SESAR SOLUTION PJ.05-W2 SOL 97 (CBAT) FOR V2/TRL4

Deliverable ID:	D3.1.071
Dissemination Level:	PU
Project Acronym:	DTT
Grant:	874470
Call:	H2020-SESAR-2019-1
Topic:	SESAR-IR-VLD-WAVE2-05-2019
Consortium Coordinator:	AT-ONE Consortium
Edition Date:	28 Oct 2022
Edition:	10.00.01
Template Edition:	03.00.01

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Document History

Edition	Date	Status	Beneficiary	Justification
		Draft	ENAV	Creation of the document
6.0	Oct 2021	Draft	ENAV Deep Blue	Removal of Sol 97.3, updated Costs/Sensitivity sections following 97.1 Consultation
6.4	Dec 2021	Draft	ENAV Deep Blue	Consolidated draft of 97.1 Unit Costs, initial draft of 97.2 Unit Costs
7.2	Feb 2022	Draft	ENAV Deep Blue	Final draft of Unit Costs, update to latest SESAR Template
8.1	Aug 2022	Draft	ENAV Deep Blue	Updated with Solution Partner comments
8.2	Sep 2022	Draft	ENAV Deep Blue	Updated for final drafts IS/TRS and VALR, working draft PAR
8.3	Oct 2022	Draft	ENAV Deep Blue	Updated following internal review, added sections 6, 7 and 8
9.1	Oct 2022	Final Draft	ENAV Deep Blue	Final draft version for approval by Solution Partners
10.0	Oct 2022	Final for Delivery	ENAV Deep Blue	Final version to be updated in STELLAR

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DIGITAL TECHNOLOGIES FOR TOWER

This Cost Benefit Analysis Technology Deliverable is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 874470 under European Union's Horizon 2020 research and innovation programme.

Abstract

Among the expected technological enhancements allocated by SJU to SESAR 2020-W2-PJ05 "***DIGITAL TECHNOLOGIES FOR TOWER***" are the development of new human machine interface (HMI) interaction modes and technologies for the CWP in the Control Tower, with the aim to minimize the load and mental strain on the Tower ATCOs, in several sub-operating Environments.

The high-level improvements addressed in the scope, defined above, may be applicable in current operations as well as in future operational concepts.

The Operational Improvements identified have been allocated to 2 sub-Solutions, under PJ.05-W2-WP3:

- ✓ PJ.05-W2-97.1 '*Virtual/Augmented reality applications for tower*'
- ✓ PJ.05-W2-97.2 '*ASR at the TWR CWP supported by AI and Machine Learning'*

The validation activities planned for the Solutions comprise 6 exercises.

This Cost Benefit Analysis Technology document presents Implementation and Operating costs, as reported for each exercise by involved actors, and monetized benefits calculated from the KPAs' assessment and reported into the PAR. The objective is to assess the economic feasibility of the Solutions at maturity level V2/TRL4, in terms of Net Present Value (NPV), with an associated sensitivity and risk analysis.

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1 Executive Summary

This document presents the Cost Benefit Analysis tailored for the Technological Solution (CBAT) related to the two solutions in *SESAR2020 Wave 2 PJ.05-W2-* WP3, namely:

- ✓ PJ.05-W2-97.1 '*Virtual/Augmented reality applications for tower*'
- ✓ PJ.05-W2-97.2 '*ASR at the TWR CWP supported by AI and Machine Learning'*

Both solutions are targeting V2 (TRL4) maturity level.

The document gathers the Costs per Solution at the Airport sub-Operating Environment levels (Very Large, Large, Medium, Small, Other), and includes the extrapolation of these costs to ECAC level, with the aim to assess the economic feasibility of the solutions and help compare different deployment alternatives. The official performance indicators as defined in the SESAR 2020 Performance Framework are used to capture the Benefits of the Solution as reported in the Performance Assessment Report [20]. In TRL4 maturity phase, the CBAT provides a quantitative assessment of both costs and benefits (i.e., the performance assessment) of the SESAR Solutions to assess the economic feasibility of the solution(s) and possibly to compare alternatives.

In accordance with the Project Handbook 10.1~~[1]~~, for V2/TRL4 the CBAT includes a first order of magnitude of costs, benefits and Net Present Value (NPV) of the different options being compared.

Quantification and collection of costs is covering the acquisition, implementation and operation of the solutions by all stakeholders.

Concerning the Benefits, the TVALP [16] includes the BIM (Benefits Impact Mechanism), which identifies and allocates the set of relevant KPAs to the two Solutions: namely **Cost Efficiency, Human Performance** and (indirectly) **Safety**. It also allocates **Capacity** (Resilience Focus Area) to Solution 97.1. The Performance Assessment Report [20] uses the reported results from the Validation Exercises [19] to provide expected ECAC-wide benefit gains for the KPAs.

The cost and benefit data are combined in a CBAT model to assess the economic feasibility of the Solutions in terms of affordability with respect to the expected benefits.

The results of the CBAT analysis demonstrate the ECAC-wide economic viability of both Solutions over the SESAR Wave 2 time period of 2022 to 2043: specifically, Solution 97.1 has an ECAC-wide NPV of **€147.6 M**, with a breakeven year of **2037**; and Solution 97.2 a NPV of **€365.6 M** with a breakeven year of **2034**.

At local level, the economic viability is very dependent on the number of airport movements to generate sufficient Cost Efficiency savings to cover the costs of implementing and operating the Solutions. Indicative results suggest that ANSPs with Very Large and Large airports have consistently positive NPVs, whereas Small and Other airports have consistently negative NPVs. The implication is that ANSPs will need to consider implementing the Solutions on a case-by-case basis at Small and Other airports to assess whether other factors, such as Multiple Remote Tower or cost avoidance (e.g., not installing ground surveillance equipment) confirm the economic viability at that location.

2 Introduction

2.1 Purpose of the document

The objective of the CBAT is to gather Costs and Benefits relevant to the validation of the technological enablers addressed by Solutions 97.1 and 97.2, to assess the economic feasibility of Solution by comparing monetized benefits calculated from the KPAs' assessment and reported into the PAR.

To that aim, per each Solution, costs to implement the Technological enablers are collected and measurements of the final benefit value relevant to allocated KPIs (Cost Efficiency, Safety and Human Performance) used to calculate the final Cost Benefit ratio and assess the Solution feasibility.

The CBAT is produced using the Reference Methodology as provided by SESAR guidelines on the CBAs, specifically: the Project Handbook 10.1[1]; Methods to assess Costs and monetize Benefits [3]; Guidelines for producing BIMs [2]; and, CBA Quality Checklist [6].

2.2 Scope

This CBAT provides collection and calculation of the costs and benefits relevant to Sol 97.1 and.2, which address, respectively:

- ✓ PJ.05-W2-97.1 '*Virtual/Augmented reality applications for tower*'
- ✓ PJ.05-W2-97.2 '*ASR at the TWR CWP supported by AI and Machine Learning'*

Solution PJ.05-W2-97 – HMI Interaction modes for Airport Tower - originally included PJ.05-W2-97.3 '*Interacting with tower CWP by means of touch screen (multi touch input)*'. Referred to as SOL97.3, it deals with introducing innovative human machine interaction for the tower controllers through the use of multi-touch input technology. This solution was terminated in September 2021 and relevant Validation Exercises did not take place. With respect to this CBAT deliverable, no Cost/Benefit assessment was performed and therefore no CBAT results were produced for SOL 97.3.

Two Operational Improvement Steps are associated with the Solutions, namely:

- ✓ *POI-0039-SDM Equivalent visual operations for tower control using applications for Virtual/Augmented Reality*
- ✓ *POI-0040-SDM Automatic Speech Recognition with AI/ML at the TWR CWP*

Timeframe scope

In accordance with SESAR SJU guidance [15] for Wave 2 projects, the period covered by the CBAT for SESAR PJ05-W2-97 is 2022 to 2043. The assumptions relating to the deployment and benefit realisation timelines for Solutions 97.1 and 97.2 are presented in Section 3.5 below.

Geographic scope

The geographical scope of SESAR's CBATs is to cover the European Civil Aviation Conference (ECAC) Countries, and the ***target*** Operating Environment scope of Solutions 97.1 and 97.2 covers deployment to all Airport Operating Environment sizes (i.e., Very Large, Large, Medium, Small and Other).

The Validation Exercises were performed in the following Airport Operating Environment sizes:

- ✓ 97.1 (Virtual Augmented Reality): Very Large[1], Medium and Other
- ✓ 97.2 (ASR): Medium and Small

This CBAT, therefore, extrapolates the validation results from the Exercises to the other target Airport Operating Environment sizes.

This assessment and the following post operational analysis will be described in the final paragraphs of this document, in particular into the Recommendation one.

2.3 Intended readership

This document has been prepared in order to allow SJU to have a complete view of the solution being studied.

Furthermore, the intended readership of the present document includes also:

- **SESAR JOINT UNDERTAKING (SJU)** as SESAR 2020 Programme coordinator.
- **SESAR 2020 PJ.05-W2-WP3** members in order to be aware of activities and methods being used and to allow coherency, consistency and comparability of the validation results of validations through all SESAR 2020 solutions.
- **SESAR 2020 PJ.19 Content Integration** that aims at assuring coherency, consistency, and comparability of the validation results throughout all SESAR2020 Solutions.
- Any **SESAR 2020 solution**, which wants to use aspects of any development in Solutions 97.1 and .2.
- Representatives of civil stakeholders: **ANSPs**.

2.4 Structure of the document

The CBAT Document is structured in the following chapters or paragraphs:

1. Executive Summary
2. Introduction, providing with an overall view of the document and the solution
3. Objectives and scope of the CBAT, where the CBAT Reference and Solution Scenario are defined

[1] It is noted that the relevant Validation Exercise (001) was conducted using an off-peak traffic solution scenario with a reduced tower controller manning profile.

4. Benefits
5. Costs Assessment
6. CBAT model
7. CBAT Results
8. Sensitivity and risk analysis
9. Recommendations

2.5 Background

PJ05-W2-SOL97.1, and PJ05-W2-SOL97.2 use and build upon the work performed in SESAR W1 projects such as PJ.16-04 (CWP HMI), as well as RETINA and MALORCA projects, executed in the context of Exploratory Research.

SESAR 2020 Wave 1 Industrial Research project PJ.16-04 investigated new HMI needs and interaction modes, including new user interface technologies such as Automatic Speech Recognition (ASR), mainly both in En-Route and Approach environments.

MALORCA developed a very novel machine learning approach, in support of the Automatic Speech Recognition system.

RETINA concept allowed the tower controllers to have a head-up view of the airport traffic even in low visibility conditions, thanks to the use of Virtual and Augmented reality.

SOL 97.1 and SOL 97.2 have a current maturity level of TRL 2 and target to reach TRL 4 maturity at the end of Wave 2 activities.

2.6 Glossary of terms

Term	Definition	Source of the definition
AIR-REPORT	A report from an aircraft in flight prepared in conformity with requirements for position, and operational and/or meteorological reporting.	*ICAO Annex 3*
Air Gesture	Gesture recognition is a type of perceptual computing user interface that allows computers to capture and interpret human gestures as commands via mathematical algorithms. Gestures can originate from any bodily motion or state but commonly originate from the face or hand. Users can use simple gestures to control or interact with devices without	SOL 97.1

	physically touching them.	
Attention Guidance	The Attention Guidance function uses perceptual cues to direct the attention of air traffic controllers towards an event. The function is triggered by relevant events determined by an Attention Guidance Logic that receives input from external sources, such as a particular safety net, an overall alerting system prioritization logic, or a particular sensor at the airport. The Attention Guidance Logic determines how the attention of the controller will be guided.	SOL 97.1
Automatic Speech Recognition	An Automatic Speech Recognition (ASR) system gets an audio signal as input and transforms it into a sequence of words, i.e., “speech-to-text” following the recognition process. The sequence of words is transcribed into a sequence of ATC concepts (“text-to-concepts”) using an ontology. E.g.: The word sequence “Lufthansa two alpha altitude four thousand feet on QNH one zero one four reduce one eight zero knots or less turn left heading two six zero” is transcribed into “DLH2A ALTITUDE 4000 ft, DLH2A INFORMATION QNH 1014, DLH2A REDUCE 180 OR_LESS, DLH2A HEADING 260 LEFT”. The resulting concepts can be used for further applications such as visualization on an HMI.	PJ.16-04
Command (Recognition) Error Rate	The number of controller commands which are wrongly recognized by ASR and which	PJ.16-04

	are not rejected divided by number of total given commands; in other words: the percentage of given commands wrongly shown on the controllers' HMI.	
Command (Recognition) Rejection Rate	The number of recognized controller commands which are correctly or wrongly rejected (plus number of given controller commands which are not recognized at all) divided by number of total given commands.	PJ.16-04
Command Hypotheses Predictor	Components needed for Assistant Based Speech Recognition which predicts a set of possible commands.	PJ.16-04
Command Prediction Error Rate	The number of controller commands which are not predicted by the Command Hypotheses Predictor divided by number of total given commands.	PJ.16-04
Command Recognition Rate	The number of controller commands which are correctly recognized by ASR and are not rejected before divided by number of total given commands; in other words: the percentage of given commands correctly shown on the controllers' HMI.	PJ.16-04
Conventional Input devices	This sentence is used to identify the current, legacy devices as keyboard, mouse and trackball. It is used as the reference system.	PJ.16-04
Direct Interaction	When touching the object directly	PJ.16-04
Drag	Move fingertip over surface without losing contact	PJ.16-04
Functional Block	A logical and cohesive grouping of automated Functions in a	EATMA Guidance Material

	Technical System	[8][10]
Gesture	Movement or posture, of the whole body or parts of the body	ISO/IEC 30113-1, 3.1
Indirect Interaction	When not touching the object directly	PJ.16-04
Interaction	Variety of ways users interact with an app, including touch, keyboard, mouse, and so on	PJ.16-04
Target Location Assistance (TLA):	Functionality evaluated for Munich Approach Area: With each spoken controller clearance the callsign shall be recognized and highlighted so that the controller can easily identify which aircraft is spoken to. The highlighting of the target will be displayed on the Executive and Planning Controller's ASW.	PJ.16-04
Net Present Value	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period	Investopedia
Technical System	A collection of Functional Blocks or Functions.	EATMA Guidance Material [8][10]
Virtual/Augmented Reality	V/AR in ATC Tower environment supports the Air Traffic Controllers by blending real world images with computer-generated data (augmented reality) in real-time, so that visual information can be enhanced to improve identification and tracking of aircraft (or vehicles) on the airport surface. Moreover, in low visibility conditions, the lack of visual information provided by the out-of-the-tower windows view can be compensated by the massive use of synthetic vision to show digital georeferenced data that	SOL 97.1 TVALP [16][15]

	supplement the missing real vision (virtual reality). Airport operations can benefit from this kind of advanced technologies, capable to provide beneficial automation support under low visibility conditions, but also, in good visibility situations, to present additional information in the labels to the controllers so to help in case of physical obstacles that obstruct vision or by reducing head-down time.	

Table 1: Glossary

2.7 List of Acronyms

Acronym	Definition
AG	Attention Guidance
AirG	Air Gestures
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
AR	Augmented Reality
ASR	Automatic Speech Recognition
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
BIM	Benefit Impact Mechanism
CATC	Conflicting ATC Clearances
CBAT	Cost Benefit Analysis tailored for the Technological Solution
CC	Capability Configuration
CMAC	Conformance Monitoring Alerts for Controllers
CWP	Controller Working Position
EATMA	European ATM Architecture
E-ATMS	European Air Traffic Management System
EN	Enabler
E-OCVM	European Operational Concept Validation Methodology
ER	En-Route
FAA	Federal Aviation Administration
HMI	Human Machine Interface
HPAP	Human Performance Assessment Plan
IER	Information Exchange Requirement
INTEROP	Interoperability Requirements
IRS	Interface Requirements Specification
ISRM	Information Services Reference Model
ML	Machine Learning
NAF	NATO Architecture Framework
NFR	Non- Functional Requirements

NOV	NAF Operational View
NPV	Net Present Value
NSOV	NAF Service Oriented View
NSV	NAF System View
OE	Operating Environment
PAR	Performance Assessment Report
QoS	Quality of Service
RMCA	Runway Monitoring and Conflict Alerting
ROI	Return on Investment
SDD	Service Description Document
SecAP	Security Assessment Plan
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SoaML	Service Oriented Architecture Modelling Language
SPR	Safety and Performance Requirements
SUT	System Under Test
TRL	Technology Readiness Level
TS	Technical Specification
TS/IRS	Technical Specification/Interface Requirements Specification
TSAP	Technical Safety Assessment Plan
TVALP	Technological Validation Plan
TVALR	Technological Validation Report
TWR	Tower
V&V	Validation and Verification
VALS	Validation Strategy
VCS	Voice Communication System
V/AR	Virtual/Augmented Reality

Table 2: Acronyms and terminology

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3 Objectives and scope of the CBAT

3.1 Problem addressed by the solution

Solution 97.1 aims to overcome the limitation of what the human eye can see out of the control tower windows, by means of using synthetic vision and augmented reality tools.

When applying V/AR, the auxiliary information is merged with the out-the-window (OTW) view and presented as an overlay on top of the real-world visual information. Computer-generated overlays such as ground vehicles, weather display, runway and taxiway layout, parking stands will be displayed by means of see-through wearable devices and superimposed on the OTW so as to provide a reliable support tool in low visibility conditions.

Displaying the tracking labels attached to each aircraft, the ATCO is no longer forced to divide his/her attention between the primary visual field (e.g., OTW view) and the auxiliary tools (such as paper or electronic flight strips, surface movement radar, gap-filler camera streams and alert indications), consequently reducing the so-called *head-down time* and increasing the *Situational Awareness* (SA).

Solution 97.2 aims to assess the benefit of using Automatic Speech Recognition in reducing ATCO's workload for aerodrome environments such as multiple remote towers. A speech recognizer analyses the ATCO-pilot communication, translates it in digital form and shows the recognitions in the label directly to the ATCO, avoiding the usual manual input currently required from the ATCO (or eventually requiring to manually correct the output of speech recognizer in limited percentage of cases).

3.2 SESAR Solution description

The TS-IRS [17]~~[17]~~ defines the technical content of the two Solutions 97.1 and 97.2, oriented to seek the *incorporation of new technology in the tower environment that should help ATCOs to better develop their tasks by examining the feasibility of applying the technology in such a demanding environment*.

The TVALP [16]~~[16]~~ develops the validation objectives targeting the TRL4 level.

Solution 97.1 is based on progressing previous research in *Synthetic vision and Virtual and Augmented Reality (V/AR)* fields as applied to a number of different aviation contexts, from the flight deck to aircraft maintenance as well as including Control Towers, with the aim to ease the job of involved staff and to enable more seamless operations.

Virtual and **Augmented Reality** technology**,** enabled in this case by head mounted displays, will allow tower ATCOs to conduct safe operations under any meteorological conditions while maintaining a high taxiway and runway throughput. Within this area, relevant technologies such as **Tracking labels, Air Gestures** and **Attention Guidance** will be investigated.

V/AR in ATC Tower environment supports the ATCOs by blending real world images with computer-generated data in real-time, so that visual information can be enhanced to improve identification and tracking of aircraft (or vehicles) on the airport surface.

Even in low visibility conditions, the lack of visual information in the OTW view can be compensated by the use of synthetic (*Virtualized*) vision to show digital georeferenced data that supplement the missing real vision.

This technology can also enable ATCOs to interact with the tracking labels by means of gaze and gestures. Translation of human body language is key to build a bridge between machines and humans and overcome the use of text user interfaces or GUIs (*Graphical User Interfaces*), based on input through a keyboard and mouse.

Furthermore, the *Attention Control system* analyzes whether specific safety net information is relevant in the current situation and therefore requires ATCOs attention to be guided though a visual cue.

Airport operations can benefit from this technological support of advanced technologies, capable to provide beneficial automation support under low visibility conditions, but also, in good visibility situations, to present additional information in the labels to the controllers to reduce head-down time or help in case of physical obstacles that obstruct vision.

