therefore, assuming the 85% of EFVS-usable LVC (RVR related) mentioned above, the probability of successful approaches in LVC conditions by using an active sensor is **85%**.

## 7 CBA Results

This chapter summarizes quantified benefits for approach operation and qualitative benefits for taxi operation. The results are assumed in case of new aircraft (forward-fit installation) because acquisition and installation costs for retrofits do not allow profitable solution compare to existing systems.

The quantified benefits are not clearly measurable. Active sensor validations indicate promising performance. However, exercise did not fully confirm values assumed for this CBA. Similarly, HMD exercise did not fully satisfied operational feasibility of this solution.

The main benefits related to approach operation and respecting KPA are in tables below. These benefits arise from the comparison against current existing systems/operations.

| Performance Framework KPA | KPI/PI from the Performance Framework                      | Unit   | 2044        |
|---------------------------|------------------------------------------------------------|--------|-------------|
| Cost efficiency           | <b>AUC3</b><br>Direct operating costs for an airspace user | €/year | - 5 500 256 |

**Table 19: HMD results of the benefits monetisation per KPA for 95 aircrafts**

| Performance Framework KPA | KPI/PI from the Performance Framework                      | Unit   | 2044         |
|---------------------------|------------------------------------------------------------|--------|--------------|
| Cost efficiency           | <b>AUC3</b><br>Direct operating costs for an airspace user | €/year | - 74 754 202 |
| Resilience                | <b>RES4a</b><br>Minutes of delays                          | €/year | - 70 213     |
|                           | <b>RES4b</b><br>Cancellations                              | €/year | - 836 067    |
|                           | Diversions                                                 | €/year | -2 234 128   |

**Table 20: Active Sensor results of the benefits monetisation per KPA for 680 aircrafts**

Break-even point presented important result for such a technology. It indicates the first year when the technology is profitable with respect all costs related to acquisition. Following table is the most important for OEMs and Airspace users considering solution technologies and sum up the overall benefit in the end of the covered time interval (NPV). This results represent overall cumulative benefits of forward-fit solution with comparison unequipped aircraft with EFVS/CVS technology. The overall cumulative benefits are very sensitive to couple main inputs. The sensitivity is described in detail in following chapter. Figure 6 and Figure 7 shows evolution of costs and benefits during lifetime. HMD technology doesn't look profitable. However, all inputs were estimated very conservatively and sensitivity chapter shows influence of LVC probability.

**Table 21: Break-even points, NPV(EUR)**

| Input                               | Break-even point | NPV (EUR)  | Number of aircraft |
|-------------------------------------|------------------|------------|--------------------|
| IR EVS camera + HMD<br>(Scenario 1) | >20              | -4 472 346 | 95                 |
| Active sensor + HUD<br>(Scenario 2) | 20               | 3 341 557  | 680                |

Figure 6: Cumulative results for HMD (Scenario 1)

