INDUSTRIAL RESEARCH

D12.2.500 - PJ14-W2-84b - TRL6 CBAT - Multi Remote Tower Surveillance module (MRT-SUR)

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PJ.14-W2-I-CNSS

PJ.14-W2-84B - TRL6 - MULTI REMOTE SURVEILLANCE MODULE

This CBA is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 874478 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document provides the **Technical Cost Benefit Analysis r**elated to SESAR Solution PJ 14-W2 84b addressing the Multi-Remote Tower Surveillance sensor.

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The objective is to set up the technological benefits related to this technological solution.

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1 Executive Summary

This document provides the Cost Benefit Analysis (CBA) related to the deployment of a SESAR Solution 84b.

The aim of this solution PJ.14-W2-84b, is to achieve the maturity level of the new enabler CTE-S10 (Multi Remote Tower Control – Surveillance) to a TRL6.

The provision of a surveillance for multi-remote tower (MRT-SUR) increases safety through the increased situational awareness of an Air Traffic Controller when controlling multiple airports simultaneously. As a technological solution PJ14-W2-84b performs no assessment of operational benefits. The MRT-SUR provides a performance tailored for the envisaged operational environment, allowing to reduce equipment cost when compared to state-of-the-art technology. Consequently, the primary benefit is cost reduction (CEF3) for the ANSP when deploying MRT-SUR.

Since the cost for MRT-SUR are expected to be 54% compared to state-of-the art technology and assuming 250 candidate airports in ECAC, as a result of this comparison it was found that a cumulative NPV of 377 M€ until 2043 can result. With the positive NPV result it is recommended to consider the MRT-SUR as surveillance sensor when deploying Multi-Remote Tower Control.

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2 Introduction

2.1 Purpose of the document

This document provides the Cost Benefit Analysis (CBA) related to SESAR Solution PJ14-W2-84b that has been validated during validation activities at a TRL6 level. Technological validation is limited to some extent since a sub-sensor was unavailable for the validation. In consequence the solution is deemed to be validated for a partial TRL6.

2.2 Scope

This document provides the Cost Benefit Analysis (CBA) related to SESAR Solution PJ14-W2-84b at (partial) TRL6 level.

It covers the benefits resulting from cost-savings (CEF3) by ECAC wide deployment at relevant airports of the specific Multi-Remote Tower Surveillance (MRT-SUR) sensor developed by the solution in comparison to state-of-the-art airport surveillance.

2.3 Intended readership

The intended audience for this document includes:

- SJU;
- SESAR 2020 PJ05-W2-35 Multiple Remote Tower and Remote Tower centre
- SESAR 2020 PJ14-W2 Surveillance solutions
- SESAR 2020 PJ19;
- Any other SJU project that may require the information included in this document for their activities.

2.4 Structure of the document

The structure of the document is composed of the following sections:

- **Section 1** provides an executive summary.
- **Section 2** introduces the purpose and scope of the document and provides a description of the intended readership and background information. It also provides a list of acronyms used in this document.
- **Section 3** describes in more detail the objectives and scope of this CBAT.
- **Section 4** describes the foreseen benefits of the solution scenario.
- **Section 5** provides a cost assessment.
- **Section 6** provides the Solution 84b ad-hoc CBAT model.
- **Section 7** provides the results of CBAT model in section 6.

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- **Section 8** provides the sensitivity analysis associated with the results of the formal CBAT model.
- **Section 9** lists recommendations and next steps.
- **Section 10** lists references and applicable documents.
- **The Appendix** provides a mapping between ATM Master Plan Performance Ambition KPAs and SESAR 2020 Performance Framework KPAs, Focus Areas and KPIs.

2.5 Background

This Solution is the direct continuation of the Solution PJ.14-04-03 task 4, the surveillance solution covering the Multi-Remote Tower Surveillance, which reached TRL4 during Wave 1. Rather than a formal and quantitative CBA, PJ.14-04-03 task 4 developed and delivered a qualitative High-Level Economic Appraisal at the end of the previous phase. The conclusions and remarks of the document are still considered applicable and are a basis of this report.