SESAR Solution ID	OI Steps ref. (coming from the Integrated Roadmap)	OI Steps definition (coming from the Integrated Roadmap)	OI step coverage	Source reference
Sol 97.1	POI-0039-SDM	Virtual/augmented reality, attention guidance and air gesture for tower controllers	Fully	D3.1.031 TVALP

Table 3: SESAR Solution 97.1 Scope and related OI steps

OI Steps ref.	Enabler[2] ref.	Enabler definition	Enabler coverage	Applicable stakeholder	Source reference
POI-0039-SDM	AERODROME-ATC-103 (Required)	Virtual and Augmented Reality systems for Tower ATC	Fully	ANSP	D3.1.031 TVALP
POI-0039-SDM	AERODROME-ATC-104 (Optional)	Controller productivity enhancements by Air gestures for Tower ATC	Fully	ANSP	D3.1.031 TVALP
POI-0039-SDM	AERODROME-ATC-105 (Optional)	Attention Guidance in V/AR applications for aerodrome tower operations	Fully	ANSP	D3.1.031 TVALP

Table 4: SESAR Solution 97.1 OI steps and related Enablers

Solution 97.2 "*Automatic Speech Recognition at the TWR CWP supported by AI and Machine Learning*" aims to investigate the improvements expected for environments such as multiple remote towers by using systems for the recognition and translation of spoken language into the TWR CWP supported by Artificial Intelligence **(AI)**/Machine Learning **(ML)** techniques. Speech recognition is widely used today in several applications and was also investigated in the frame of previous SESAR validations with focus on EnRoute and Approach environments, demonstrating that it could significantly reduce ATCOs' workload in certain circumstances. Based on these facts, Solution 97.2 aims to investigate and assess that is reasonable to introduce this technological enabler in the TWR environment too.

An *Automatic Speech Recognition (ASR)* system gets an audio signal from the *Controller Working Position (CWP)* as input and transforms it into a sequence of words, so called "*speech-to-text*". The sequence is then translated into a sequence of Air Traffic Control Concepts ("*text-to-concepts*"[3]).

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[2] This includes System, Procedural, Human, Standardisation and Regulation Enablers

[3] For example, the word sequence "Bonjour, Air France two four eight six line up and wait runway two seven left" will be transformed into "AFR2486 LINEUP RW27L".

The **ASR** system may benefit from surveillance data, flight plans, meteorological data, routing information and can also be supported by **AI/ML** algorithms, that receive contextual information updates and integrate them to feed the "*Command Hypotheses Predictor*", so to outline the right recognition hypotheses, predict possible future ATCO commands and increase the command recognition rate.

SESAR Solution ID	OI Steps ref. (coming from the Integrated Roadmap)	OI Steps definition (coming from the Integrated Roadmap)	OI step coverage	Source reference
Sol 97.2	POI-0040-SDM	Automatic Speech Recognition with AI/ML at the TWR CWP	Fully	D3.1.020 TS/IRS

Table 5: SESAR Solution 97.2 Scope and related OI steps

OI Steps ref.	Enabler[4] ref.	Enabler definition	Enabler coverage	Applicable stakeholder	Source reference
POI-0040-SDM	AERODROME-ATC-106 (Required)	Automatic Speech Recognition supported by AI and ML algorithms for aerodrome tower operations	Fully	ANSP	D3.1.031 TVALP

Table 6: SESAR Solution 97.2 OI steps and related Enablers

3.3 Objectives of the CBAT

The purpose of this document is to develop a quantitative Cost Benefits Analysis, given the objective to reach the **TRL4** status of the Solution, in order to analyse the consequences in terms of costs and benefits, related to deployment options for the introduction of the automated functions for improving the ATCOs' awareness and for improving the controller productivity too.

[4] This includes System, Procedural, Human, Standardisation and Regulation Enablers

The CBAT will assess whether the benefits of the deployed Solution are expected to exceed the costs over the CBAT time horizon. Then, the CBAT results can be used to support the decision to move to the next stage of life cycle at the maturity gates.

Deployment options for the Solutions are identified hereafter:

Solution 97.1: Enablers covering Air Gestures and Attention Guidance are identified as Optional, therefore an airport has the option to deploy one of the following Enabler combinations:

- ✓ AERODROME-ATC-103 Virtual and Augmented Reality systems for Tower ATC
- ✓ AERODROME-ATC-103 Virtual and Augmented Reality systems for Tower ATC with AERODROME-ATC-104 Controller productivity enhancements by Air gestures for Tower ATC
- ✓ AERODROME-ATC-103 Virtual and Augmented Reality systems for Tower ATC with AERODROME-ATC-105 Attention Guidance in V/AR applications for aerodrome tower operations.
- ✓ AERODROME-ATC-103 Virtual and Augmented Reality systems for Tower ATC with both AERODROME-ATC-104 Controller productivity enhancements by Air gestures for Tower ATC and AERODROME-ATC-105 Attention Guidance in V/AR applications for aerodrome tower operations.

Solution 97.2: A single deployment option is identified:

- ✓ AERODROME-ATC-106 Automatic Speech Recognition supported by AI and ML algorithms for aerodrome tower operations

As well as technical and user feasibility, the TVALP identifies that the validation exercises are expected to demonstrate:

- ✓ Increase in situational awareness of ATCOs, in normal and low visibility conditions
- ✓ Reduction of ATCOs workload
- ✓ Increased ATCOs efficiency and productivity
- ✓ Improved HMI and usability and performance of interactions
- ✓ Increased or maintained level of Safety.

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3.4 Stakeholders' identification

ANSP are the main entities that will be impacted by PJ05-Solution 97.x changes. ANSPs are continuously looking for optimal solutions to maintain the standard and non-nominal provision of ATM services, raising performances and benefits on Operational Efficiency and Resilience, supported by improved technology introduced for the purpose.

Other ATM entities that will be impacted are listed in **Fehler! Verweisquelle konnte nicht gefunden werden.**~~Table 7~~, with details on the specific expected type of benefit introduced by the new technologies investigated.

The entire ECAC Network and ATM System, including ANSPs and ATCOs as main actors involved, will remain the main recipient of the benefits.

Stakeholder impacted

Main stakeholders impacted:

1. Stakeholders that will have to make investment
2. Stakeholders that have to change the way they work
3. Stakeholders that have to establish common procedures
4. Stakeholders that have to implement common infrastructures (ANSPs) procedures
5. Stakeholders that will get the benefits (ATCOs – ANSPs)
6. Comparison of current facilities vs future infrastructures (Virtual Centre)

Stakeholder	The type of stakeholder and/or applicable sub-OE	Type of Impact	Involvement in the analysis	Quantitative Results available in the current CBAT version
ANSPs	Airport Operating Environment, all sizes	ANSPs are interested in exploiting the full capabilities of new interaction modes in specific operational cases for runway and ground controllers. ANSPs expect to improve cost-effectiveness and resilience by using	Representatives should be involved in the definition, preparation, conduct and analysis of the validation exercises. Even though it's an enabler that maybe less of a necessity, ANSP feedback on the concept ideas will be valuable.	Cost Efficiency based on reduction of Controller Workload (CEF2)

		these enablers.		
ATCOs		The improvements will impact ATCOs directly (Human Performance safety) The Human Machine Interfaces (HMI) must be compatible with ATCO activities (acceptable, usable).	Direct contribution to the exercises defining them and testing the technologies.	Cost Efficiency based on reduction of ATCO Workload but maintaining the same SAF & HP level of satisfaction. Qualitative assessment only will be provided for these 2 KPAs.
Industry Partners		Develop and test prototypes in exercises with operational experts, so they are prepared for the future.	Provider of prototypes or receiver of prototype specifications, depending on exercise	Not applicable
Airspace Users	No impact	They will be impacted by the results coming from the research (e.g., higher resilience).	No direct implication	Not applicable
Airport Operator	No impact	They will need to ensure that the concept definition and validation activities are in line with airport regulations.	No direct implication	Not applicable
SJU		They will need to ensure that the concept definition and validation activities are in line with the general SESAR Joint Undertaking approach.	As reviewer of the solution documents and witness of the simulations	Not applicable

Table 7: CBAT Stakeholders and impacts for Sol 97.1 and 97.2

3.5 CBAT Scenarios and Assumptions

For each Solution, the costs related to the specific technology validated will be analyzed with reference to the different Operational Environments.

Relevant costs include costs sustained for all actors involved, for training, for technological installation as well as capital and operational costs etc.

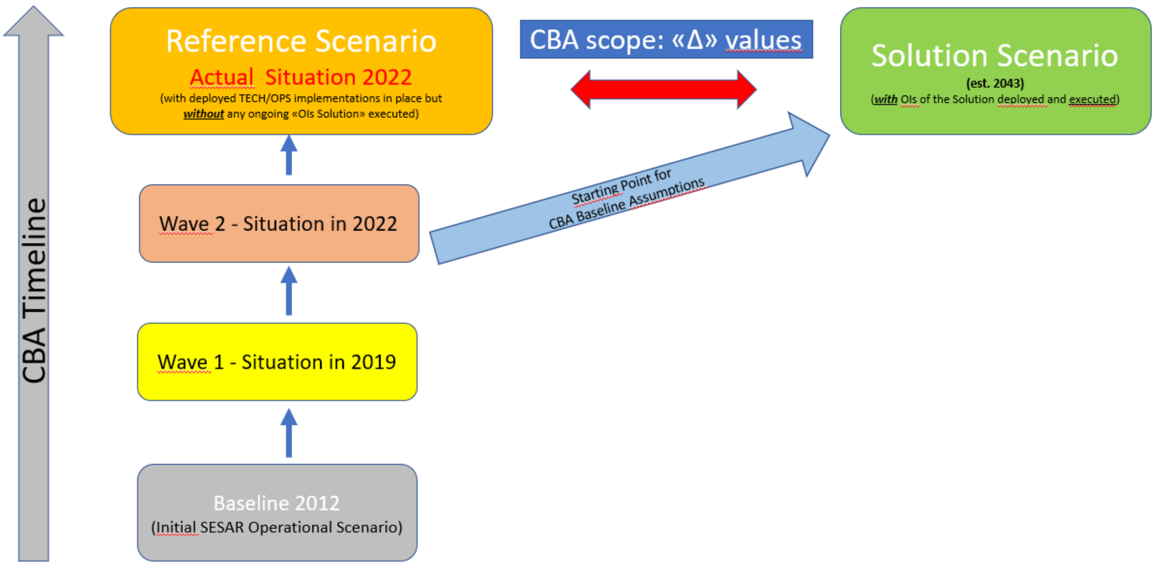

Figure 1: CBAT Scenario Sources

3.5.1 Reference Scenario

The CBAT **Reference** Scenario is the baseline against which the costs and benefits of 97.x Solutions are compared. It is common for both the PJ.05-W2-97.x Solutions in that it represents the operational situation *without* the 97.x Solution in the timeframe of the CBAT (2022 to 2043) and as such includes the SJU CBAT Common assumptions [10] regarding, for example, airport traffic volumes by sub-Operating Environment.

3.5.2 Solution Scenario

The CBAT **Solution** Scenarios reflect the deployment options for 97.1 and 97.2 that have been identified. They are based on the scenarios used in the Validation Exercises as described in the following sub-sections.

Expected benefits from the introduction of these ATC enablers in a Control Tower's operating environment for the Solutions, can be summarized as:

- ✓ Increasing of ATCO task efficiency and situational awareness by introducing new kind of interfaces in tower environment.
- ✓ Reduction of Controller Workload with expected decrease of human error input, with consequent reduction of cost per flight.
- ✓ Improved use of HMI that enables enhanced functions for ATCOs Commands and interactions.

Dates	Years (SOL 97.1)	Years (SOL 97.2)
Start year of CBAT Period for SESAR Standard: the first year for the CBAT quantification for the SESAR scopes.	2022	2022
Start year of Deployment date: the start year for the first deployment OE	2030	2030
End year of Deployment date: the end year of the investment for the last deployment OE	2034	2034
Initial Operational Capability (IOC) date: the time (year) when the first benefits occur following the ***deployment*** necessary to provide them. Investment Costs continue after this date as further deployment occurs at other locations.	2030	2030
Final Operational Capability (FOC) date: the date (year) starting from when maximum benefits can be counted at all locations where the implementation has been full deployed. Investment costs are considering completed although Operating Costs impacts would continue.	2034	2034
End year of CBAT Period for SESAR Standard: the final year for the CBAT quantification for the SESAR scopes.	2043	2043

Table 8: Key Dates for Sol 97.1 and 97.2

Note: The Start and End date of the CBAT Period are in accordance with current guidance from SESAR for Wave 2 Solutions.

Based on the above table and the schedule:

- ✓ Investment costs are spread between the Start and the End of Deployment dates (a duration of 4 years from 01/06/2030 to 01/06/2034), with an increase during the middle years, reflecting a ramp-up and ramp-down period, with a resultant deployment profile of:

2030	2031	2032	2033	2034
7.5%	25%	35%	25%	7.5%

Table 9: Deployment Profile for Sol 97.1 and 97.2

- ✓ Benefits will start being counted at the OE where the Technological enablers are fully deployed, immediately and without any Ramp-up Time. Benefits will be considered until the end of the CBAT period.

- ✓ Also Operating Costs will start at the IOC and will continue linearly in parallel with the implementation rate to the FOC, continuing until the rest of the CBAT Timeframe.

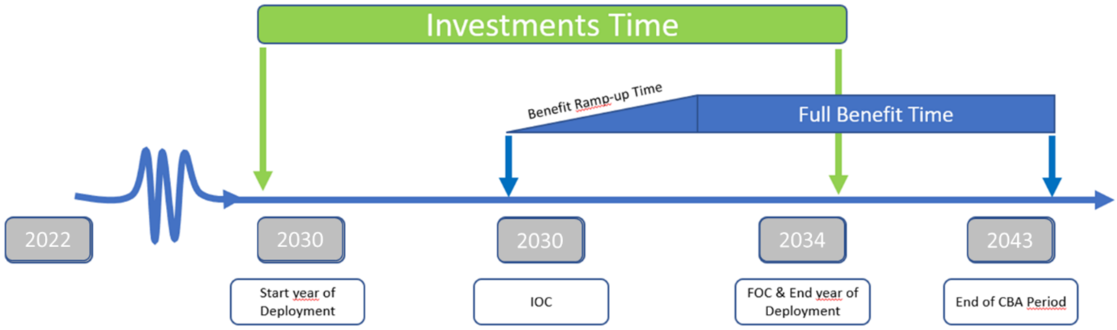

Figure 2: Sol 97.x Investment and Benefit Timeline

3.5.2.1 PJ.05-W2-97.1: Virtual/Augmented Reality applications for tower

This paragraph summarises into high level concepts the technological project features of Solution 97.1 that have been validated in technological validation exercises addressing the ***Virtual/Augmented Reality (V/AR)*** Operational Improvement. The exercises were:

- ✓ ***EXE-001***: Royal NLR / Amsterdam Schiphol Airport / Schiphol Tower, with a focus on Augmented Reality Attention Guidance
- ✓ ***EXE-002***: ENAV / UNIBO CAVE tower simulator with Bologna Airport environment with a focus on Augmented Reality Multimodal Control Tower Interaction
- ✓ ***EXE-005***: ENAIRE / Vitoria Airport with a focus Augmented Reality in the Tower Environment

A generic description of Scenarios follows, while different ATM players will carry out the Operational EXEs.

Each exercise ran two scenarios: The **Reference scenario**, reflecting the current airport environment, traffic situation and controller tool technologies, and the **Solution scenario**, with V/AR technology (HoloLens) included.

ATCOs needed some time to familiarise with the new tools (HoloLens) by an initial timeframe dedicated to training. After that, ATCOs were fully engaged in controlling the traffic and talking to the pilots.

EXE-001 RTS investigated V/AR applications for a conventional tower environment of Schiphol Airport with focus on Attention Getting and Attention Guidance, characterised by urgent, unexpected (and rare) events or unusual situations that could require the ATCO's immediate attention. The scope of Schiphol was reduced to off-peak traffic scenario with one controller being responsible for one arrival and one departure runway to reduce complexity of team interactions.

Different types of alerts that are currently given in the Schiphol tower environment, such as Go-around Detection (*GARD*) and Runway Incursion Alerting Schiphol (*RIAS*), were displayed in the *V/AR* device.

EXE-002 and ***EXE-005*** focused on the Air gestures and track label functions of V/AR.

- ✓ ***EXE-002*** investigated the use of air gestures with V/AR device, in different weather conditions, including degraded visibility and very low visibility conditions.
- ✓ ***EXE-005*** investigated the use of air gestures with V/AR device, in a Shadow-mode trial.

The exercises focused on *V/AR* in order to assess the expected benefits in terms of *Human Performance, Cost efficiency* and (indirectly) *Safety* for the related airport operation environment. Possible impacts on resilience will be considered as well.

Allocation of exercises to identified Use Cases [17]~~[16]~~ is provided in the following table.

Solution 97.1 - Virtual/Augmented Reality applications for tower							
EX	**Who**	**Where**	**OE**	**Type**	**Tracking Label Use Cases**	**Air Gesture Use Cases**	**Attention Guidance Use Cases**
VAR 001	NLR	Schiphol	Very Large	RTS	Information retrieval (103) Landing/Operating Labels (104) Conflict Alert Labels (105)	Issue Clearances (106)	Critical Situation (101) Missed Command Action cues (102)
VAR 002	ENAV	Bologna	Medium	RTS	Information retrieval (103) Landing/Operating Labels (104)	Issue Clearances (106)	Critical Situation (101) Missed Command Action cues (102)
VAR 005	ENAIRE	Vitoria	Other	Shadow Mode	Information retrieval (103) Landing/Operating Labels (104)	-	-

3.5.2.2 PJ.05-W2-97.2: Improving controller productivity by ASR at the Tower CWP

This paragraph summarises into high level concepts the operational and technological project features of Solution 97.2, dealing with the Automatic Speech Recognition at Tower CWP.

An *Automatic Speech Recognition (ASR)* system gets an audio signal from the controller working position (CWP) as input and transforms it into a sequence of words. The sequence of words is transcribed into a sequence of air traffic control (ATC) concepts (*text-to-concepts*). A *ML algorithm* can support the ASR engine to figure out a set of command hypothesis in order to reduce the error rate, basing on contextual information updates such as surveillance data, flight plan data, route information, clearance information, weather information etc.

The exercises were:

- ✓ ***EXE-004-ASR***: led by INDRA Navia with InNOVA Remote & InNOVA ITWP platform, with a focus on Improved controller productivity by using speech recognition in a multiple remote tower environment.
- ✓ ***EXE-006***: led by DLR at DLR Remote Tower, with a focus on Assistant Based Speech Recognition in Multiple Remote Tower Environment.
- ✓ ***EXE-007***: led by LDO at LDO platform located in Rome with Sofia Airport environment, with a focus on Assistant Based Speech Recognition as support to ATCOs.

Each exercise ran two scenarios: **Reference scenario**, reflecting the current airport environment, traffic situation and controller tool technologies and **Solution scenario**, with *Automatic Speech Recognition (ASR)* supported by *AI/ML*. The content was used to enable enhanced support functionalities for the ATCO such as aircraft label maintenance with given clearance contents. The whole system and the enabler wish to facilitate the ATCOs workload by prefilling an appropriate system mask (which contain the clearances updated according to the ATCO instruction) using the content of verbal communication.

The 97.2 validations follow the results obtained in En-route and approach environments, that has proven that *Automatic Speech Recognition* can significantly reduce ATCOs' workload when recognition error rates are below 2.5%.

EXE-004-ASR was performed by INDRA and Hungarocontrol at Asker Airport, where controller workload was investigated by using speech recognition in a multiple Remote Tower environment. The EXE performed the integration of a speech recognition system in a next-gen CWP.

EXE-006, performed by DLR, ANS, ACG, CCL and ON, investigated the benefits of an Assistant Based Speech Recognition (ABSR) system for a simulated Multiple Remote Tower environment, mainly with respect to a reduction of controller workload.