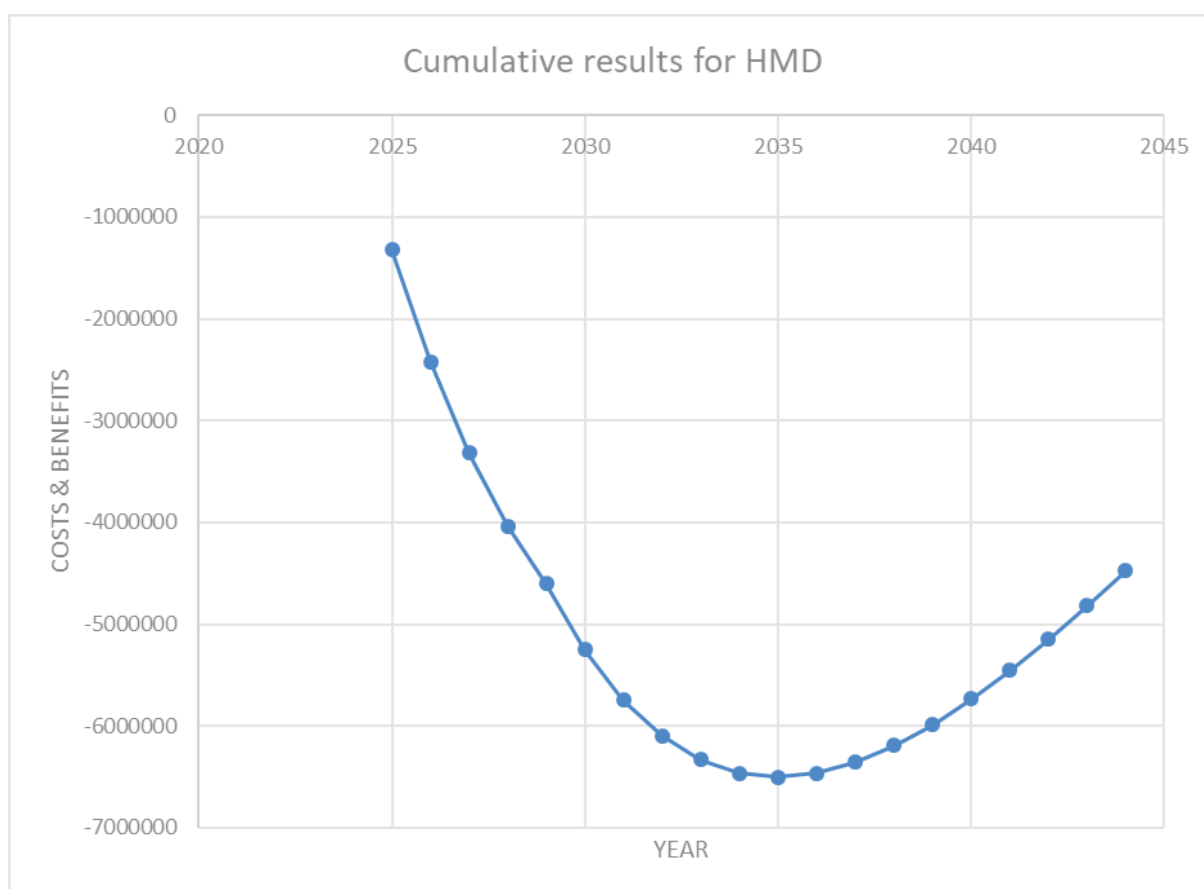
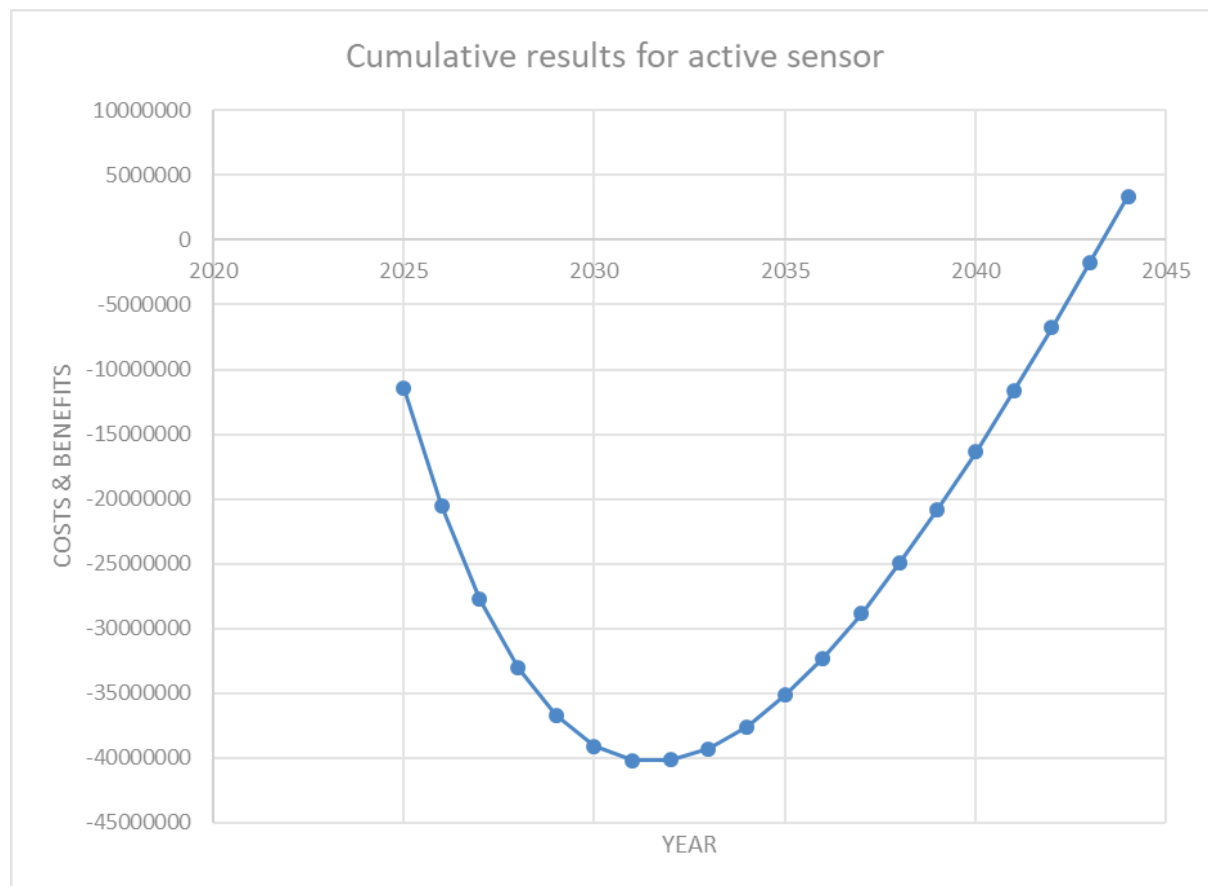