2.6 Glossary of terms

Term	Definition	Source of the definition
Active Non-Rotating Secondary Ranging	Active non-rotating secondary ranging measures the range from transmitter via target to receiver. Transmitter and receiver can be co-located or separated. The resulting line of sight will differ between both options and hence the algorithms which have to be applied need to be selected accordingly. It can be based on Mode-A/C or Mode-S signals.	Term introduced in this solution
A-SMGCS	A-SMGCS (Advanced Surface Movement Guidance & Control System) is a system providing routing, guidance and surveillance for the control of aircraft and vehicles in order to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level (AVOL) while maintaining the required level of safety	*ICAO Doc 9830*
AIR-REPORT	A report from an aircraft in flight prepared in conformity with requirements for position, and	ICAO Annex 3

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	operational and/or meteorological reporting.	
Capital Expenditure	Capital expenditures (Capex) are funds used by a company to acquire, upgrade, and maintain physical assets such as property, plants, buildings, technology, or equipment.	*Investopedia*
Cost benefit analysis	A cost-benefit analysis is a systematic process that businesses use to analyze which decisions to make and which to forgo. The cost-benefit analyst sums the potential rewards expected from a situation or action and then subtracts the total costs associated with taking that action.	*Investopedia*
MLAT	Surveillance system based on Multi-Lateration used in Advanced Surface Movement Guidance and Control Systems (A-SMGCS) with a performance specified in ED-117.	
Mini-MLAT	A mini-MLAT is a MLAT with a performance below what is specified in ED-117 (MLAT)	Term introduced in this solution
Net Present Value	Net Present Value (NPV) is the sum of all discounted cash inflows and outflows during the time horizon period.	*Investopedia*
Non-Rotating Secondary Ranging	Umbrella term for active non-rotating secondary (Mode-A/C, Mode-S) ranging and passive non-rotating secondary (Mode-A/C, Mode-S).	Term introduced in this solution
Operational expenditure	An operational expenditure (Opex) is an expense a business incurs through its normal business operations.	*Investopedia*
Partial Measurement	A partial measurement is a measurement not containing a full position solution e.g. range, range difference, azimuth and elevation angle.	Term introduced in this solution
Passive Non-Rotating Secondary Ranging	Passive non-rotating secondary ranging measures the range difference (difference between target to two different receivers) between two not co-	Term introduced in this solution

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	located receivers. It can be based on Mode-A/C or Mode-S signals.	
Reference scenario	To measure the performance impact of a SESAR Solution, at least two different situations must be assessed and compared: a Reference Scenario and a Solution Scenario. One situation should be a scenario that does not have the concept element (the reference scenario) and, then, a second situation that equals the first except that it includes the new concept element (the Solution scenario). The descriptions of the reference scenario(s) and of the solution scenario(s) can include, depending on the scope of the validation exercise, airport information, airspace information, traffic information, etc. The reference scenario is matched in time with the solution scenario but DOES NOT include the SESAR solution(s) that is the subject of the validation. The only difference between the solution and the reference scenario is that the former includes the SESAR solution(s) that is the subject of the validation.	*SESAR 2020 Performance Framework*
Sensitivity analysis	Sensitivity analysis determines how different values of an independent variable affect a particular dependent variable under a given set of assumptions. In other words, sensitivity analyses study how various sources of uncertainty in a mathematical model contribute to the model's overall uncertainty. This technique is used within specific boundaries that depend on one or more input variables.	*Investopedia*
Siting	To situate or locate on a site	*thefreedictionary*
Solution scenario	See Reference scenario	*SESAR 2020 Performance Framework*

Table 2-1: Glossary of terms

2.7 List of Acronyms

Acronym	Definition
ANSP	Air Navigation Service Provider
ATCO	Air traffic controller
ATM	Air Traffic Management
Cat	ASTERIX Category
Cat015	ASTERIX Category for independent non-cooperative surveillance target reports.
Cat020	ASTERIX Category for MLAT/WAM
Cat021	ASTERIX Category for ADS-B
Cat025	Generic ASTERIX Service Category
Cat062	ASTERIX Category for track output reports.
CBA	Cost-Benefit Analysis
CBAT	Cost-Benefit assessment Technological
CEF3	Cost Efficiency 3
CNS	Communication Navigation Surveillance
FIS	Flight information Service
GS	Ground Station
IRS	Interface Requirements Specification
MLAT	Multi Lateration
MRT	Multi Remote Tower
MRTC	Multi-Remote tower control
MRT-SUR	Multi Remote Tower Surveillance