EXE-007, performed by LDO at Rome simulating Sofia airport, investigated the integration of a speech recognition system in a next-gen CWP to facilitate the ATCOs work by prefilling an appropriate system mask (which contain the clearances updated according to the ATCO instruction) using the content of verbal communication.

The exercises focused on ASR in order to assess the expected benefits in terms of Human Performance, Cost efficiency and (indirectly) Safety for the related airport operation environment.

Allocation of exercises to identified Use Cases [17]~~[16]~~ is provided in the following table.

Solution 97.2 - ASR at the TWR CWP supported by AI and Machine Learning					
EX	**Who**	**Where**	**OE**	**Type**	**Tracking Label Use Cases**
ASR 004	INDRA	Asker (simulating multiple remote tower)	Small	RTS	Highlighting of recognised callsign (201) Showing full recognised utterance/command in HMI (202) Manual manipulation of an ASR ouptut (203) Automatic acceptance of ASR ouput (204)
ASR 006	DLR	Braunschweig (simulating Vilnius, multiple remote tower)	Medium	RTS	Highlighting of recognised callsign (201) Showing full recognised utterance/command in HMI (202) Manual manipulation of an ASR ouptut (203) Automatic acceptance of ASR ouput (204)
ASR 007	LDO	Roma (simulating Sofia)	Medium	RTS	Highlighting of recognised callsign (201) Showing full recognised utterance/command in HMI (202) Manual manipulation of an ASR ouptut (203)

3.5.3 Assumptions

It is assumed, for Solutions 97.1 and 97.2 that the:

- SJU CBAT Common assumptions [10] regarding, for example, airport traffic volumes by sub-Operating Environment are applicable for the aggregation of unit results to ECAC wide results

4 Benefits

This Section describes, for each Solution in a dedicated sub-paragraph, the expected benefits as identified for the KPAs/KPIs that are described in detail in the document present in STELLAR, called *PJ19-W2: Validation Targets - Wave 2*.

Just to introduce and complement what below detailed, the expected benefits and the related performance targets are defined and identified in a qualitative manner, by identifying all the KPAs/KPIs, and by providing a cross reference with the Validation results provided by HP and Safety assessments.

4.1 Solution 97.1 Virtual/Augmented Reality

The Validation Plan [16][16] includes a Benefit Impact Mechanism for this Solution which identifies the expected benefits for ***V/AR*** as follows:

- Increase of **Cost Efficiency** and Situational Awareness by reducing workload experienced in switching between head-down and head-up visualizations.
- Improvement of **Resilience** by possibly avoiding Low Visibility Procedures, thanks to virtual displaying of relevant airport and traffic information even in bad weather visibility conditions.
- Improvement of **Safety** by increasing situational awareness and information accessibility, and decrease of human error through provision of more intuitive head up display
- Improvement of **Human Performance** by decreasing cognitive workload, improving information accessibility and decreasing human error.

The Validation Targets for Solution 97.1, as expected from SESAR PJ19.04 (visible into the released document, present in STELLAR, called ***PJ19-W2: Validation Targets - Wave 2***) are given in the table below; the coloured scale allows a better vision of the expectation impact for the SESAR Performance, planned to be accomplished with the Wave 2 of the SESAR 2020's expected benefits.

SOL. CODE	SAF	FEEF1	TEFF1	CAP3	CAP1	CAP2	PRD1	PUN1	CEF2	CEF3	HP
PJ.05-W2-97-a	ISI	N/I	N/I	N/I	N/I	N/I	N/I	N/I	1	N/I	YES

Table 10: Validation Targets apportioned to the SESAR PJ.10-W2-97.1 Solution

The PJ05-WP3 Performance Assessment Report [20] provides an analysis of the CEF2 Cost Efficiency Key Performance Indicator based on the results from the Validation Exercises as recorded in the Validation Report [19]. It concludes that the expected performance gain ECAC-wide for Solution 97 is **+1.63%**, and for Solution 97.1 is **+1.54%,** which have been entered into the CBAT Model presented in Section 6.

The Resilience Key Performance Area has no Validation Targets assigned to it; however, it is noted that qualitative measurements were taken in the Validation Exercises and analysed in the Performance Assessment Report [20], which concluded they were only applicable case-by-case at local level. It is not possible, therefore, to include them within the monetised benefit analysis.

In accordance with the standard approach to SESAR CBATs, Safety and Human Performance KPAs are not included in the monetised benefit analysis presented. An overall analysis of the Safety and Human Performance results from the Exercises are presented in PJ05-WP3 Performance Assessment Report [20].

4.2 Solution 97.2 Automatic Speech Recognition

The Validation Plan [16][16] includes a Benefit Impact Mechanism for this Solution which identifies the expected benefits for ***ASR+AI/ML*** as follows:

- Increase of **Cost Efficiency** by reducing workload through improved usability and the automatic update of clearances
- Improvement of **Safety** by decreasing cognitive workload and decreasing human error
- Improvement of **Human Performance** by decreasing cognitive workload and decreasing human error.

The Validation Targets for Solution 97.2, as expected from SESAR PJ19.04 (**[12][14]**) are given in the table below; the coloured scale allows a better vision of the expectation impact for the SESAR Performance, to be accomplished with the Wave 2 of the SESAR 2020's expected benefits.

SOL. CODE	SAF	FEFF1	TEFF1	CAP3	CAP1	CAP2	PRD1	PUN1	CEF2	CEF3	HP
PJ.05-W2-97-2	ISI	N/I	N/I	N/I	N/I	N/I	N/I	N/I	1	N/I	YES

Table 11: Validation Targets apportioned to the SESAR PJ.10-W2-97.2 Solution

The PJ05-WP3 Performance Assessment Report [20] provides an analysis of the CEF2 Cost Efficiency Key Performance Indicator based on the results from the Validation Exercises as recorded in the Validation Report [19]. It concludes that the expected performance gain ECAC-wide for Solution 97 is **+1.63%**, and for Solution 97.2 **+1.75%**, which have been entered into the CBAT Model presented in Section 6. In accordance with the standard approach to SESAR CBATs, Safety and Human Performance KPAs are not included in the monetised benefit analysis presented. An overall analysis of the Safety and Human Performance results from the Exercises are presented in PJ05-WP3 Performance Assessment Report [20].

4.3 Solution 97 Summary

A summary of the ECAC-wide Benefits, based on the PAR analysis of the Exercise results as discussed in the above sub-sections, is presented in the following table.

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Performance Framework KPA[5]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBAT	Unit	Year 2030	Year 2034	Year 2043
Solution 97								
Cost Efficiency	ANS Cost Efficiency	**CEF2** Flights per ATCO hour on duty	Nb	ATCO employment Cost Change	€/year	€11.6M	€64.5M	€76.7M
				Support Staff Employment Cost Change	€/year	€12.4M	€69.0M	€82.0M
Solution 97.1 A/VR								
Cost Efficiency	ANS Cost Efficiency	**CEF2** Flights per ATCO hour on duty	Nb	ATCO employment Cost Change	€/year	€11.0M	€61.0M	€72.5M
				Support Staff Employment Cost Change	€/year	€11.7M	€65.2M	€77.5M
Solution 97.2 ASR								
Cost Efficiency	ANS Cost Efficiency	**CEF2** Flights per ATCO hour on duty	Nb	ATCO employment Cost Change	€/year	€12.5M	€69.2M	€82.3M
				Support Staff Employment Cost Change	€/year	€13.3M	€74.0M	€88.0M

Table 12: Results of the benefits monetisation per KPA

[5] For information, the mapping to the Performance Ambition KPAs (used in the ATM Master Plan) is available in the Appendix.

5 Cost assessment

Note: ANSPs and ATCOs are identified directly impacted Stakeholder groups; ATCOs are part of ANSP organisations and therefore the costs associated with them are included within the ANSP analysis presented in the following sections.

5.1 ANSPs costs

The CBAT needs to consider the investment costs of acquiring the systems as well as the project management involved with installation, testing, transition periods, developing and documenting procedures, training costs, etc. (i.e., everything needed to get the system operational).

It is also necessary to assess the impact on Operating costs during the CBAT period. For example, what is the impact on maintenance costs or ongoing training – will they increase, decrease or remain stable.

ANSPs will incur the costs. No other stakeholder will incur any costs considering the relevant scenarios.

5.1.1 ANSPs cost approach

Three costs groups have been considered during the CBAT:

1. *Pre-Implementation Costs*: all costs required to define the needs, to develop solutions (R&D), to decide which solution best serves the needs. These costs are already incurred in the SESAR Development Phase. Any pre-implementation surveys/investigation conducted locally are assumed to be part of Implementation costs; therefore, no pre-implementation costs are identified.
2. *Implementation costs*: all costs related to the acquisition and implementation of the solutions such as training, license, patent, program management. It is assumed that implementation will commence in 20xx, based on the Timeframe scope presented in Section 2.2.
3. *Operating costs*: Costs required for the day to day running and maintenance of the solutions that are additional to current normal operation without the Solutions.

Inputs from PJ.16-04 (Controller Working Position HMI) and EUROCAE have identified potential standardisation needs for both Solutions 97.1 and 97.2 that are recorded as recommendations for further study to achieve TRL6 in both the TS/IRS [17] and VALR [19]. These may have cost implications, for example, to adapt existing standards or define and ratify new ones; and, therefore, a Recommendation is included in Section 9 to assess the cost implications of any standardisation needs in the future CBAT to support achieving TRL6.

The outcomes of the Validation Exercises as reported in the VALR [19] have resulted in a number of changed and new requirements and implementation recommendations for both Solutions 97.1 and 97.2 as recorded in the TS/IRS [17]. These may have cost implications, for example, to address the

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required provisions and improvements to make the V/AR concepts workable in all environments or the adaptation of ASR for each specific target environment; and, therefore, a Recommendation is included in Section 9 to assess the cost implications of the requirement changes and implementation recommendations in the future CBAT to support achieving TRL6.

5.1.1.1 Quantitative Analysis Solution 97.1: Virtual/Augmented Reality

Costs are categorized by the:

- deployment and on-going maintenance of the V/AR devices and related infrastructure
- deployment and on-going maintenance of the V/AR functions and associated integration with existing controller tools related to display of track labels, display of attention guidance warnings and the use of air gestures
- one-off training of ATCOs in the use, and ATSEPs in the maintenance, of the V/AR devices and functions. It is assumed that this one-off cost will include incorporation into on-going recurrent and new ATCO training courses and will require no change to the existing duration of those courses, therefore no *additional* operating training costs are incurred for ATCOs and ATSEPs.
- update and maintenance of ATCO procedures and guidance on local use of the V/AR technology and functions, including associated project management, certification and validation activities.

As presented in Section 2.2, Solution 97.1 is applicable to all Aerodrome Operating Environment sizes. Although traffic volume and associated controller workload may not be sufficiently high at Small and Other categories for them to need additional V/AR based ATCO visual aids[6], local circumstances and traffic profiles may justify deployment[7]. Costs are, therefore, grouped for ***Very Large/Large, Medium*** and ***Small/Other*** categories of aerodrome.

Implementing costs:

- Acquisition, installation, configuration, testing/certification and setting to work V/AR infrastructure equipment comprising communications network (e.g., Wi-Fi) and servers required for the V/AR headsets. It is assumed that:
    - implementation is per Control Tower;
    - includes back up/failure provision;

[6] For example, it is considered *(assumption based on operational judgement)* that V/AR based ATCO visual aids might only be necessary during peak hours or Low Visibility Conditions at aerodromes categorised as ***Medium or less.*** That obviously depending by the Operational technological infrastructures that are installed on the Airport with the aim to support ATM Services.

[7] For example, Victoria airport, serving Bilbao, Spain, is classified as Other in 2025; however, it is operational 24/7 and has no aerodrome radar. Therefore, V/AR may be a cost-effective alternative to radar at the time when this study is delivered and the amount of traffic expected by 2040 is expected to re-categorize the Aerodrome to a higher classification, i.e., Small or Medium. Victoria is the Aerodrome site of ***EXE-005***.

- is compliant to any required technical standard; and,
- a single V/AR infrastructure will cover the needs of the three V/AR functions (track labels, attention guidance and air gestures)

It is recognised that there are many possible implementation options depending on the existing infrastructure at a given Control Tower, taking into account performance and safety requirements of adding V/AR technology. These options include:

- Servers and communication systems dedicated to V/AR
- V/AR servers and communication systems included within existing servers and communication systems
- Use of physical or virtual servers.

These options are reflected in the range of costs presented.

The cost driver is:
*[**Cost of Server & SW**] + [**Cost of Comms network**]*, where:

- ***Cost of Server & SW*** = Cost of [acquisition + installation + configuration + testing and certification to applicable standards + operational deployment]
- ***Cost of communications network*** = Cost of [acquisition + installation + configuration + testing and certification to applicable standards + operational deployment]

In accordance with SESAR CBA guidance (STELLAR FAQ_CBA_v4_ (1_1)) the overall scales of *Cost of Server & SW* and *Cost of Comms Network* are estimated rather than the individual aspects.

It is assumed that costs for implementation in a Very Large and Large TWR are similar, while for a Medium TWR they will be lower at 30% of VL/L airport costs and 15% of VL/L airports for Small/Other TWR (*source: Stakeholder Judgement*)

(*Source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Server & SW	30	70	150
Comms Network	25	50	100
Total (VL/L)	55	120	250
Medium			
Server & SW	9	21	45
Comms Network	7.5	15	30
Total (M)	16.5	36	75
Small/Other			
Server & SW	4.5	10.5	22.5
Comms Network	3.75	7.5	15
Total (S/O)	8.25	18	37.5

Table 13: V/AR Infrastructure Costs - Implementation

- Acquisition, installation, configuration, testing/certification and setting to work V/AR headsets.

  It is assumed that:
  - each tower controller will be issued with a headset as personal equipment. *Experience from the validation exercises including a survey of the participating controllers*[8] *indicates that a headset may require specific calibration for each individual. Sharing headsets also raised issues regarding the need to re-configure them depending on the controller role in addition to matters of hygiene.*
  - additional headsets (*Stakeholder opinion:* 50% of personal equipment numbers) will be held in stock as contingency covering back-up provision, staff turnover and time taken to recharge[9]
  - installation includes charging station
  - configuration includes calibration for the individual controller's visual acuity, setting up the orientation of the headsets, synchronisation with airport layout, etc
  - is compliant to any required technical standard
  - a single initial set up will cover the needs of the three V/AR functions i.e., track labels, air gestures and attention guidance.

  The cost driver is:
  *[**Cost of Headset** * (**# of Tower Controllers** * **Back-up factor (1.5)**)]*, where:
  - ***Cost of Headset*** = Cost of [acquisition + installation + configuration + testing and certification to applicable standards + operational deployment]
  - ***# Of tower controllers*** = 60 for Very Large/Large TWR, 25 for Medium TWR, 12 for Small/Other TWR (*source: Stakeholder Judgement*)

  The number of tower controllers is based on an analysis of a control tower similar in size to Amsterdam Schiphol (very large size): which quantifies as 60 ATCOs on average assigned and qualified to be able to operate. Considering a presence per shift (Morning-Afternoon-Night) of 10 people (6 in operational position, 3 reliefs and 1 TWR Supervisor), we can define that a Control Tower must be equipped with 60 HLs to be distributed as personal equipment to ATCOs and 30 spare headsets to have "in stock" and to be immediately available whilst headsets are recharging or in case of failure or malfunction. The corresponding average numbers of controllers for Medium TWR is considered to be 25 and Small/Other 12.

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[8] See Appendix 2 for a description of the Survey performed to elicit expert opinion on whether headsets should be deployed as personal equipment

[9] A HoloLens 2 V/AR headset has a battery life of 2 to 3 hours and requires 65 minutes to fully recharge (*Source: Microsoft HoloLens 2 website FAQs. Experience in Exercise 1 showed a HoloLens required 30 minutes charging after 1 to 1.5 hours use.*). Recharging is expected to be performed during a controller's normal rest periods; however, it is noted that an ATCO may need access to an additional headset whilst their headset is charging, one that is available immediately within the Control Tower.

In accordance with SESAR CBA guidance (STELLAR FAQ_CBA_v4_ (1_1)) the overall scale of *Cost of Headset* is estimated rather than each individual aspect, based on the advertised purchase price of a typical industrial standard V/AR headset (specifically, Microsoft's HoloLens 2).

(*Source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Cost/ Headset	4	8	15
Total (VL/L)	360	720	1350
Medium			
Cost/ Headset	4	8	15
Total (M)	150	300	563
Small/Other			
Cost/ Headset	4	8	15
Total (S/O)	72	144	270

Table 14: V/AR Headset Costs - Implementation

- Acquisition, installation, configuration, testing/certification and setting to work of ***track label functions for V/AR***. It is assumed that this comprises both a server/network aspect of integrating the functions to existing systems, including adaptation of any track positioning and prediction functionality to meet headset display requirements (update rates, smoothing etc.)), and a set-up per headset.

  The cost driver is:
  [Server Cost] + [Cost by Headset * # of headsets], where:
  - ***Server Cost*** = Cost of [licence + installation + configuration + testing and certification to applicable standards + operational deployment]
  - ***Cost by Headset*** = Cost of [licence + installation + configuration + testing and certification to applicable standards + operational deployment]
  - ***# Of headsets*** = 90 (Very Large/Large aerodromes), 38 (Medium), 18 (Small/Other) in accordance with the assumptions above, i.e., operational and back-up provision headsets for each controller

In accordance with SESAR CBA guidance (STELLAR FAQ_CBA_v4_ (1_1)) the overall scales of the *V/AR Function Cost* are estimated rather than the individual aspects.

(*Source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Server Cost	10	25	50
Cost/Headset	1	4	7
Total (VL/L)	100	385	680
Medium			
Server Cost	10	25	50
Cost/Headset	1	4	7

Total (M)	48	175	313
Small/Other			
Server Cost	10	25	50
Cost/Headset	1	4	7
Total (S/O)	28	97	176

Table 15: V/AR Track Label Function Costs - Implementation

- Acquisition, installation, configuration, testing/certification and setting to work of ***air gesture functions for V/AR***. It is assumed that this comprises both a server/network aspect of integrating the functions to existing systems and a set-up per headset, including any local tailoring of built-in air gesture functions.

  The cost driver is:
  *[**Server Cost**] + [**Cost by Headset** * **# of headsets**]*, where:
  - ***Server Cost*** = Cost of [licence + installation + configuration + testing and certification to applicable standards + operational deployment]
  - ***Cost by Headset*** = Cost of [licence + installation + configuration + testing and certification to applicable standards + operational deployment]
  - ***# Of headsets*** = 90 (Very Large/Large aerodromes), 38 (Medium), 18 (Small/Other) in accordance with the assumptions above, i.e., operational and back-up provision headsets for each controller

  In accordance with SESAR CBA guidance (STELLAR FAQ_CBA_v4_ (1_1)) the overall scales of the *V/AR Function Cost* are estimated rather than the individual aspects.

(*Source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Server Cost	10	25	50
Cost/Headset	1	4	7
Total (VL/L)	100	385	680
Medium			
Server Cost	10	25	50
Cost/Headset	1	4	7
Total (M)	48	175	313
Small/Other			
Server Cost	10	25	50
Cost/Headset	1	4	7
Total (S/O)	28	97	176

Table 16: V/AR Air Gesture Function Costs - Implementation

- Acquisition, installation, configuration, testing/certification and setting to work of ***attention alert and guidance functions for V/AR***. It is assumed that this comprises both a server/network aspect of integrating the functions to existing systems and a set-up per headset.

It is assumed that *Attention Alert and Guidance functions* are already available for the existing CWPs and that this cost covers the adaptation and deployment of these safety net functions for use in the A/VR headsets.

The cost driver is:
[***Server Cost] + [Cost by Headset * # of headsets],*** where:

- ***Server Cost*** = Cost of [licence + installation + configuration + testing and certification to applicable standards + operational deployment]
- ***Cost by Headset*** = Cost of [licence + installation + configuration + testing and certification to applicable standards + operational deployment]
- ***# of headsets*** = 90 (Very Large/Large aerodromes), 38 (Medium), 18 (Small/Other) in accordance with the assumptions above, i.e., operational and back-up provision headsets for each controller

In accordance with SESAR CBA guidance (STELLAR FAQ_CBA_v4_ (1_1)) the overall scales of the *V/AR Function Cost* are estimated rather than the individual aspects.