Figure 7: Cumulative results for Active sensor (Scenario 2)



The overall impact of the solution is on resilience in terms of reduction of aircraft delays, cancelations and diversions.

Airspace users' quantitative benefits (resulting from reduced diversion and delays) are presented in Table 22 and Table 23. First table shows benefits per one aircraft and one flight comparing to unequipped aircraft. Second table shows same benefits per one aircraft and one flight comparing to aircraft equipped with existing systems.

**Table 22: AU benefits w/o disc. rate compare to unequipped aircraft**

| Input                               | One aircraft benefits (EUR/year) | Benefit/flight (EUR) |
|-------------------------------------|----------------------------------|----------------------|
| IR EVS camera + HMD<br>(Scenario 1) | 54 087                           | 255                  |
| Active sensor + HUD<br>(Scenario 2) | 74 018                           | 350                  |

**Table 23: AU benefits w/o disc. rate compare to existing solution / reference scenario**

| Input                               | Benefits (EUR/year)                      | Benefit/flight (EUR)                     |
|-------------------------------------|------------------------------------------|------------------------------------------|
| IR EVS camera + HMD<br>(Scenario 1) | N/A<br>(no reduction of<br>delays, etc.) | N/A<br>(no reduction of<br>delays, etc.) |
| Active sensor + HUD<br>(Scenario 2) | 19 931                                   | 95                                       |

Following list is related to qualitative benefits of HMD supporting equivalent taxi operation.

The foreseen qualitative benefits are recalled below:

- Reduction of injuries or fatalities linked to runway incursion and traffic collisions.
- Reduction of overshoot of landing path and go arounds linked to unstabilized approaches.
- Reduction of the risk for the pilot to get lost during taxi phase thanks to taxi clearance display.
- Reduction of the risk of ground collision with other traffic or vehicle thanks to the display of conformal traffic.

## 8 Sensitivity and risk analysis

There are a number of uncertainties behind the assumptions considered in this analysis.

### Weather statistics

The global warming impact on weather statistics used as the inputs for this study may significantly change the outcome of this analysis, independently on the technological enablers performance and price. Beside mentioned above weather variates on airport geolocation and many other aspects. Detailed analyses also shown significant influence of this parameter to benefits. Following tables indicate this influence.

**Table 24: Break-even points, NPV(EUR); probability of LVC = 2,5%**

| Input                               | Break-even point | NPV (EUR)  |
|-------------------------------------|------------------|------------|
| IR EVS camera + HMD<br>(Scenario 1) | 19               | 678 904    |
| Active sensor + HUD<br>(Scenario 2) | 13               | 54 857 761 |

**Table 25: Break-even points, NPV(EUR); probability of LVC = 3 %**

| Input                               | Break-even point | NPV (EUR)   |
|-------------------------------------|------------------|-------------|
| IR EVS camera + HMD<br>(Scenario 1) | 14               | 5 830 154   |
| Active sensor + HUD<br>(Scenario 2) | 10               | 106 373 964 |

Therefore, results presented in this document have to be considered with extreme care and are specific to each airport.