(*Source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Server Cost	20	40	80
Cost/Headset	2	5	10
Total (VL/L)	200	490	980
Medium			
Server Cost	20	40	80
Cost/Headset	2	5	10
Total (M)	95	228	455
Small/Other			
Server Cost	20	40	80
Cost/Headset	2	5	10
Total (S/O)	56	130	260

Table 17: V/AR Attention Function Costs - Implementation

- ***Training for controllers***: It is assumed training covers the three V/AR functions (track labels, air gestures and attention guidance). Initial training is assumed to be a total of 5 days comprising 2 days for classroom/simulator training (a theoretical session of 2 hours for each day and the rest of the 5 hours with practical exercises) including a qualification test at the end of the training period and 3 days On-the-job training. (*Source: Stakeholder Judgement*).

  The cost is assumed to comprise three elements:
  - the cost of a classroom/simulator training course to the ANSP (which may be provided by a third-party provider or could be "internal charging" to an in-house provider);
  - the cost of the ATCOs attending the classroom/simulator training (which could be regarded as the additional cost of employment for the additional training days or as the opportunity cost for the time they are not available for operational duty); and,
  - the cost of On-the-job training ("internal charging" to an in-house provider) following ATCO attendance at the classroom/simulator course.

The cost driver is:
*[**Cost of Classroom/Simulator Course** * **# of courses**] + [**Cost of an ATCO attendance** * **# of ATCOs**] + [**Cost of OJT Training** * **# of ATCOs**]* where:

- ***Cost of Classroom/Simulator Course*** = [# of days in training course * cost of training day], where:
  - ✓ Number Of days in training course is 2 (*source: Stakeholder Judgement*)
  - ✓ cost of training day, based on 3 trainers (supporting theory, simulation runs and ATCO guidance) + simulation facility + materials.
    - If externally provided it is unlikely to be less than €2K, median €6, unlikely to be more than €10K per day i.e., €4K, €12K and €20K for a 2-day course (*source: Stakeholder Judgement*)
    - If internally provided, assume based on cost recovery[10] of personnel providing the training i.e., Cost of ATCO (#ATCO Hours/Day (8) * ATCO Cost/Hour (€131)
      * # of Trainers (3)) adjusted for 2024 (annual change in ATCO cost (*source ACE report [13]*) = €3.144K per day, total of €6.3K for a two-day course, however this does not include preparation of materials, simulators etc. and therefore is a only a component of the course. (*Source: Stakeholder Judgement*)
  - ✓ Therefore, Cost of training course is considered to be between €4K and €20K with a median value of €12K
- ***# Of Courses*** = [# ATCOs / # of ATCOs at each training session], where:
  - ✓ # ATCOs is 60 for Very Large/Large, 25 for Medium and 12 for Small/Other (*source: Stakeholder Judgement*)
  - ✓ # of ATCOs at each training course is 6 (*source: Stakeholder Judgement*)
  - ✓ Therefore, # of Courses is 10 for Very Large/Large, 5 for Medium, 2 for Small/Other.
- ***Cost of an ATCO attendance*** = [# ATCO training days * # ATCO Hours/Day * ATCO cost/hour], where:
  - ✓ # of ATCO training days is 2 (*source: Stakeholder Judgement*)
  - ✓ # of ATCO Hours/Day is 8 (*source: SESAR common assumptions*)
  - ✓ ATCO cost/hour is €131 (*source: ACE Report [13]), for day is €1048 adjusted for 2024 annual cost increase (source ACE report [13]) = €1.101K/day*
  - ✓ Therefore, Cost of an ATCO attendance is €2.203K
- ***# of ATCOs*** = 60 for Very Large/Large and 25 for Medium, 12 for Small/Other.

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[10] The cost of the additional training tasks for ATCO dedicated training personnel or those removed from operational duties to provide training

- ***Cost of OJT Training***, assumed to be internally provided and therefore is cost recovery of personnel providing the training. i.e. Cost of ATCO (#ATCO Hours/Day (8) * ATCO Cost/Hour (€131) * # of Trainers (1)) = €1.048K per ATCO trained adjusted for 2024 (annual change in ATCO cost (*source ACE report [13]*) = €1.101K/day. For each trainer it is assumed that between 1 and 3 days per ATCO are required with a median of 2 day (*source: Stakeholder Judgement*).

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Cost of Training Course	40	120	200
Cost of ATCO Attendance	132.2	132.2	132.2
Cost of OJT	66.1	132.2	198.3
Total (VL/L)	238.3	384.4	530.5
Medium			
Cost of Training Course	20	60	100
Cost of ATCO Attendance	55.1	55.1	55.1
Cost of OJT	27.5	55.1	82.6
Total (M)	102.6	170.2	237.7
Small/Other			
Cost of Training Course	8	24	40
Cost of ATCO Attendance	26.4	26.4	26.5
Cost of OJT	13.2	26.4	39.6
Total (S/O)	47.6	76.8	106.1

Table 18: V/AR Training Costs (ATCO) - Implementation

- ***Training for ATSEPs:*** It is assumed that training covers the technical operation and maintenance of the V/AR headsets, the three V/AR functions (track labels, air gestures and attention guidance) and the associated integration with existing controller tools and equipment. It is assumed this would comprise a set of separate classroom and practical sessions lasting 5 days held concurrently with the ATCO training, including any required ATSEP qualification tests at the end of the course.

  The cost is assumed to comprise two elements:
  - the cost of a classroom/practical training course to the ATSEP (which may be provided by a third-party provider or could be "internal charging" to an in-house provider);
  - the cost of the ATSEPs attending the classroom/simulator training (which could be regarded as the additional cost of employment for the additional training days or as the opportunity cost for the time they are not available for operational duty)

  The cost driver is:
  [Cost of Course * # of Courses] + [Cost an ATSEP attendance * # of ATSEPs] where:
  - ***Cost of Course*** = [Cost of Training Day * # of Days of Course] where:
    - *Cost of Training Day* is unlikely to be less than €0.3K or more than €1K with a median value of €0.6K (*source: Stakeholder judgement*)
    - *Number of days of course* is 5 [*Source: Stakeholder judgement*]

- Therefore, *Cost of Course* is unlikely to be less than €1.5K or more than €5K with a median value of €3K
- ***# Of Courses*** = [# of ATSEPs/# of ATSEPs at a course] where:
  - *# of ATSEPs* is 25 for Very Large/Large, 20 for Medium and 15 for Small/Other (*source: Stakeholder judgement*)
  - *# of ATSEPs at a course* is 5 (*source: Stakeholder judgement*)
  - Therefore, the *# of courses* is 5 for Very Large/Large, 4 for Medium and 3 and Small/Other
- ***Cost of ATSEP attendance*** = [# ATSEP training days * # ATSEP Hours/Day * ATSEP cost/hour], where:
  - *# of ATSEP training days* is 5 (*source: Stakeholder Judgement*)
  - *# of ATSEP Hours/Day* is 8 (*source: SESAR common assumptions*)
  - *ATSEP cost/hour* is €139 (*source: ACE Report [13]),* for day is €1112 adjusted for 2024 annual cost increase *(source ACE report [13])* = €1.169K/day
  - Therefore, *Cost of an ATSEP attendance* is €5.844K
- ***# of ATSEPs*** is 25 for Very Large/Large, 20 for Medium and 15 for Small/Other (*source: Stakeholder judgement*)

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Cost of Training Course	8	15	25
Cost of ATSEP Attendance	146.1	146.1	146.1
Total (VL/L)	153.1	161.1	171.1
Medium			
Cost of Training Course	6	12	20
Cost of ATSEP Attendance	116.9	116.9	116.9
Total (M)	122.9	128.9	136.9
Small/Other			
Cost of Training Course	4.5	9	15
Cost of ATSEP Attendance	87.6	87.6	87.6
Total (S/O)	92.1	96.6	102.6

Table 19: V/AR Training Costs (ATSEP) - Implementation

- ***Project management, update of local manuals and procedures, certification and validation and general administration*** in relation to the installation of A/VR with track label, air gesture and attention guidance functionality at an aerodrome.

  With regard to certification and validation aspects it is estimated, based on similar activities in the past, that this would be equivalent of 2 Administrative staff over a period of a week (i.e., a total of 10 working days). The cost driver is, therefore:

  [Cost of Certification/Validation] = [Cost of Admin staff/hour * # of hours/day * # of days] * # of Admin Staff, where:
  - ***Cost of Admin staff/hour (2019)*** is €139 (*source: ACE Report[13]*)
  - # of hours/day is 8, Cost of Admin staff day = 8*139 = €1112, adjusted for 2024 (annual change in ATCO cost (*source ACE report [13]*) @ 1.051 = €1.169K
  - # of days is 5

- # of Admin Staff is 2

The median cost of Certification/Validation is, therefore, between €5.8K and €23.4K with a median value of €11.7K.

It is not possible to provide a detailed breakdown of the remaining project management, documentation and general administration one-off costs due to relative immaturity of the Solution. A range of bundled values have been determined based on the experience of implementing similar technological advances (e.g., 30 days of operational staff time for PM and manuals/procedures updates). They are considered to be the same irrespective of Operating Environment.

(*Source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Certification/Validation	5.8	11.7	23.4
PM, Documentation, Admin	75	100	150
Total (VL/L)	81.8	112.7	173.4
Medium			
Certification/Validation	5.8	11.7	23.4
PM, Documentation, Admin	75	100	150
Total (M)	81.8	112.7	173.4
Small/Other			
Certification/Validation	5.8	11.7	23.4
PM, Documentation, Admin	75	100	150
Total (S/O)	81.8	112.4	173.4

Table 20: V/AR Certification/PM Costs - Implementation

In summary, the estimated One-Off costs for Solution 97.1 are shown in the following table for each of the Airport Operating Environment sizes (Very Large/Large (VL/L), Medium (M) and Small/Other (S/O)).

Cost Item	Short description	Median Cost VL/L	Median Cost M	Median Cost S/O	Source
Training	All the training and staff costs related to the use of A/VR	€545K	€299K	€174K	Stakeholder judgement
Administrative costs	related to the acquisition, installation, configuration and testing of A/VR devices and associated functions	€112K	€112K	€112K	Stakeholder judgement, SESAR common assumptions and references
Infrastructure Installation & Commissioning	Installation and configuration costs. Initial Test and evaluation	€120K	€36K	€18K	Stakeholder judgement
V/AR Equipment Installation & Commissioning	Installation and configuration costs. Initial Test and evaluation	€720K	€300K	€144K	Stakeholder judgement
Track Label functions	System integration of controller functionality	€385K	€175K	€97K	Stakeholder judgement
Air gesture functions	System integration of controller functionality	€385K	€175K	€97K	Stakeholder judgement
Attention Guidance functions	System integration of controller functionality	€490K	€228K	€130K	Stakeholder judgement
TOTAL		***€2,757K***	***€1,324K***	***€771K***	

Table 21: V/AR Implementation Costs Summary

Operating costs:

1. ***Device and infrastructure replacement.***

It is assumed that:

- ✓ the infrastructure equipment will be replaced on ***five-year cycle*** throughout the CBAT period at the full initial implementation cost
- ✓ this periodic one-off cost includes provision of updates and patches etc. throughout the ***5-year period***:

(*source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Server & SW	30	70	150
Comms Network	25	50	100
Total (VL/L)	55	120	250
Medium			
Server & SW	9	21	45
Comms Network	7.5	15	30
Total (M)	16.5	36	75
Small/Other			
Server & SW	4.5	10.5	22.5
Comms Network	3.75	7.5	15
Total (S/O)	8.25	18	37.5

Table 22: V/AR Infrastructure Costs - On-going

V/AR headset technology is under continuous change both in design and new functionalities (as it is for cell phones), and for this reason it is assumed that all controller headsets will need to be replaced on a ***2 year-cycle*** at the full initial implementation cost***.***

(*Source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
A/VR Headset	4	8	15
Total	360	720	1,350
Medium			
A/VR Headset	4	8	15
Total (M)	150	300	563
Small/Other			
A/VR Headset	4	8	15
Total (S/O)	72	144	270

Table 23: V/AR Headset Costs - On-going

*2. **V/AR Functionality***

For the update and maintenance of the V/AR track label, air gesture and attention guidance functionality an annual cost of 10% of initial costs is assumed.

For each of ***Track Label and Air Gesture Functions*** (*source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Total (VL/L)	10	39	68
Medium			
Total (M)	5	18	31
Small/Other			
Total (S/O)	3	10	18

Table 24: V/AR Track Label and Air Gesture Functions Costs - On-going

For ***Attention Guidance Functions*** (*source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Total (VL/L)	20	49	98
Medium			
Total (M)	10	23	46
Small/Other			
Total (S/O)	6	13	26

Table 25: V/AR Attention Guidance Function Costs - On-going

In summary, the estimated Operating Costs for Solution 97.1 are shown in the following table for each of the Airport Operating Environment sizes (Very Large/Large (VL/L), Medium (M) and Small/Other (S/O)).

Cost Item	Short description	Median Cost VL/L	Median Cost M	Median Cost S/O	Source
Replacement Infrastructure Installation & Commissioning	5-year replacement Installation and configuration costs.	€120K	€36K	€18K	Stakeholder judgement
Replacement V/AR Equipment Installation & Commissioning	2-year replacement Installation and configuration costs.	€720K	€300K	€144K	Stakeholder judgement
Annual Track Label function licence	System integration of controller functionality	€39K	€18K	€10K	Stakeholder judgement
Annual Air gesture function licence	System integration of controller functionality	€39K	€18K	€10K	Stakeholder judgement
Annual Attention Guidance function licence	System integration of controller functionality	€49K	€23K	€13K	Stakeholder judgement
TOTAL	***Annual* *2yr replace* *5yr replace***	***€126K* *€720K* *€120K***	***€58K* *€300K* *€36K***	***€33K* *€144K* *€18K***	

Table 26: V/AR Operating/Recurrent Costs Summary

5.1.1.2 Quantitative Analysis Solution 97.2: Automatic Speech Recognition

Costs are categorized by the:

- deployment and on-going maintenance of the ASR tool, connection/integration with Controller Working Position(s), AI/ML functions[11] and ASR functions[12]
- initial training of ATCOs in the use of, and ATSEPs in the maintenance of, the ASR functions. It is assumed that this one-off cost will include incorporation into on-going recurrent and new ATCO and ATSEP training courses and will require no change to the existing duration of those courses, therefore no *additional* operating training costs are incurred for ATCOs and ATSEPs.
- update and maintenance of ATCO procedures and guidance on local use of the ASR functions on the CWP.

As presented in Section 2.2, Solution 97.2 is applicable to all Aerodrome Operating Environment sizes. Although traffic volume and associated ATCO workload may not be sufficiently high at Small and Other categories for them to need ASR functions, local circumstances and traffic profiles may justify deployment (for example, Remote Tower operations that are being investigated in EXE-004).

Costs are, therefore, grouped for ***Very Large/Large, Medium*** and ***Small/Other*** categories of aerodrome

Note: ***EXE-004 and EXE-007*** are being conducted for aerodromes classified as ***Small & Medium***, therefore cost and benefit results from these Validation Exercises will need to be extrapolated to the other target Airport Operating Environment sizes.

Implementing costs:

- Acquisition, installation, configuration, testing/certification and setting to work ASR infrastructure equipment comprising the:
  - ✓ Hardware/Software platform required for the ASR functionality and connection/integration to CWPs.
  - ✓ ASR functionality. This includes the set up and configuration of the AI/ML algorithms using locally recorded pilot/ATCO voice command exchanges
  - ✓ ASR related functions for the CWPs.

  It is assumed that:

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[11] Specifically, *Command Prediction*, *Command Extraction* and *Usage of Speech Information* (*source: European ATM Master Plan Portal – Working: DS21 Draft/EATMA v14 Draft Functions related to Functional Block "ASR (PJ.05-W2-97.2*)")

[12] Specifically *Accept Command Automatically*, *Accept Command Manually*, *Correct Command Manually*, *Display Full Recognized Command*, *Highlight Callsign* and *Reject Command Manually* (source: *European ATM Master Plan Portal – Working: DS21 Draft/EATMA v14 Draft Functions related to Functional Block "Controller Human Machine Interaction Management Aerodrome"*)

- ✓ the implementation is by control tower and may be based on either a physical server associated with each CWP or centralised in a virtualised server environment[13];
- ✓ the ASR function will not be implemented at all CWPs[14];
- ✓ includes back up/failure provision; and
- ✓ is compliant to any required technical standard.

In accordance with SESAR CBA guidance (STELLAR FAQ_CBA_v4_ (1_1)) the overall scales of costs are estimated rather than the individual aspects. The cost driver is:

*[**Cost of AI/ML ASR Tool**] + [**Cost of Licence for use of Tool**] (source: Stakeholder Judgement)*, where:

- ○ ***Cost of AI/ML ASR Tool*** = Cost of infrastructure [acquisition + installation + configuration + testing and certification to applicable standards + operational deployment] and integration with existing Tower systems.
  Assumed to be the same for all airport OEs, ***unlikely to be less than €350K, unlikely to be more than €700K with a median value of €500K*** (*source: Stakeholder judgement*)
- ○ ***Cost of licence of use*** = Cost of licence for use of AI/ML functions for each CWP. Assumed to be valid for a period of 10 years.
- ○ Assumed to be the same for all airport OEs, and ***is unlikely to be less than €80K, unlikely to be more than €120K with a median value of €100K***. (*source: Stakeholder judgement*)

(*Source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
For all airport OEs			
AI/ML ASR Tool	350	500	700
License for Use	80	100	120
Total	430	600	820

Table 27: ASR Tool Costs - Implementation

- ***Training for controllers***: Initial training is assumed to be a total of 5 days comprising 2 days for classroom/simulator training (a theoretical session of 2 hours for each day and the rest of the 5 hours with practical exercises) including a qualification test at the end of the training period and 3 days On-the-job training. (*Source: Stakeholder Judgement*).

  The cost is assumed to comprise three elements:
  - the cost of a classroom/simulator training course to the ANSP (which may be provided by a third-party provider or could be "internal charging" to an in-house provider);

[13] For the purposes of this CBAT, the range of costs presented for the AI/ML platform is considered to cover either architecture

[14] ASR may be operationally appropriate for ATC Ground Clearance and/or Taxi Instructions; however, not for Take-Off and/or RWY Clearance due to operational and safety constraints.

- the cost of the ATCOs attending the classroom/simulator training (which could be regarded as the additional cost of employment for the additional training days or as the opportunity cost for the time they are not available for operational duty); and,
- the cost of On-the-job training ("internal charging" to an in-house provider) following ATCO attendance at the classroom/simulator course.

The cost driver is:
*[**Cost of Classroom/Simulator Course** * **# of courses**] + [**Cost of an ATCO attendance** * **# of ATCOs**] + [**Cost of OJT Training** * **# of ATCOs**]* where:

- ***Cost of Classroom/Simulator Course*** = [# of days in training course * cost of training day], where:
  - ✓ Number Of days in training course is 2 (*source: Stakeholder Judgement*)
  - ✓ cost of training day, based on 3 trainers (supporting theory, simulation runs and ATCO guidance) + simulation facility + materials.
    - If externally provided it is unlikely to be less than €2K, median €6, unlikely to be more than €10K per day i.e., €4K, €12K and €20K for a 2-day course (*source: Stakeholder Judgement*)
    - If internally provided, assume based on cost recovery[15] of personnel providing the training i.e., Cost of ATCO (#ATCO Hours/Day (8) * ATCO Cost/Hour (€131)
      * # of Trainers (3)) adjusted for 2024 (annual change in ATCO cost (*source ACE report [13]*) = €3.144K per day, total of €6.3K for a two-day course, however this does not include preparation of materials, simulators etc. and therefore is a only a component of the course. (*Source: Stakeholder Judgement*)
  - ✓ Therefore, Cost of training course is considered to be between €4K and €20K with a median value of €12K
- ***# Of Courses*** = [# ATCOs / # of ATCOs at each training session], where:
  - ✓ # ATCOs is 60 for Very Large/Large, 25 for Medium and 12 for Small/Other (*source: Stakeholder Judgement*)
  - ✓ # of ATCOs at each training course is 6 (*source: Stakeholder Judgement*)
  - ✓ Therefore, # of Courses is 10 for Very Large/Large, 5 for Medium, 2 for Small/Other.
- ***Cost of an ATCO attendance*** = [# ATCO training days * # ATCO Hours/Day * ATCO cost/hour], where:
  - ✓ # of ATCO training days is 2 (*source: Stakeholder Judgement*)
  - ✓ # of ATCO Hours/Day is 8 (*source: SESAR common assumptions*)
  - ✓ ATCO cost/hour is €131 (*source: ACE Report [13]), for day is €1048 adjusted for 2024 annual cost increase (source ACE report [13]) = €1.101K/day*
  - ✓ Therefore, Cost of an ATCO attendance is €2.203K
- ***# of ATCOs*** = 60 for Very Large/Large and 25 for Medium, 12 for Small/Other.

[15] The cost of the additional training tasks for ATCO dedicated training personnel or those removed from operational duties to provide training

- ***Cost of OJT Training***, assumed to be internally provided and therefore is cost recovery of personnel providing the training. i.e. Cost of ATCO (#ATCO Hours/Day (8) * ATCO Cost/Hour (€131) * # of Trainers (1)) = €1.048K per ATCO trained adjusted for 2024 (annual change in ATCO cost (*source ACE report [13]*) = €1.101K/day. For each trainer it is assumed that between 1 and 3 days per ATCO are required with a median of 2 day (*source: Stakeholder Judgement*).

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Cost of Training Course	40	120	200
Cost of ATCO Attendance	1322	132.2	132.2
Cost of OJT	66.1	132.2	198.3
Total (VL/L)	238.3	384.4	530.5
Medium			
Cost of Training Course	20	60	100
Cost of ATCO Attendance	55.1	55.1	55.1
Cost of OJT	27.5	55.1	82.6
Total (M)	102.6	170.2	237.7
Small/Other			
Cost of Training Course	8	24	40
Cost of ATCO Attendance	26.4	26.4	26.4
Cost of OJT	13.2	26.4	39.6
Total (S/O)	47.6	76.8	106.0

Table 28: ASR Training Costs (ATCO) - Implementation

- ***Training for ATSEPs:*** It is assumed that training covers the technical operation and maintenance of ASR with AI/ML functions and the associated integration with existing controller tools and equipment. It is assumed this would comprise a set of separate classroom and practical sessions lasting 5 days held concurrently with the ATCO training, including any required ATSEP qualification tests at the end of the course.

  The cost is assumed to comprise two elements:
  - the cost of a classroom/practical training course to the ATSEP (which may be provided by a third-party provider or could be "internal charging" to an in-house provider);
  - the cost of the ATSEPs attending the classroom/simulator training (which could be regarded as the additional cost of employment for the additional training days or as the opportunity cost for the time they are not available for operational duty)

  The cost driver is:
  [Cost of Course * # of Courses] + [Cost an ATSEP attendance * # of ATSEPs] where:
  - ***Cost of Course*** = [Cost of Training Day * # of Days of Course] where:
    - *Cost of Training Day* is unlikely to be less than €0.3K or more than €1K with a median value of €0.6K (*source: Stakeholder judgement*)
    - *Number of days of course* is 5 [*source: Stakeholder judgement*]
    - Therefore, *Cost of Course* is unlikely to be less than €1.5K or more than €5K with a median value of €3K
  - ***# Of Courses*** = [# of ATSEPs/# of ATSEPs at a course] where:

- ○ *# of ATSEPs* is 25 for Very Large/Large, 20 for Medium and 15 for Small/Other (*source: Stakeholder judgement*)
- ○ *# of ATSEPs at a course* is 5 (*source: Stakeholder judgement*)
- ○ Therefore, the *# of courses* is 5 for Very Large/Large, 4 for Medium and 3 and Small/Other
- ***Cost of ATSEP attendance*** = [# ATSEP training days * # ATSEP Hours/Day * ATSEP cost/hour], where:
  - ○ *# of ATSEP training days* is 5 (*source: Stakeholder Judgement*)
  - ○ *# of ATSEP Hours/Day* is 8 (*source: SESAR common assumptions*)
  - ○ *ATSEP cost/hour* is €139 (*source: ACE Report [13]),* for day is €1112 adjusted for 2024 annual cost increase *(source ACE report [13])* = €1.169K/day
  - ○ Therefore, *Cost of an ATSEP attendance* is €5.844K
- ***# of ATSEPs*** is is 25 for Very Large/Large, 20 for Medium and 15 for Small/Other (*source: Stakeholder judgement*)

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Cost of Training Course	8	15	25
Cost of ATSEP Attendance	146.1	146.1	146.1
Total (VL/L)	153.1	161.1	171.1
Medium			
Cost of Training Course	6	12	20
Cost of ATSEP Attendance	116.9	116.8	116.9
Total (M)	122.9	128.8	136.9
Small/Other			
Cost of Training Course	4.5	9	15
Cost of ATSEP Attendance	87.7	87.7	87.7
Total (S/O)	92.2	96.7	102.7

Table 29: ASR Training Costs (ATSEP) - Implementation

- ***Project management, update of local manuals and procedures, certification and validation and general administration*** in relation to the installation of A/VR with track label, air gesture and attention guidance functionality at an aerodrome.

  With regard to certification and validation aspects it is estimated, based on similar activities in the past, that this would be equivalent of 2 Administrative staff over a period of a week (i.e., a total of 10 working days). The cost driver is, therefore:

  [Cost of Certification/Validation] = [Cost of Admin staff/hour * # of hours/day * # of days] * # of Admin Staff, where:
  - ○ ***Cost of Admin staff/hour (2019)*** is €139 (*source: ACE Report[13]*)
  - ○ # of hours/day is 8, Cost of Admin staff day = 8*139 = €1112, adjusted for 2024 (annual change in ATCO cost (*source ACE report [13]*) @ 1.051 = €1.169K
  - ○ # of days is 5
  - ○ # of Admin Staff is 2

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The median cost of Certification/Validation is, therefore, between €5.844K and €23.374K with a median value of €11.687K.

It is not possible to provide a detailed breakdown of the remaining project management, documentation and general administration one-off costs due to relative immaturity of the Solution. A range of bundled values have been determined based on the experience of implementing similar technological advances (e.g., 30 days of operational staff time for PM and manuals/procedures updates).

(*source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
Very Large/Large			
Certification/Validation	5.8	11.7	23.4
PM, Documentation, Admin	75	100	150
Total (VL/L)	80.8	111.7	173.4
Medium			
Certification/Validation	5.8	11.7	23.4
PM, Documentation, Admin	75	100	150
Total (M)	80.8	111.7	173.4
Small/Other			
Certification/Validation	5.8	11.7	23.4
PM, Documentation, Admin	75	100	150
Total (S/O)	80.8	111.7	173.4

Table 30: ASR Certification/PM Costs - Implementation

In summary, the estimated One-Off costs for Solution 97.2 are shown in the following table for Airport Operating Environment Sizes Very Large/Large (VL/L), Medium (M) and Small/Other (S/O).

Cost Item	Short description	Median Cost VL/L	Median Cost M	Median Cost S/O	Source
Training	All the training and staff costs related to the use of ASR	€545K	€299K	€174K	Stakeholder judgement
Administrative costs	All the administrative costs related to the acquisition, installation, configuration and testing of ASR and associated functions	€112K	€112K	€112K	Stakeholder judgement, SESAR common assumptions and standard references
ASR AI/ML Installation, Commissioning and licence	Installation and configuration costs. Initial Test and evaluation	€600K	€600K	€600K	Stakeholder judgement
TOTAL		***€1257K***	***€1011K***	***€885K***	

Table 31: ASR Implementation Costs Summary

Operating costs:

Infrastructure replacement.

It is assumed that:

- the ASR Tool is subject to a five-year periodic one-off cost (@5% of original costs) to include provision of updates and patches etc. (*source: Stakeholder judgement*)
- the Licence of Use is renewed every ten years @120% of original costs (*Source: Stakeholder judgement*)

(*source: Stakeholder Judgement*):

Item	Unlikely <€K	Median €K	Unlikely >€K
For all airport OEs			
ASR Tool	17.5	25	35
Licence renewal	96	120	144
Total	114	145	179

Table 32: ASR Infrastructure Costs - On-going

In summary, the estimated Operating Costs for Solution 97.2 are shown in the following table for Airport Operating Environment Sizes Very Large/Large (VL/L), Medium (M) and Small/Other (S/O).

Cost Item	Short description	Median Cost VL/L	Median Cost M	Median Cost S/O	Source
ASR Tool update and patch costs	5-year replacement Installation and configuration costs.	€25K	€25K	€25K	Stakeholder judgement
ASR Use licence	10-year renewal of licence	€120K	€120K	€120K	Stakeholder judgement
TOTAL	***5-year ASR Tool*** ***10-year Licence***	***€25K*** ***€120K***	***€25K*** ***€120K***	***€25K*** ***€120K***	

Table 33: ASR Operating/On-going Costs Summary

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5.1.2 Number of investment instances (units)

Solutions 97.1 and 97.2 are specifically targeted at new human machine interface interaction modes and technologies for the Controller Working Position in airport Control Towers, therefore the number of investment instances is restricted to airports with Control Towers in the ECAC area. Note that of the 41 ANSPs in ECAC, 1 (MUAC) does not control any towers, therefore the number of ANSP investment instances is **40**.

As discussed in the previous sections, it is assumed that the Solutions are all applicable to all sizes[16] of aerodrome, i.e., ***Very Large, Large, Medium, Small and Other***. The Airport Operating Environment Dataset ([14]) has been used to compile the number of the investment instances.

For Solution 97.1, with regard to airports classified as Other, it is noted that they cover a wide range of annual movements from 10's to 15,000. The Solution aims at improving controller productivity through the use of V/AR technology; therefore, it is considered that it is very unlikely that all airports classified as Other would benefit; therefore, an arbitrary threshold of Other airports with greater than 7,300 movements a year (i.e. an average of 20 movements per day) has been applied (*source: Stakeholder Judgement*).

Airport				
Very Large	Large	Medium	Small	Other
12	19	77	88	91

Table 34: Sol 97.1 Number of Investment Instances - ANSPs

For Solution 97.2, it is noted that the Solution is also intended to be applicable to Operating Environments that are conducting Remote Tower operations, therefore an adjustment to the number of airports classified as Other used for Solution 97.1 needs to be made. The V2 CBA for Solution PJ05_03, Multiple Remote Tower [18] provided the following assessment for the number of relevant investment instances:

> *CBAT results are aggregated to ECAC level assuming there are 90 RTC based in existing ANSP buildings. This includes 6 RTC in 15 countries each controlling 4 aerodromes so 360 aerodromes in total.*

The total number of instances for Solution 97.1 is 287 including all Very Large, Large, Medium and Small aerodromes listed in the Airport Operating Environment Dataset ([14]). To be consistent, therefore, with the investment instance analysis conducted in PJ05_03 an additional 73 Other airports have been added to make the overall total 320.

Airport				
Very Large	Large	Medium	Small	Other
12	19	77	88	164

Table 35: Sol 97.2 Number of Investment Instances - ANSPs

[16] Using the SESAR 2020 Classification scheme

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5.1.3 Cost per unit

Cost category	Airport				
	Very Large	Large	Medium	Small	Other
Solution 97.1 Deployment Option 1: Track Labels (AERODROME-ATC-103)					
Pre-Implementation Costs	N/A	N/A	N/A	N/A	N/A
Implementation costs	€1882K	€1882K	€922K	€544K	€544K
Operating costs	€879K	€879K	€354K	€172K	€172K
Solution 97.1 Deployment Option 2: Track Labels (AERODROME-ATC-103) and Air Gestures (AERODROME-ATC-104)					
Pre-Implementation Costs	N/A	N/A	N/A	N/A	N/A
Implementation costs	€2267K	€2267K	€1097K	€641K	€641K
Operating costs	€917K	€917K	€371K	€181K	€181K
Solution 97.1 Deployment Option 3: Track Labels (AERODROME-ATC-103) and Attention guidance (AERODROME-ATC-105)					
Pre-Implementation Costs	N/A	N/A	N/A	N/A	N/A
Implementation costs	€2372K	€2372K	€1149K	€674K	€674K
Operating costs	€928K	€928K	€376K	€185K	€185K
Solution 97.1 Deployment Option 4: Track Labels (AERODROME-ATC-103), Air Gestures (AERODROME-ATC-104) and Attention Guidance (AERODROME-ATC-105)					
Pre-Implementation Costs	N/A	N/A	N/A	N/A	N/A
Implementation costs	€2757K	€2757K	€1324K	€771K	€771K
Operating costs	€966K	€966K	€394K	€194K	€194K
Solution 97.2 ASR supported by Artificial Intelligence and Machine Learning (AERODROME-ATC-106)					

Pre-Implementation Costs	N/A	N/A	N/A	N/A	N/A
Implementation costs	€1257K	€1257K	€1011K	€885K	€885K
Operating costs	€145K	€145K	€145K	€145K	€145K

Table 36: Cost per Unit - by Airport Category

Note: The number of investment units (by Airport classification) and associated unit costs (by Airport classification), as detailed above, have been used in the ECAC-wide CBAT model presented in Section 6. To derive *indicative* CBAT values at Stakeholder level of ANSP, some additional aggregation assumptions have been applied in the local CBAT model presented in Section 6, using the Airport classifications and associated unit costs as detailed above.

5.2 Other relevant stakeholders

N/A at this Stage (V2)

6 CBAT Model

Two CBAT models are embedded in the document:

Sol97%20ECAC%20
Model%20(SESAR%2

1. **ECAC-Wide.**

   The SESAR Cost Benefit Analysis Single Solution (Wave 2) Version s7.3.8 model, as provided by SESAR/Eurocontrol, has been used to provide the ECAC-wide results based on the Number of Investment Instances and associated Unit Costs presented in Sections 5.1.2 and 5.1.3 plus the Benefit gain results for Cost Efficiency CEF2 reported by the PAR [20] and presented in Sections 4.1 and 4.2.

   Three scenarios are presented in the ECAC-wide model:

   - Solution 97, comprising both V/AR and ASR functions
   - Solution 97.1 alone, comprising only V/AR
   - Solution 97.2 alone, comprising only ASR.

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Model%20Final%20I

2. **Local.**

   This CBAT model is the supporting Excel workbook to both the ECAC-wide model and detailed analysis presented in this document, and is provided for information. Specifically, it details:

   - The Common and Local assumptions and their sources used in the calculations
   - The detailed airport based cost models for Solutions 97.1 and 97.2 as detailed in Section 5.1
   - The aggregation of the costs for Solutions 97.1 and 97.2 for input into the ECAC-wide CBAT model using the airport Investment Instances and associated Unit Costs detailed in Sections 5.1.2 and 5.1.3
   - The assumptions and aggregation of Unit Costs to provide *indicative* values for ANSPs of different sizes {Large (>1M airport(s) movements/year), Medium (>100K <1M airport(s) movements/year) and Small (<100K airport(s) movements/year).
   - The assumptions and derivation of Benefits to provide *indicative* values for ANSPs of different sizes {Large (>1M airport(s) movements/year), Medium (>100K <1M airport(s) movements/year) and Small (<100K airport(s) movements/year) with their associated CBAT model ouputs.

- The combination of 97.1 and 97.2 Costs and Benefits at ANSP level to provide a CBAT result for Solution 97.

The CBAT models provide the results in terms of Net Present Value (i.e., Cumulative Benefit-Cumulative Cost), Return on Investment (Total Benefit/Total Cost) and Breakeven Year (the year in which cumulative Benefits become greater than cumulative Costs) discounted in accordance with the SESAR Common Assumptions [10]

7 CBAT Results

7.1 ECAC-Wide

The SESAR Single Solution Wave 2 model (see Section 6) has been used to derive the ECAC level CBAT results. Three scenarios have been modelled:

- Solution 97 V/AR + ASR
- Solution 97.1 V/AR
- Solution 97.2 ASR

The following input parameters were entered into the model:

Scenario	Dep Start	IOC	FOC	ANSP Ground Costs (€M's)	ANSP Change Operating Costs (€M's)	CEF2 Cost Efficiency Ref: PAR [20]
Sol 97	2030	2030	2034	665.4	57.8	+1.63%
Sol 97.1	2030	2030	2034	325.5	51.7	+1.54%
Sol 97.2	2030	2030	2034	339.9	6.1	+1.75%

Table 37: ECAC CBAT Model - Input Parameters

The sources of the data are:

- Deployment Start, IOC and FOC dates as described in Section 3
- ANSP Ground Costs and Change in Operating Costs from the Local model (see Section 6), which multiplies the Unit Costs for Very Large, Large, Medium, Small and Other airports with the Number of Investment Instances as described in the Section 5
- CEF2 Cost Efficiency from the Performance Assessment Report [20].

The traffic profile used in the SESAR Single Solution Wave 2 model is the default SESAR recommended "Regulation and Growth" profile.

The following table summarises the results of the model in terms of

- Net Present Value (NPV) i.e. Cumulative Benefits over the period – Cumulative Costs over the period
- Return on Investment (ROI) i.e., Cumulative Benefits/Cumulative Costs
- Breakeven Year i.e. the year in which Cumulative Benefits exceed Cumulative Costs.

All € values are discounted at the SESAR common assumption ([10]) rate of 8%.

Scenario	NPV (€M's)	ROI	Breakeven Year
Sol 97	6.706	1.01	2043
Sol 97.1	147.614	1.46	2037
Sol 97.2	365.653	3.17	2034

Table 38: ECAC Model results for Sol 97, Sol 97.1 and Sol 97.2

The following graphs present a summary of the cash flow for each scenario in terms of costs, benefits and the cumulative net cash flow (i.e. cumulative benefit-cumulative cost).

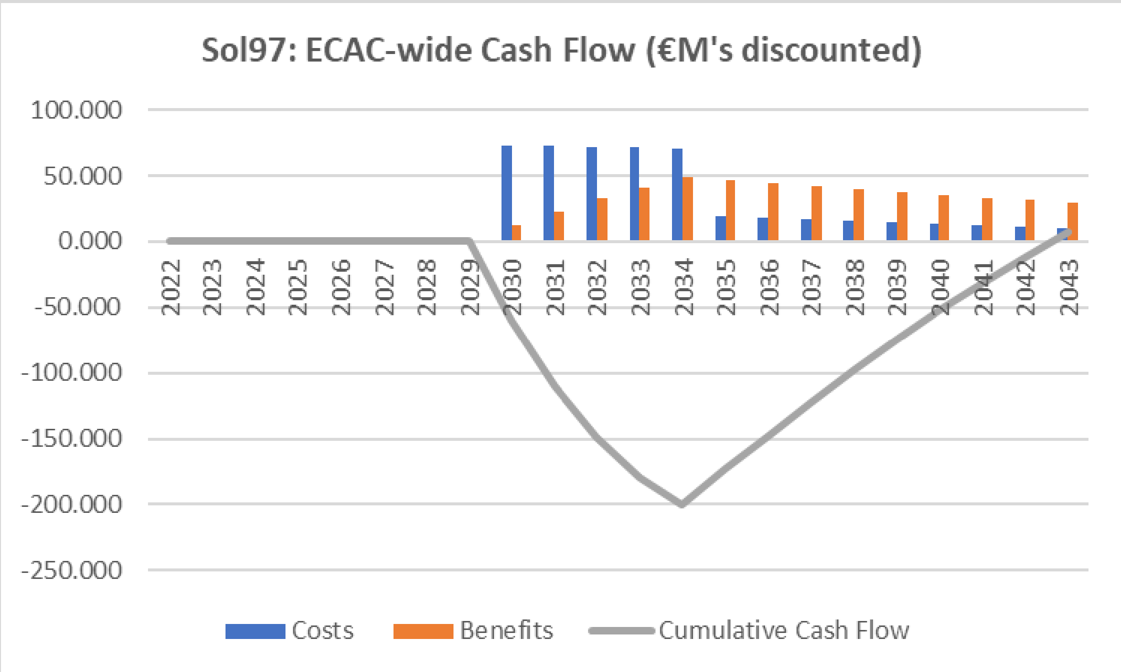

Figure 3: Sol 97 ECAC-wide Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97 as a whole shows a positive NPV 6.706M), a POI of greater than 1 (1.01) and that breakeven is achieved in 2043, i.e. 9 years following FOC. In other words, the expected benefit gain through CEF2 cost savings covers the costs of deploying and operating *both* V/AR and ASR across the ECAC region over the period of the CBAT.