Other inputs have lower influence on the overall results.

## Traffic growth

The expected growth of air traffic depends on a number of traditionally variables factors including fuel price and geopolitical environment. The advent of Shame-To-Fly contestation may also negatively impact the air traffic growth in the coming years.

## Performances/acquisition cost

As mentioned above, the expected performances of active sensor will also be a major driver of the dissemination of EFVS/CVS capacity, as will its price. The HMD actual cost will also strongly impact the results.

## Opportunity loss

In all scenarios, an opportunity loss factor is considered. The opportunity loss is described as the possible loss of passenger income due to missing a meeting or an important event as a result of flight cancelation or diversion. The figure considered for opportunity loss is by nature arbitrary since opportunity loss can be extremely variable and may range from nothing to millions of dollars (when an important deal is missed). There can also be many indirect and hardly quantifiable costs linked with meetings or events.

## 9 Recommendations and next steps

As mentioned above, the uncertainties regarding the considered assumptions strongly limit the confidence in the results provided in the document.

The partners recommend further work, especially on the technological enablers to provide consolidated values and results from validation supporting all CBA inputs and assumptions.

In particular:

- HMD actual selling price remains to be consolidated since no certified product is currently available on the market.
- The Active Sensor performance in bad weather conditions needs to be validated in target environment within further flight tests. Moreover, the system capability to display a clear and non-ambiguous image based on radar is still unanswered. Therefore, next development shall focus on representation of radar data and validation with pilots to cover overall EFVS/CSV concept with active sensor. The validated active sensor performance and later estimated acquisition costs at the end of V3 phase will be a major driver for the update of CBA result in future if necessary.

As a conclusion, the partners recommend updating the current document when active Sensor has reached V3 in order to confirm the potential and cost of this technology, and when a certified or near certification HMD product is available on the market.

# 10 References and Applicable Documents

## 10.1 Applicable Documents

- [1] SESAR 2020 Project Handbook
- [2] SESAR 16.06.06-D26\_04, Guidelines for Producing Benefit and Impact Mechanisms, Edition 03.00.01
- [3] SESAR 16.06.06-D26\_03, Methods to Assess Costs and Monetise Benefits for CBAs, Edition 00.02.02

## 10.2 Reference Documents

- [4] Common assumptions for CBAs as maintained by PJ19 (provisionally the ones included in the 16.06.06- D68\_Part 1, New CBA Model and Methods 2015, Edition 00.01.01 can be used)
- [5] European ATM Master Plan Portal <https://www.atmmasterplan.eu/>
- [6] SESAR C.02-D110, Updated D02 after MP Campaign, Edition 00.01.01
- [7] SESAR 2020 D108, Transition Performance Framework, Edition 00.06.00
- [8] PJ19.04.01 D4.5 Validation Targets (2019), Edition 00.01.00, February 2019
- [9] SESAR 2020 D86, Guidance on KPIs and Data Collection – Support to SESAR2020 transition, Edition 00.01.01
- [10] PJ19 D19.2.1 SESAR 2020 Concept Of Operations Edition 2017
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- [17] <https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tps00173&plugin=1>
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## 10.3 Other references

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- [20] ICAO ANNEX 14, Airport
- [21] ICAO Doc. 4444, Air Traffic Management, Procedures for Air Navigation Services
- [22] EVAIR Safety Bulletin N°19, 24 April 2018 (Shelton, Kramer, & Ellis, 2012)
- [23] Synthetic and Enhanced Vision Systems (SEVS) for NextGen simulation (2012)
- [24] Runway Safety Analysis for 2015 to 2017.
- [25] National Runway Safety Report 2013-2014 – FAA
- [26] GAMA 2018 Annual Report
- [27] Eurocontrol Business-aviation-infographic – 2016
- [28] AMSTAT Business Aviation Market Update Report
- [29] SESAR 1 WP9.29 CBA
- [30] SESAR LSD02.02 AAL1
- [31] EASA All Weather Operation (AWO) Regulatory Impact Assessment