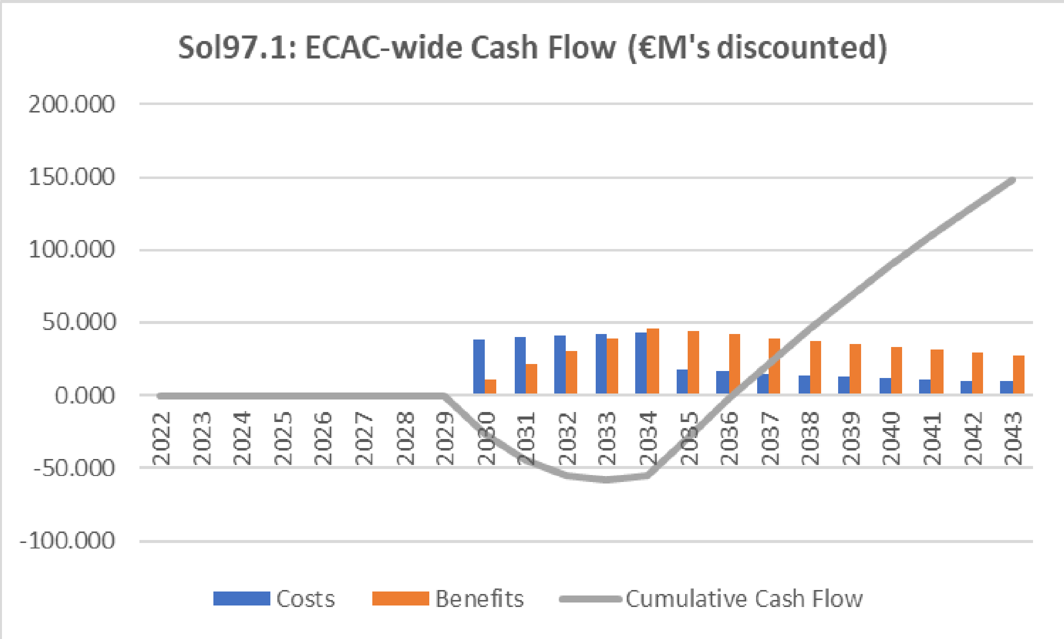

Figure 4: Sol 97.1 ECAC-wide Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97.1 shows a positive NPV (€147.614M), a POI of greater than 1 (1.46) and that breakeven is achieved in 2037, i.e. 3 years following FOC. In other words, the expected benefit gain through CEF2 cost savings easily covers the costs of deploying and operating V/AR across the ECAC region over the period of the CBAT.

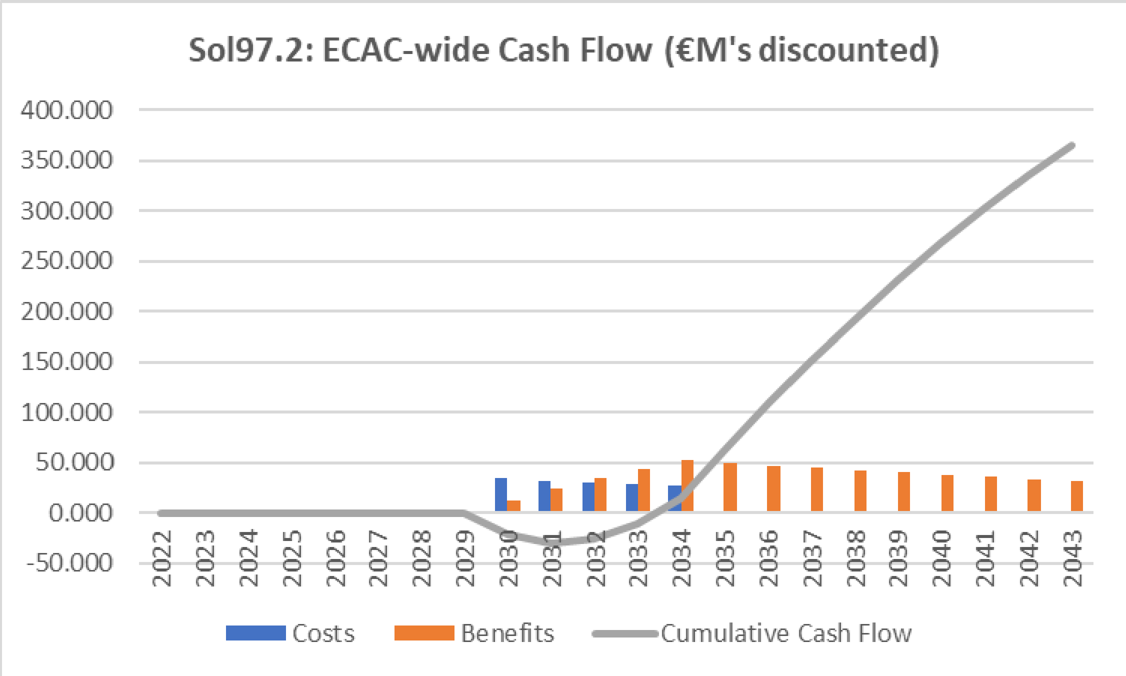

Figure 5: Sol 97.2 ECAC-wide Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97.2 shows a positive NPV (€365.653M), a POI of greater than 1 (3.17) and that breakeven is achieved in 2034, i.e. at FOC. In other words, the expected benefit gain through CEF2 cost savings easily covers the costs of deploying and operating ASR across the ECAC region over the period of the CBAT.

The weakly positive result for the Solution 97 as whole compared with the strongly positive results for Solutions 97.1 and 97.2 is a consequence of the relatively artificial combination of two sub-Solutions that represent separate technological advances in Controller HMI that are independent of each other. The resultant large initial ground costs whilst the expected cost efficiency gain remains similar results in a significant increase in the time required for the cumulative benefits to cover the cumulative costs.

In summary, the ECAC CBAT modelling indicates that Solutions 97.1 and 97.2 individually are economically viable with positive Net Present Value and Return on Investment values and breakeven periods well within the Wave 2 CBAT period. The result for Solution 97 as a whole is weakly positive, however this is considered to be a consequence of artificially combining independent Solution results.

7.2 ANSP Level

Solution 97.x is deployed at Airport level and the costs and benefits have been analysed at that level and extrapolated, as necessary, to all target Operating Environments, i.e., Very Large, Large, Medium, Small and Other airports. The impacted Stakeholder group, however, is ANSP that provide ATM/ATS services at airport control towers. The airport level data, therefore, needs to be aggregated further to provide a cost benefit view at Stakeholder level of ANSP.

There are 41 ANSPs in the ECAC region, 40 of which provide airport tower services[17]. The ECAC ANSPs range widely in numbers and categories of airports controlled and number of airport movements handled, therefore it is not considered to be realistic to consider a single "average" ANSP.

The Airport Operating Environment dataset [14] has been used to define three representative ANSP profiles for each Solution based on the annual number of airport movements controlled and typical number of each airport category as follows:

SOL 97.1 V/AR							
ANSP Category	**Annual Movements**	**# Very Large**	**# Large**	**# Medium**	**# Small**	**# Other**	**# ECAC ANSPs**
Large	>1M	2	1	5	4	5	6
Medium	<1M >100K	0	1	2	3	3	15
Small	<100K	0	0	1	1	1	19
SOL 97.2 ASR							
ANSP Category	**Annual Movements**	**# Very Large**	**# Large**	**# Medium**	**# Small**	**# Other**	**# ECAC ANSPs**
Large	>1M	2	1	5	4	10	6
Medium	<1M >100K	0	1	2	3	5	15
Small	<100K	0	0	1	1	2	19

Table 39: Aggregation of Airport categories to ANSPs

The number of airports in each category has been normalised to be consistent with the number of investment instances presented in Section 5.

These profiles were used to derive an aggregated cost value for an ANSP of a given category. For the purposes of calculating a cash flow profile across the CBAT timeframe of 2022 to 2043, it is assumed the one-off ground costs are incurred in the Deployment Year as defined in Section 3, and the operating costs are distributed according to the periodicity of the relevant cost item as defined in Section 5 from the Ioc date as defined in Section 3.

The Benefits are assessed at ECAC level from the Performance Assessment Report [15], and therefore need to be distributed across the ECAC ANSPs. The CEF2 Cost Efficiency Key Performance Indicator is directly proportional to the volume of airport movements handled (to derive the ATCO cost per flight). The proportion of total airport movements (derived from the Airport Operating

[17] The ECAC ANSP MUAC does not provide services to an airport.

Environment dataset [14]) was used to define a Benefit Ratio in order to derive a Benefit value for each ANSP category defined above. This is summarised in the following table:

SOL 97					
ECAC Wide Benefit (€M's)		1730.8			
ANSP Category	**Total # ECAC airport movements**	**# ANSPs**	**Airport Movement/ ANSP**	**Benefit Ratio**	**Benefit (€M's)**
Large	10,808,771	6	1,801,462	0.105	181.8
Medium	5,415,739	15	361,049	0.021	36.4
Small	930,459	19	48,972	0.003	4.9
SOL 97.1					
ECAC Wide Benefit (€M's)		1636.1			
ANSP Category	**Total # ECAC airport movements**	**# ANSPs**	**Airport Movement/ ANSP**	**Benefit Ratio**	**Benefit (€M's)**
Large	10,808,771	6	1,801,462	0.105	171.8
Medium	5,415,739	15	361,049	0.021	34.4
Small	930,459	19	48,972	0.003	4.7
SOL 97.2					
ECAC Wide Benefit (€M's)		1857			
ANSP Category	**Total # ECAC airport movements**	**# ANSPs**	**Airport Movement/ ANSP**	**Benefit Ratio**	**Benefit (€M's)**
Large	10,808,771	6	1,801,462	0.105	195.0
Medium	5,415,739	15	361,049	0.021	39.1
Small	930,459	19	48,972	0.003	5.3

Table 40: Benefit apportionment to ANSPs

The benefit values presented are undiscounted. For the purposes of calculating a cash flow profile across the CBAT timeframe of 2022 to 2043, it is assumed the benefits are spread evenly across the timeframe starting in the IOC Year as defined in Section 3.

Note: The confidence level of the following CBAT analysis at ANSP level is considered ***Low***, due to the number of assumptions made in deriving the input cost and benefit figures as detailed above and recognising there are alternative approaches to aggregating the unit and benefit values to ANSPs. The ANSP CBAT results presented should be considered, therefore, as only ***indicative*** of ***potential*** economic viability.

All ANSP CBATs have been calculated using the Local CBAT model described in Section 6. All € values are discounted at the SESAR common assumption ([10]) rate of 8%.

7.2.1 ANSP Solution 97 CBAT Results

The following table summarises the results of the model in terms of

- Net Present Value (NPV) i.e. Cumulative Benefits over the period – Cumulative Costs over the period
- Return on Investment (ROI) i.e. Cumulative Benefits/Cumulative Costs
- Breakeven Year i.e. the year in which Cumulative Benefits exceed Cumulative Costs.

ANSP Category	NPV (€M's)	ROI	Breakeven Year
Large	21.376	1.594	2034
Medium	-5.194	0.689	N/A
Small	-3.513	0.307	N/A

Table 41: Sol 97 ANSP CBAT Results

The following graphs present a summary of the cash flow for each scenario in terms of costs, benefits and the cumulative net cash flow (i.e. cumulative benefit-cumulative cost).

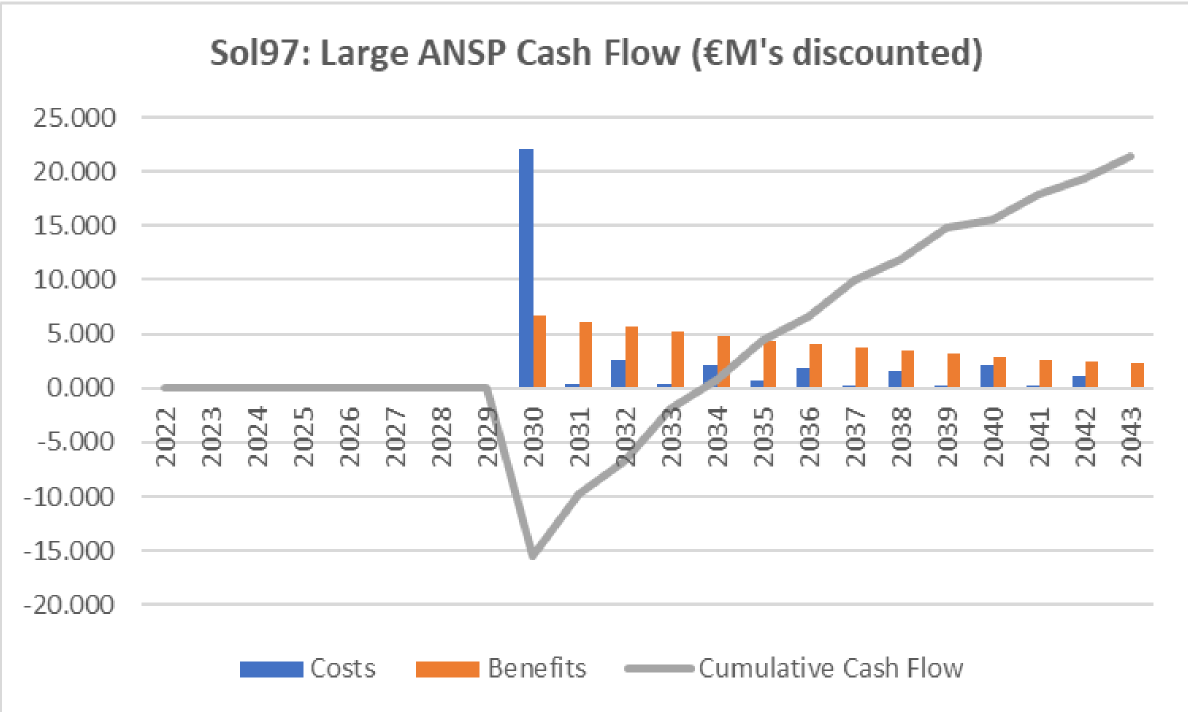

Figure 6: Sol 97 Large ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97 for a Large ANSP shows a positive NPV (€21.376M), a POI of more than 1 (1.594) and that breakeven is achieved in 2034, i.e. 3 years following IOC. In other words, the expected benefit gain through CEF2 cost savings easily

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covers the costs of deploying and operating *both* V/AR and ASR in a Large ANSP over the period of the CBAT.

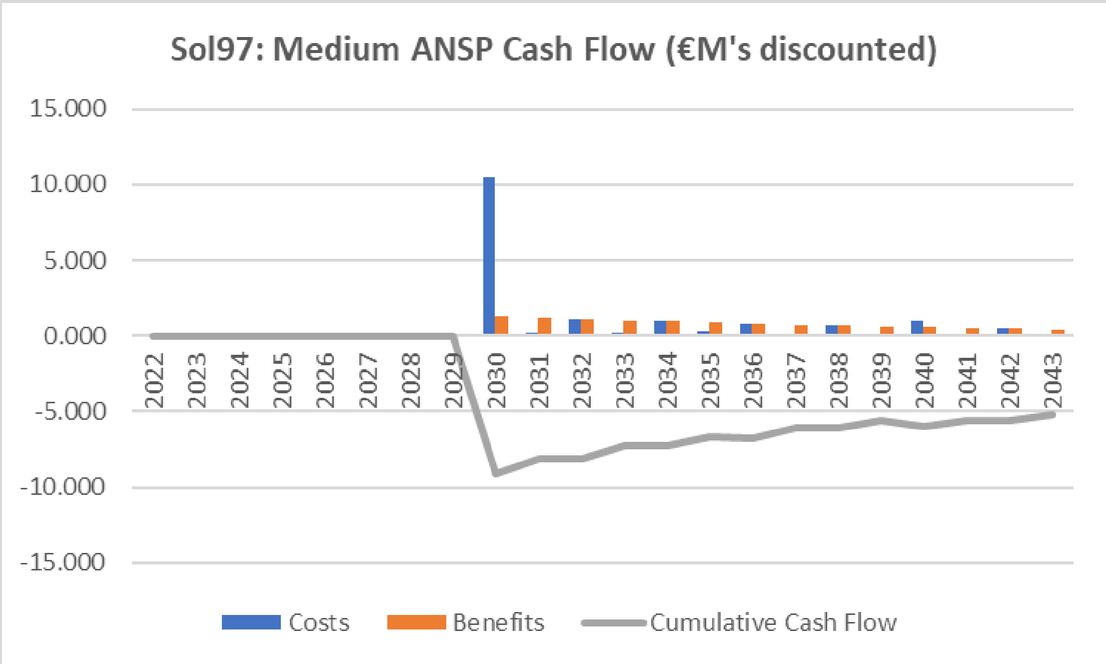

Figure 7: Sol 97 Medium ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97 for a Medium ANSP shows a negative NPV (-€5.194M), a POI of less than 1 (0.689) and that breakeven is not achieved during the period of the CBAT. In other words, the expected benefit gain through CEF2 cost savings does not cover the costs of deploying and operating V/AR for a Medium ANSP over the period of the CBAT.

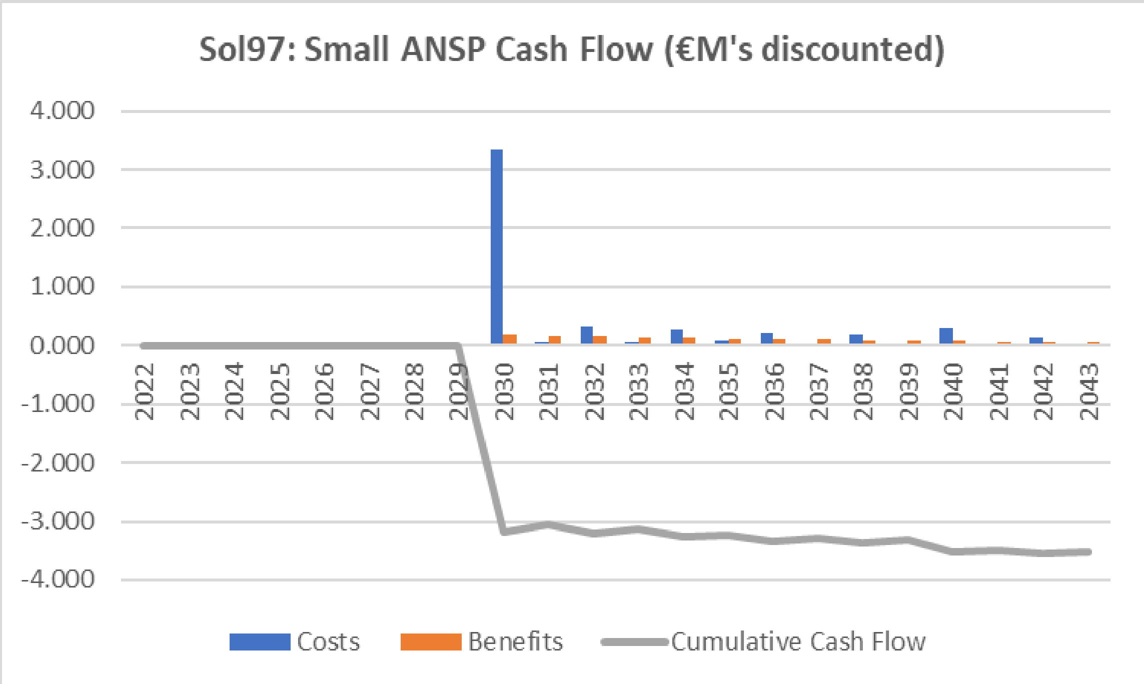

Figure 8: Sol 97 Small ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97 for a Small ANSP shows a negative NPV (-€3.513M), a POI of less than 1 (0.307) and that breakeven is not achieved during the period of the CBAT. In other words, the expected benefit gain through CEF2 cost savings does not cover the costs of deploying and operating V/AR for a Small ANSP over the period of the CBAT.