# 11 Appendix

Mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs, source reference [7]

| ATM Master Plan<br>SESAR Performance<br>Ambition KPA | ATM Master Plan<br>SESAR Performance<br>Ambition KPI       | Performance<br>Framework KPA        | Focus Area            | #KPI / (#PI) /<br><Design<br>goal> | KPI definition                                                                                                                                                         |
|------------------------------------------------------|------------------------------------------------------------|-------------------------------------|-----------------------|------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Cost efficiency                                      | PA1 - 30-40%<br>reduction in ANS<br>costs per flight       | Cost efficiency                     | ANS Cost efficiency   | CEF2                               | Flights per ATCO hour on duty                                                                                                                                          |
|                                                      |                                                            |                                     |                       | CEF3                               | Technology Cost per flight                                                                                                                                             |
| Capacity                                             | PA7 - System able to<br>handle 80-100% more<br>traffic     | Capacity                            | Airspace capacity     | CAP1                               | TMA throughput, in challenging<br>airspace, per unit time                                                                                                              |
|                                                      |                                                            |                                     |                       | CAP2                               | En-route throughput, in challenging<br>airspace, per unit time                                                                                                         |
|                                                      | PA6 - 5-10%<br>additional flights at<br>congested airports |                                     | Airport capacity      | CAP3                               | Peak Runway Throughput (Mixed<br>Mode)                                                                                                                                 |
|                                                      |                                                            |                                     | Capacity resilience   | <RES1>                             | % Loss of airport capacity avoided                                                                                                                                     |
|                                                      | <RES2>                                                     | % Loss of airspace capacity avoided |                       |                                    |                                                                                                                                                                        |
|                                                      | PA4 - 10-30%<br>reduction in<br>departure delays           | Predictability and<br>punctuality   | Departure punctuality | PUN1                               | % of Flights departing (Actual Off-<br>Block Time) within +/- 3 minutes of<br>Scheduled Off-Block Time after<br>accounting for ATM and weather<br>related delay causes |

| ATM Master Plan<br>SESAR Performance<br>Ambition KPA | ATM Master Plan<br>SESAR Performance<br>Ambition KPI                                            | Performance<br>Framework KPA | Focus Area                                                 | #KPI / (#PI) /<br><Design<br>goal> | KPI definition                                                                                          |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------|------------------------------|------------------------------------------------------------|------------------------------------|---------------------------------------------------------------------------------------------------------|
| Operational Efficiency                               | PA5 - Arrival predictability: 2 minute time window for 70% of flights actually arriving at gate |                              | Variance of actual and reference business trajectories     | PRD1                               | Variance of differences between actual and flight plan or Reference Business Trajectory (RBT) durations |
|                                                      | PA2 - 3-6% reduction in flight time                                                             | Environment                  | Fuel efficiency                                            | (FEFF3)                            | Reduction in average flight duration                                                                    |
|                                                      | PA3 - 5-10% reduction in fuel burn                                                              |                              |                                                            | FEFF1                              | Average fuel burn per flight                                                                            |
| Environment                                          | PA8 - 5-10% reduction in CO2 emissions                                                          |                              |                                                            | (FEFF2)                            | CO2 Emissions                                                                                           |
| Safety                                               | PA9 - Safety improvement by a factor 3-4                                                        | Safety                       | Accidents/incidents with ATM contribution                  | <SAF1><br>see section 3.4          | Total number of fatal accidents and incidents                                                           |
| Security                                             | PA10 - No increase in ATM related security incidents resulting in traffic disruptions           | Security                     | Self- Protection of the ATM System / Collaborative Support | (SEC1)                             | Personnel (safety) risk after mitigation                                                                |
|                                                      |                                                                                                 |                              |                                                            | (SEC2)                             | Capacity risk after mitigation                                                                          |
|                                                      |                                                                                                 |                              |                                                            | (SEC3)                             | Economic risk after mitigation                                                                          |



| ATM Master Plan<br>SESAR Performance<br>Ambition KPA | ATM Master Plan<br>SESAR Performance<br>Ambition KPI | Performance<br>Framework KPA | Focus Area | #KPI / (#PI) /<br><Design<br>goal> | KPI definition                                          |
|------------------------------------------------------|------------------------------------------------------|------------------------------|------------|------------------------------------|---------------------------------------------------------|
|                                                      |                                                      |                              |            | (SEC4)                             | Military mission effectiveness risk<br>after mitigation |

Table 26: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs

**-END OF DOCUMENT-**

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