The negative result for the Solution 97 for Medium and Small ANSPs compared with the positive results for a Large ANSP is a consequence of the the fact there is an insufficient number of airport movements for these categories to provide the level of cost efficiency savings to cover the costs of deploying and operating the Solution as a whole.

In summary, the CBAT modelling indicates that Solution 97 as a whole is potentially economically viable with positive Net Present Value and Return on Investment values and breakeven periods well within the Wave 2 CBAT period for a Large ANSP.

7.2.2 ANSP Solution 97.1 CBAT Results

The following table summarises the results of the model in terms of

- Net Present Value (NPV) i.e. Cumulative Benefits over the period – Cumulative Costs over the period
- Return on Investment (ROI) i.e. Cumulative Benefits/Cumulative Costs
- Breakeven Year i.e. the year in which Cumulative Benefits exceed Cumulative Costs.

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ANSP Category	NPV (€M's)	ROI	Breakeven Year
Large	30.024	2.24	2031
Medium	-0.057	0.995	N/A
Small	-1.568	0.485	N/A

Table 42: Sol 97.1 ANSP CBAT Results

The following graphs present a summary of the cash flow for each scenario in terms of costs, benefits and the cumulative net cash flow (i.e. cumulative benefit-cumulative cost).

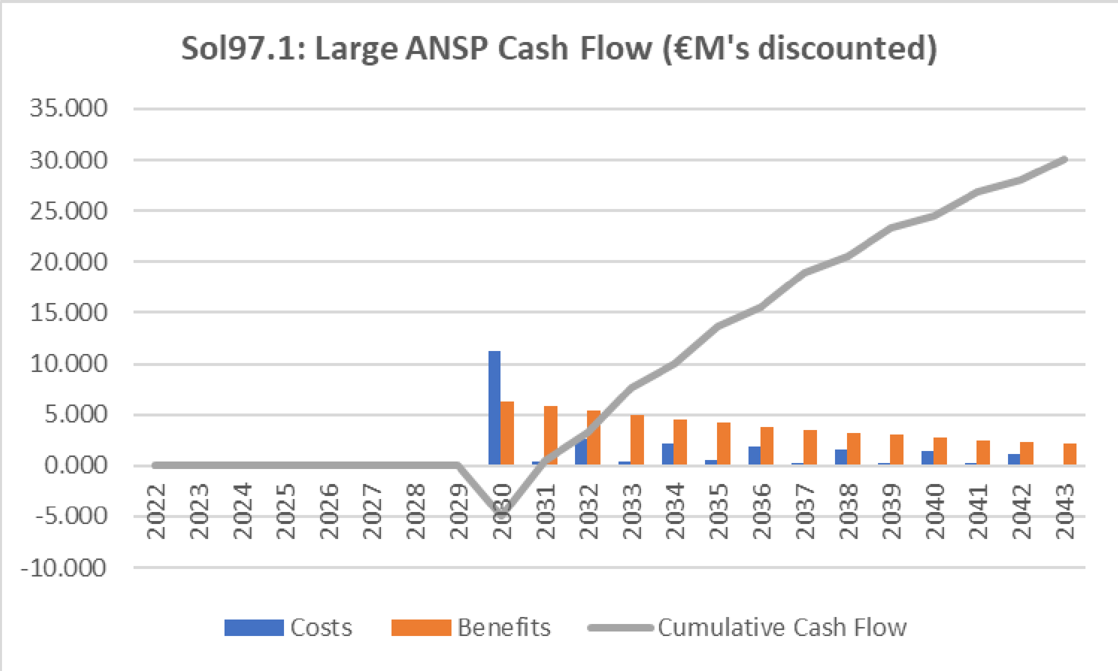

Figure 9: Sol 97.1 Large ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97.1 for a Large ANSP shows a positive NPV (€30.024M), a POI of more than 1 (2.24) and that breakeven is achieved in 2031, i.e. the year following IOC. In other words, the expected benefit gain through CEF2 cost savings easily covers the costs of deploying and operating V/AR in a Large ANSP over the period of the CBAT.

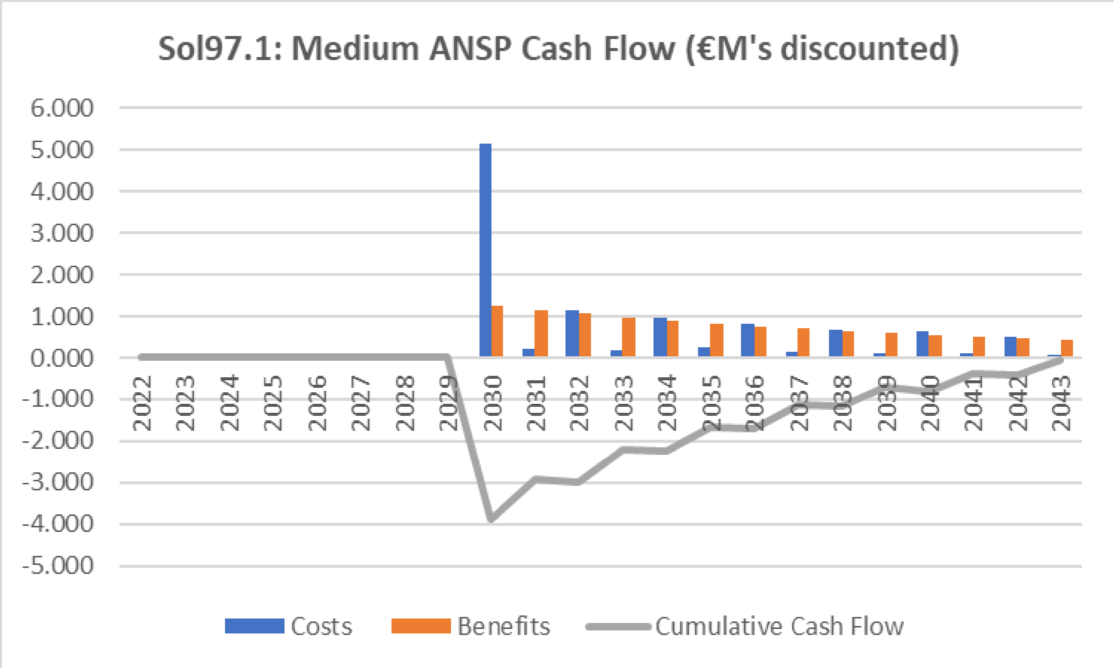

Figure 10: Sol 97.1 Medium ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97.1 for a Medium ANSP shows a negative NPV (-€0.057M), a POI of less than 1 (0.995) and that breakeven is not achieved during the period of the CBAT. In other words, the expected benefit gain through CEF2 cost savings does not cover the costs of deploying and operating V/AR for a Medium ANSP over the period of the CBAT, however the NPV and POI results are marginal and the net cumulative cash flow tred suggests breakeven would be achieved in approximately 2044.

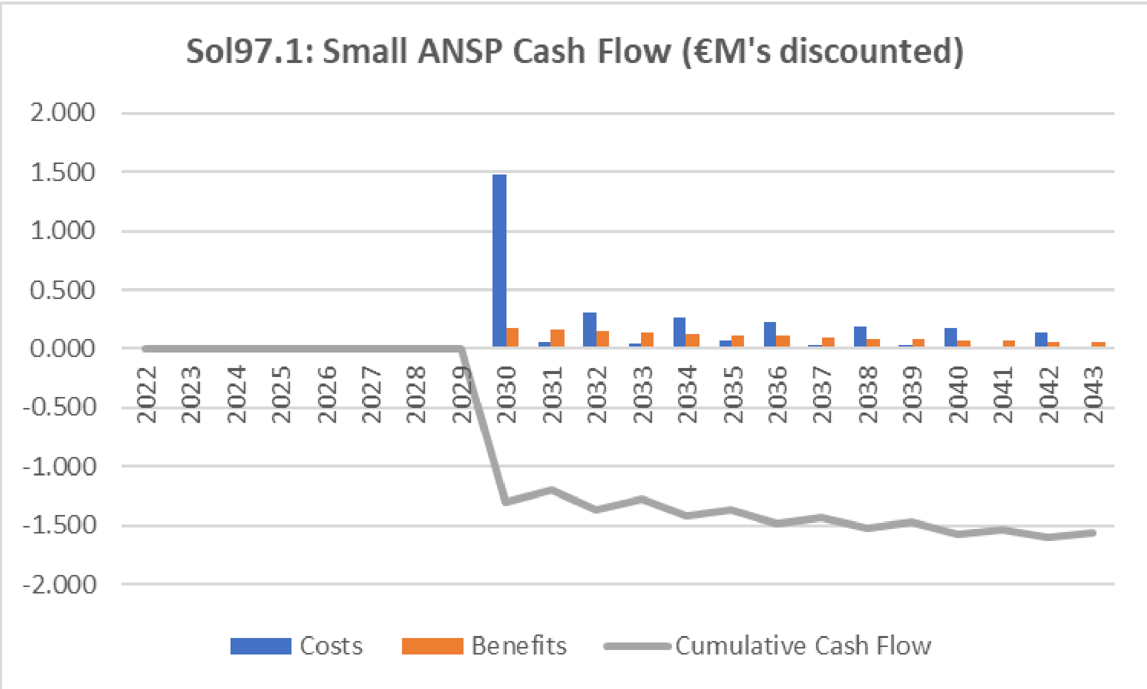

Figure 11: Sol 97.1 Small ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97.1 for a Small ANSP shows a negative NPV (-€1.568M), a POI of less than 1 (0.485) and that breakeven is not achieved during the period of the CBAT. In other words, the expected benefit gain through CEF2 cost savings does not cover the costs of deploying and operating V/AR for a Small ANSP over the period of the CBAT.

The negative result for the Solution 97.1 for Medium and Small ANSPs compared with the positive results for a Large ANSP is a consequence of the fact that operating costs are relatively high, due the device replacement periodicty and that there is an insufficient number of airport movements for these categories to provide the level of cost efficiency savings to cover the costs of deploying and operating the Solution as a whole.

In summary, the CBAT modelling indicates that Solution 97.1 V/AR is potentially economically viable with positive Net Present Value and Return on Investment values and breakeven periods well within the Wave 2 CBAT period for a Large ANSP.

7.2.3 ANSP Solution 97.2 CBAT Results

The following table summarises the results of the model in terms of

- Net Present Value (NPV) i.e. Cumulative Benefits over the period – Cumulative Costs over the period
- Return on Investment (ROI) i.e. Cumulative Benefits/Cumulative Costs
- Breakeven Year i.e. the year in which Cumulative Benefits exceed Cumulative Costs.

ANSP Category	NPV (€M's)	ROI	Breakeven Year
Large	49.764	5.222	2031
Medium	6.57	2.14	2034
Small	-0.358	0.824	N/A

Table 43; Sol 97.2 ANSP CBAT Results

The following graphs present a summary of the cash flow for each scenario in terms of costs, benefits and the cumulative net cash flow (i.e. cumulative benefit-cumulative cost).

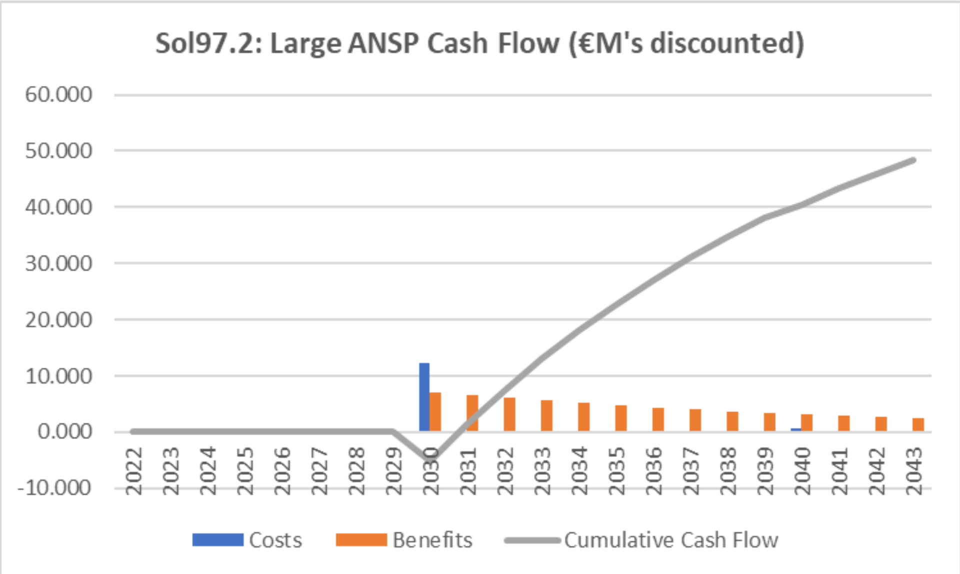

Figure 12: Sol 97.2 Large ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97.2 for a Large ANSP shows a positive NPV (€49.764M), a POI of more than 1 (5.222) and that breakeven is achieved in 2031, i.e. 1 year following IOC. In other words, the expected benefit gain through CEF2 cost savings easily covers the costs of deploying and operating ASR in a Large ANSP over the period of the CBAT.

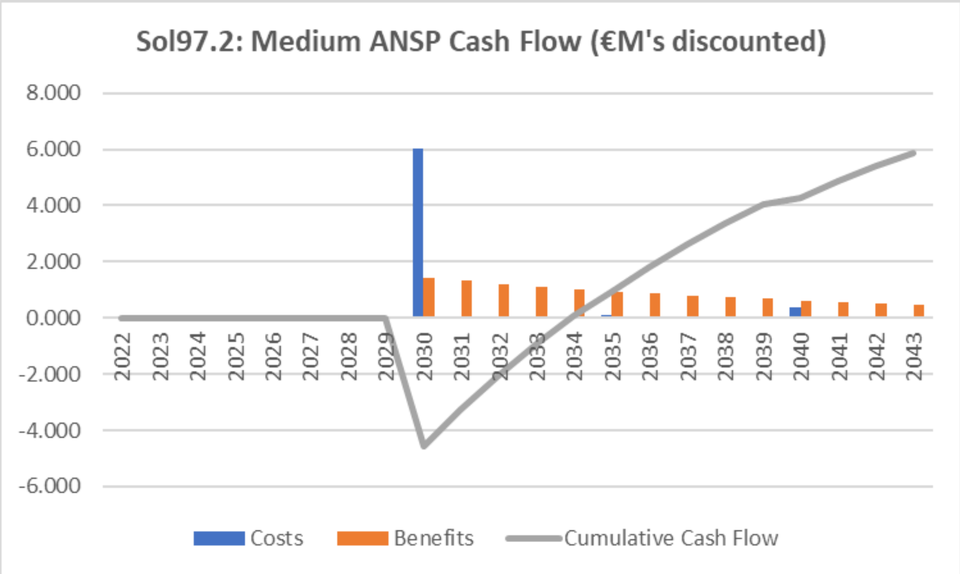

Figure 13: Sol 97.2 Medium ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97.2 for a Medium ANSP shows a positive NPV (€6.57M), a POI of more than 1 (2.14) and that breakeven is achieved in 2034, i.e. 4 years following IOC. In other words, the expected benefit gain through CEF2 cost savings easily covers the costs of deploying and operating ASR in a Medium ANSP over the period of the CBAT.

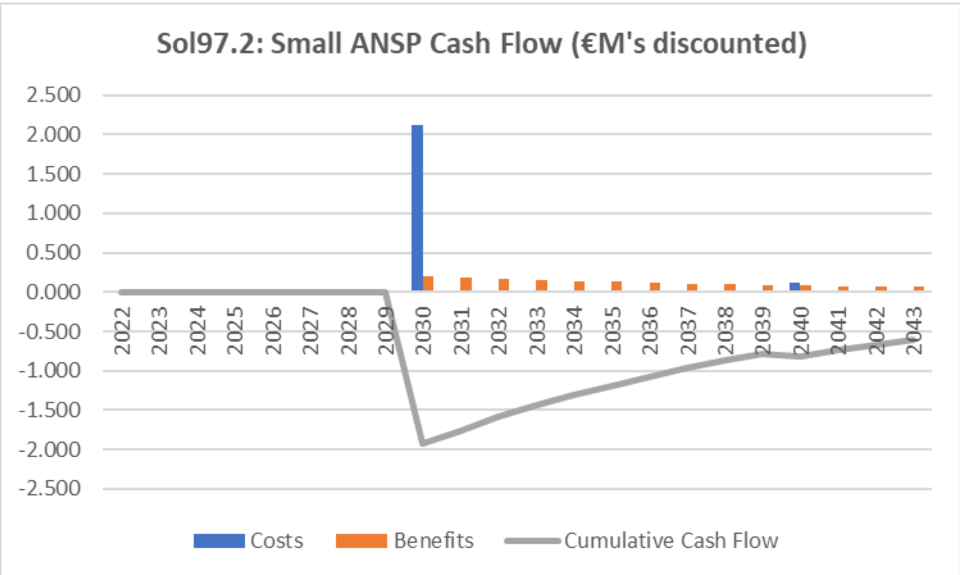

Figure 14: Sol 97.2 Small ANSP Discounted Cash Flow

Over the SESAR Wave 2 period of the CBAT (2022 to 2043), Solution 97.2 for a Small ANSP shows a negative NPV (-€0.358M), a POI of less than 1 (0.824) and that breakeven is not achieved during the period of the CBAT. In other words, the expected benefit gain through CEF2 cost savings does not cover the costs of deploying and operating ASR for a Small ANSP over the period of the CBAT.

The negative result for the Solution 97.2 for the Small ANSPs compared with the positive results for Large and Medium ANSPs is a consequence of the fact that there is an insufficient number of airport movements for this category to provide the level of cost efficiency savings to cover the costs of deploying and operating the Solution as a whole.

In summary, the CBAT modelling indicates that Solution 97.2 ASR is potentially economically viable with positive Net Present Value and Return on Investment values and breakeven periods well within the Wave 2 CBAT period for both Large and Medium ANSPs.

7.3 CBAT Analysis Conclusions

At ECAC level, the individual Solutions 97.1 V/AR and 97.2 ASR are economically viable over the SESAR Wave 2 timeperiod of 2022 to 2043 with:

- positive Net Present Values, i.e. Solution 97.1 = €147.6M and Solution 97.2 = €365.k7M;
- Return on Investment values greater than 1, i.e. Solution 97.1 = 1.46 and Solution 97.2 = 3.17; and,
- Breakeven years for Solution 97.1 of 2037 and 97.2 of 2034, i.e within 2 or 3 years following the FOC date.

The indicative ANSP analysis shows that, at local level, the economic viability is very dependent on the number of airport movements to generate sufficient Cost Efficiency savings to cover the costs of implementing and operating the Solutions. ANSPs with Very Large and Large airports have consistently positive NPVs and ROIs of greater than 1 for both Solution 97.1 and Solution 97.2, i.e., are economically viable for those categories of airport on their own. ANSPs with only Medium, Small and Other airports have consistently negative NPVs and ROIs less than 1 for both Solution 97.1 and 97.2. It is recognised that the economic viability of V/AR and ASR at these smaller categories of Airport may be dependent on whether they are supporting other local initiatives, for example, Multiple Remote Towers or, as in the case of Vitoria airport, avoiding the cost of installing ground surveillance equipment. The implication of the results is, therefore, that ANSPs will need to assess the economic viability of Solutions 97.1 and 97.2 at Small and Other airports on a case-by-case basis.

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8 Sensitivity and risk analysis

Sensitivity analysis is a systematic method for examining how the outcome of benefit-cost analysis changes with the variation of inputs, assumptions, or the manner in which the analysis is set up.

Key input parameters into the CBAT calculations have been examined to determine their effect on the overall result in terms of the absolute value of the NPV as presented in Section 7. Each parameter was adjusted independently to determine the change in overall NPV. The parameters examined are:

- Overall Costs, considered to be at a confidence level of medium, therefore adjusted between the bounds of -25% and +25%
- Overall Benefits, considered to be at a confidence level of medium, therefore adjusted between the bounds of -25% and +25%
- Discount Rate, as applied at SESAR common assumption rate of 8%, adjusted between the bounds of 0% and 12%

The analysis has been performed only on the ECAC-wide results presented in Section 7. The ANSP level results are at a confidence level of Low, therefore it is considered inappropriate to analyse these further for the purposes of this CBAT.

The results are presented in the form of tornado bar diagrams with parameters ordered top to bottom from most effect on NPV to least effect on NPV within the bounds set. The variation is presented as the absolute change in the base NPV in €M's, with the limit NPVs displayed at the end of the bars.

For Solution 97 as a whole:

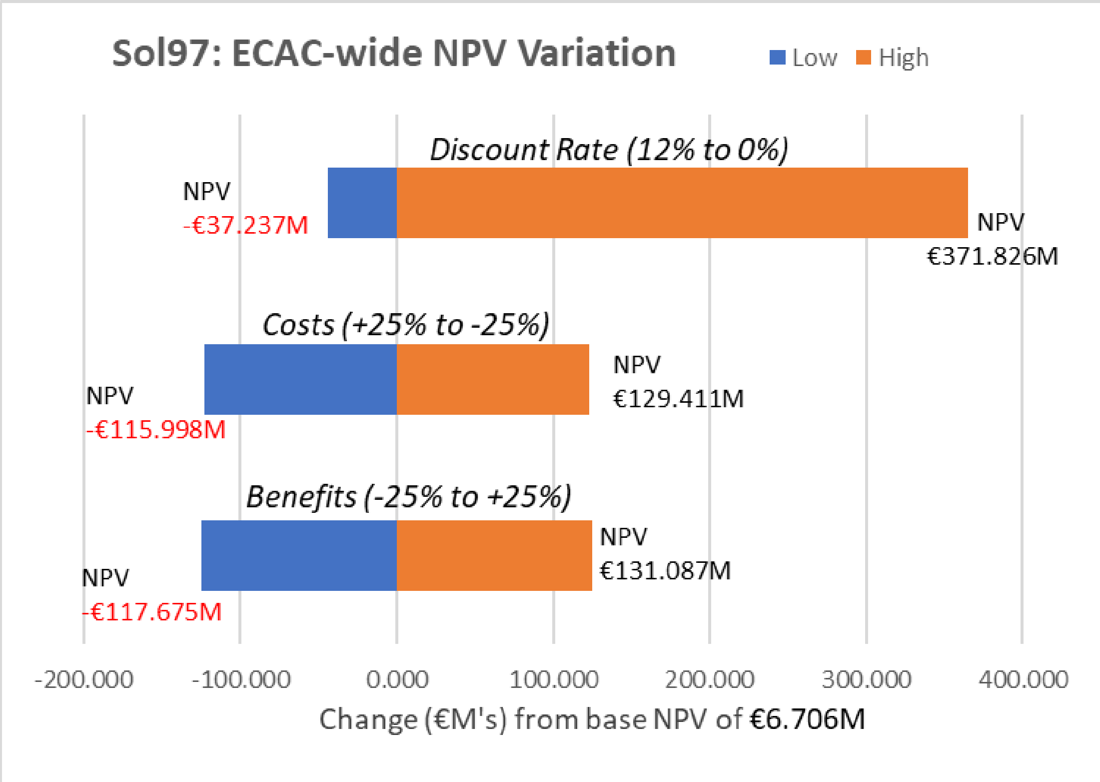

Figure 15: Sol 97 ECAC-wide NPV Variation

The Discount Rate applied in the calculations has the greatest effect on NPV, with a range of (minus) €37.3M at 12% to €371.8M at 0%. Costs have a range of (minus) €116.0M at +25% to €129.4M at -25% and Benefits a range of (minus) €117.7M at -25% and €131.1M at +25%.

The base NPV for Solution 97.1 is weakly positive (€6.706M) and the sensitivity analysis shows that all parameters have an effect on whether a positive NPV can be achieved or not. An examination of the variance shows that the NPV would become negative (i.e., not economically viable) for Solution 97 compared with the base NPV with:

- a discount rate of greater than 8%; or,
- an overall increase of 2% or more in costs; or,
- a decrease of 2% or more in cost savings.

For Solution 97.1 V/AR:

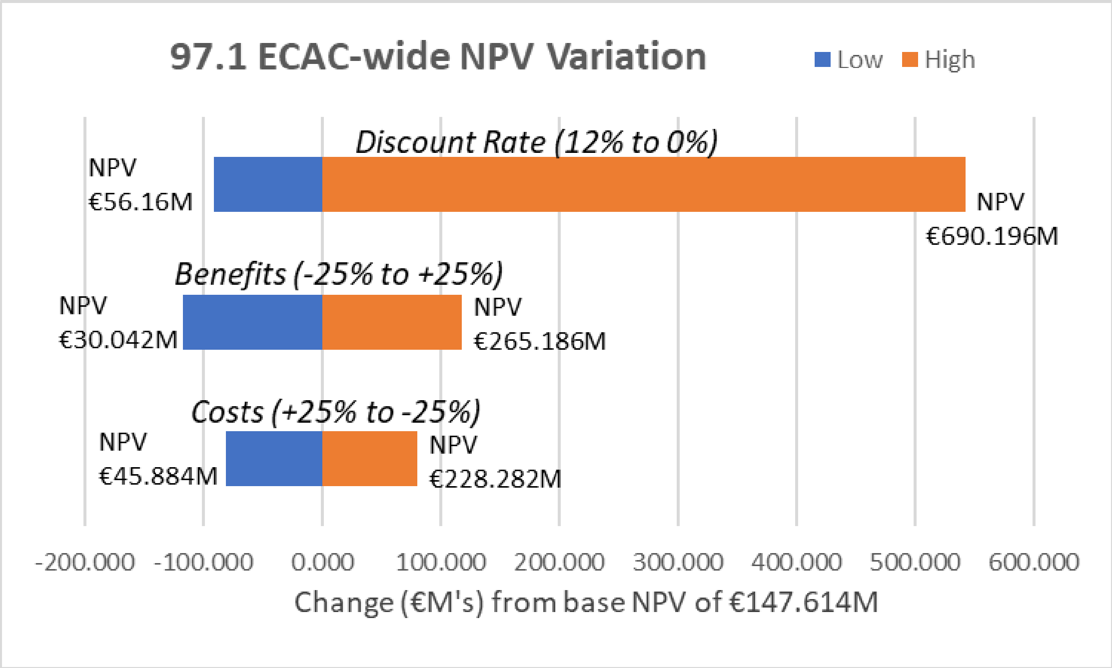

Figure 16: Sol 97.1 ECAC-wide NPV Variation

The Discount Rate applied in the calculations has the greatest effect on NPV, with a range of €56.2M at 12% to €690.2M at 0%. Benefits have a range of €30.1M at -25% to €265.2M at +25% and Costs a range of €45.9M at +25% and €228.3M at -25%.

All variations applied result in the positive NPV for Solution 97.1. Note that, unlike Solution 97, Benefits have a greater impact on the NPV than Costs.

For Solution 97.2:

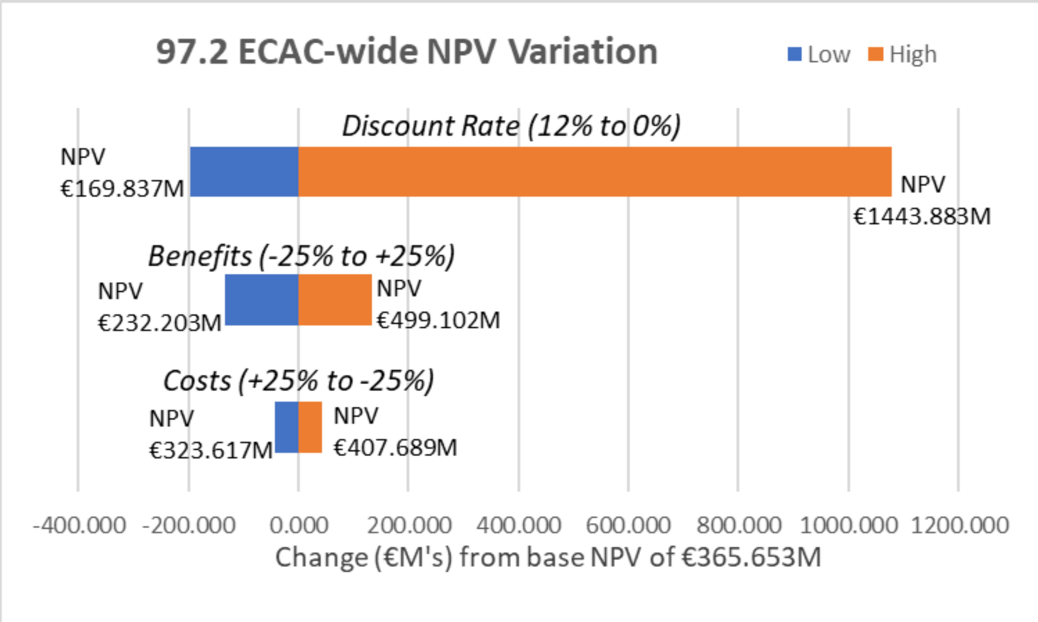

Figure 17: Sol 97.2 ECAC-wide NPV Variation

The Discount Rate applied in the calculations has the greatest effect on NPV, with a range of €169.8M at 12% to €1443.9M at 0%. Benefits have a range of €232.2M at -25% to €499.1M at +25% and Costs a range of €323.6M at +25% to €407.7M at -25%.

All variations applied result in the positive NPV for Solution 97.2. Note that, unlike Solution 97, Benefits have a greater impact on the NPV than Costs.

9 Recommendations and next steps

This CBAT has assessed the economic feasibility of Solutions PJ05 Sol 97.1 and 97.2 in terms of the costs incurred in the implementation, deployment and operational use and the economic value of benefits accrued. In performing the assessment, the following recommendations are noted:

1. Inputs from PJ.16-04 (Controller Working Position HMI) and EUROCAE have identified potential standardisation needs for both Solutions 97.1 and 97.2 that are recorded as recommendations in both the TS/IRS [17] and VALR [19] for further study in future Phases. These may have cost implications, for example, to adapt existing standards or define and ratify new ones; therefore, future phases need to assess the cost implications of any standardisation needs to support achieving TRL6.

2. The outcomes of the Validation Exercises as reported in the VALR [19] have resulted in a number of changed and new requirements and implementation recommendations for both Solutions 97.1 and 97.2 as recorded in the TS/IRS [17]. These may have cost implications, for example, to address the required provisions and improvements to make the V/AR concepts workable in all environments or the adaptation of ASR for each specific target environment; therefore, future phases need to assess the cost implications of the requirement changes and implementation recommendations to support achieving TRL6.

3. Deployment Options are identified in Section 3 for Solution 97.1 based on whether the associated Enablers are Required or Optional. The CBAT has presented Costs for these Deployment Options in Section 5. The Benefit results from the Validation Report [19] and Performance Assessment Report [20] provided values for Solution 97.1 as a whole i.e. the Deployment Option Track Labels plus Air Gestures plus Attention Guidance. It is recommended that Validation activities to achieve TRL6 consider providing the relevant performance measures (e.g., CEF2) for each of the Solution 97.1 Deployment Options to enable the economic viability of them to be assessed individually.

4. Regarding the structure of the CBAT:
   - The Solutions 97.1 and 97.2 are independent of each other, therefore the combination of the results to provide an overall CBAT for Solution 97 is considered a largely artificial construct in that it is likely that an ANSP would assess the viability of each Solution separately. It is recommended that the CBAT for TRL 6 should consider whether presentation of a combined Solution analysis is required.
   - The target environment for Solutions 97.1 and 97.2 are Airports of all categories. The Costs presented in Section 5 are based on Airports. To provide a Stakeholder CBA, the CBAT has attempted to provide an analysis at ANSP level in Section 7. An ANSP's decision to implement either Solution is likely to be taken on a case-by-case basis for each of the airports to which they provide tower services. It is recommended, therefore, that the CBAT for TRL6 considers presenting CBAT results at the Airport level for each category rather than ANSP.

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10 References Documents

10.1 Applicable Documents

[1] SESAR 2020 Project Handbook v02.02.00 for W2, 8 June 2020;

[2] Guidelines for Producing Benefit and Impact Mechanisms, Edition 03.00.01;

[3] SESAR JU, Methods to Assess Costs and Monetise Benefits for CBAs, Edition 00.02.02.

[4] SESAR 2020 Cost-Benefit Analysis Model

[5] EUROCONTROL Standard Inputs for Economic Analyses (Edition Number: 9.0, Edition date: December 2020)

[6] ATM CBA Quality checklist, Edition 02.00.01

[7] SESAR 2020 Requirements and Validation Guidelines – May 2020 – edition 00.02.01

[8] SESAR 2020 – PJ19: EATMA Guidance Material and Report (2018), Edition 01.00.02, 11 March 2019

[9] SESAR 2020 - PJ19.04 - D4.7 Performance Framework (2019) Edition 01.00.01

[10] D4_0_30-PJ19-SESAR2020_Common Assumptions_2019 (1_0)

[11] European ATM Master Plan 2020 - SESAR Joint Undertaking, 2020

[12] PJ19.04 – D4.7 - Validation targets PJ19-W2 Validation Targets – SESAR2020 Wave 2 & Wave 3, ed.00.00.03, 14 April 2021.

[13] ATM Cost-Effectiveness (ACE) 2020 Benchmarking Report with 2021-2024 Outlook, Final Report, Performance Review Unit (PRU) with the ACE Working Group, June 2022

[14] Airport Operating Environment Dataset, SESAR 2020 PJ20 WP2.2 Working Group, Version 1_0, December 2019

[15] STELLAR SJU Coordination Group – ATM Performance Assessment (APA) [www.stellar.sesarju.eu]

10.2 Reference Documents

[16] D3.1.033 - PJ05-W2 Sol 97 Technical Validation Plan (TVALP), Final Version Edition 00.01.00, 30 November 2021

[17] D3.1.022 - SESAR Solution PJ.05-W2-97.1, 97.2 - TS/IRS for TRL4 – Final Version, Edition 00.02.04, 28 September 2022

[18] D3.1.011 – Solution PJ.05-03: Cost Benefit Analysis (CBA) for V2, Edition 00.04.00, 28 November 2019

[19] D3.1.050 PJ.05-W2 SESAR Solution 97 TVALR, Edition 00.01.12, Draft, 19 September 2022

[20] SESAR Solution 97.1 and 97.2 SPR/INTEROP-OSED – Part V – Performance Assessment Report (PAR), Edition 00.00.03 Draft, 30 September 2022

11 Appendix 1

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

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

ATM Master Plan SESAR Performance Ambition KPA	ATM Master Plan SESAR Performance Ambition KPI	Performance Framework KPA	Focus Area	#KPI / (#PI) / <Design goal>	KPI definition
Operational Efficiency	PA5 - Arrival predictability: 2minute time window for 70% of flights actually arriving at gate		V/ARiance of actual and reference business trajectories	PRD1	V/ARiance 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> 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
				(SEC4)	Military mission effectiveness risk after mitigation

Table 44. Table Mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs

12 Appendix 2

An opinion survey was conducted with the ATCOs participating in the Solution 97.1 (V/AR) Validation Exercises. The aim was to capture their subjective views on the use of V/AR in the Control Tower based on their experiences in the Validation Exercises.

Of particular interest was the feedback regarding whether the V/AR headsets should be considered personal equipment as this is a key assumption regarding numbers of headsets in the determining the cost of Solution 97.1.

The results of the survey regarding use of the V/AR headsets are covered in the Validation Report [*Ref to be included*]. The responses regarding V/AR headsets as personal equipment were unianimous and can be summarised as follows:

The expectation is that controllers will find the shared use as problematic. Even before covid, for hygienic reasons, controllers used their own headphones and kept them in their personal locker.

It is true that there are shifts where a GCO and Assistant change position during the day and also during the night shift, a TWR (meaning: runway) will take over GCO duties. So when different settings or software packages are used for each position, the devices would need to be re-configured.

At large airports that problem might multiply due to the large number of different working positions (e.g. 2 TWR, 3 GCO, 4 ASS) that may need different configurations.

Controller preference is clearly to have their own device, and it should be figured out whether it is possible to have one software with different settings/pre-sets to choose from when starting the device.

The survey form used is given below:

Augmented Reality for enhancing air traffic control operations
Knowledge survey on a voluntary basis among ATCOs in ECAC

Hello dear Colleague,

We are part of the Cost Benefit Analysis Team for the SESAR project PJ05-SOL 97, which includes further research into the use of Virtual/Augmented Reality (V/AR) in the airport Control Tower. As such, we are responsible for assessing the associated Cost and Benefits of this new technology and need to determine its impact on all affected Stakeholders, in particular ANSPs and especially the work of ATCOs.

As part of this activity we are inviting you to take part in this brief survey to capture your personal and professional views about the use of V/AR in the Control Tower. Our project is developing a number of tailored V/AR Control Tower functions including track labels and safety net attention guidance, which are expected to provide the following benefits for your work:

- ✓ Increased situation awareness and increased head-up time and, as a consequence, increased Safety, since the interface provides all needed information as head-up conformal symbols super-imposed to the *out-of-the-tower view*.
- ✓ More efficient operations especially in *low visibility conditions*, as the controller is provided with a head-up view of the air traffic similar to the enhanced vision currently used in the cockpit.
- ✓ Increased *airport resiliency* to low-visibility conditions as the overlays provided by means of *augmented reality* enhance the controller's capabilities of managing air traffic in low-visibility conditions leading to overcome limitations on the airport capacity.

The survey is anonymous and will be conducted among the ATCOs of the Control Towers where the project's Validation Exercises will be performed, as well as at other Control Towers representative in importance within ECAC.

We invite you to share your opinions in the following three sections.

1. Professional information of the interviewee and Knowledge and perception on the characteristics of the Enabler and the Technology connected to it.

In this section we will collect anonymous information on the characteristics of the ATCO (e.g., age, professional qualification) in order to be able to adequately profile them, as well as your knowledge with the technology related to the SESAR Solution object.
The goal is also to see if there are variables that allow us to interpret and contextualize the answers that will be given to the subsequent sections of the survey.

What is your workplace, the Control Tower where you are qualified and where do you work? What is your professional qualification?

Do you have knowledge of the SESAR Project that deals with the Research & Development relating to the enabler and the Technology associated to *Attention Guidance* and *Augmented Reality* in Control Towers, as well as *ASR - Automatic Speech Recognition*?

What are your impressions and what is your opinion on these new technologies to support your work and the world of aviation?

Here below there are some links, with integrated videos, which can give you a series of information about the argument.

- ✓ *SESAR Joint Undertaking | SESAR project leads the way on augmenting air traffic control*
- ✓ *https://www.youtube.com/watch?v=hQ_icHVys0w*
- ✓ *https://www.remote-tower.eu/wp/videos*

2. Technical and hardware characteristics that the enabler should have in order to integrate the person with the technology.

In this section we will ask you to provide us with information regarding the characteristics that you, Air Traffic Controller user of the technology, want the enabler to have.

Are you interested in an integration with the microphone/earphone to use for the operational frequency, the possibility to integrate other software such as ASR - Automatic Speech Recognition, and above all and focal point, is whether you believe the Virtual Reality Headset should be classed as personal ATCO equipment (as judged for IPI or Training regulations in addition to hygiene considerations) or be a shared resource, e.g., between controllers associated with a Working Position?

3. Other tips for the Knowledge Investigation

What do you think of this Enabler and the Technology connected to it, aimed at favoring Human Performances as well as the Safety of Operations, as well as increasing the level of integration with other Tools that interact in case of hazard events that increment risk mitigation?

Do you have any additional tips or comments about this you want to share with us?

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