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NPV	Net Present Value
RTC	Remote Tower Control
SESAR	Single European Sky ATM Research Programme
SDPS	Sensor Data Processing System
SJU	SESAR Joint Undertaking (Agency of the European Commission)
TS	Technical Specification
TVALP	Technical Validation Plan
VALP	Validation Plan
WAM	Wide Area Multilateration

Table 2-2: List of acronyms

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3 Objectives and scope of the CBA

3.1 Problem addressed by the solution

Depending on the operational concept as defined by PJ.05-W2-35 for multiple remote tower control, a surveillance sensor is an optional part of the concept in order to enhance the controllers' situational awareness. Multiple remote tower control is envisaged for small and other aerodrome environments with low traffic density.

The solution PJ14-W2-84b develops a new cost-efficient surveillance sensor providing a basic surveillance service for small and regional airports to increase the situational awareness of a multi remote tower controller. SESAR research covers combining enhanced video camera plot extraction with Automatic Dependent Surveillance Broadcast (ADS-B) and multilateration (MLAT) by the multi-sensor data fusion (MSDF).

The present CBA assesses the costs and benefits by the solution through comparison against a reference scenario. The reference is formed by an A-SMGCS as defined by current standards, whereas the solution scenario covers the tailored performance and cost efficient Multi-Remote Tower surveillance sensor developed by PJ.14 -W2-84b.

3.2 SESAR Solution description

Composite surveillance solutions have the potential to lower implementation costs and deliver appropriate levels of performance to meet the needs of regional airports or remote tower environments. This solution aims to provide a surveillance service to increase situational awareness for the multi remote tower controller in a cost-effective way. It provides a basic surveillance service for a small to medium sized airport below the performance specified in ED-87D within a range of around 20 nautical miles by augmenting the performance of existing surveillance equipment. SESAR research aims to enhance the video camera plot extraction used as a non-cooperative source for the tailored multi-remote tower surveillance layer, consisting of video and infrared cameras, multilateration (MLAT) and multi-sensor data fusion (MSDF). The multi-remote surveillance module enables the event generation for multi-remote tower center (MRTC) operation. A key element is the monitoring of stop bars between the taxiway system and the runway. The solution also enables enhanced control of a pan tilt zoom (PTZ) camera.

The multi-remote tower surveillance solution defines a set of requirements for the technical solution enabling surveillance for multiple remote tower control. These requirements address the electro-optical sensor, the non-rotating Mode-S ranging component as well as the data fusion component. All three components are closely connected with one another to establish a logical surveillance layer.

The goal of solution 84b is to provide an adequate and economically reasonable surveillance solution for Multi Remote Tower Control – Surveillance (CTE-S10).

The core objective of PJ.14-W2-84b is to establish a surveillance performance class below the performance specified in the applicable ground surveillance standard. The main driver is to offer a cost efficient tailored-performance solution for providing an appropriate air and ground situation for small airports as beneficial for Multi Remote Tower Control.

The required performance for the output of a tracker of an A-SMGCS System is specified in the EUROCAE standard ED-87C (Minimum Aviation System Performance Specification for Advanced

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Surface Movement Guidance and Control Systems (A-SMGCS)). To achieve this performance, sensors according to ED-116 (SMR) and ED-117 (MLAT) are necessary. From an economical point of view, these sensors are not suitable and from operational perspective not necessarily needed for the designated target airports for multi remote tower operations.

The envisaged enabling solution is composed of data fusion of ADS-B and a mini-MLAT / non-rotating ranging with an electro-optical sensor in addition to the existing / already available surveillance infrastructure. The non-cooperative surveillance coverage is addressed by the electro-optical sensor using Cat015 as data container for azimuth and elevation angle data. For non-ADS-B equipped targets, the secondary coverage relies on a mini-MLAT system with a performance potentially below the specified values of ED-117 (Minimum Operational Performance Specification for Mode S Multilateration Systems for Use in Advanced Surface Movement Guidance and Control Systems (A-SMGCS)). In addition to WGS-84 position solutions, this mini-MLAT is capable of providing range and range difference measurements directly to the ATC tracking system. The ADS-B performance is fully compliant with ED-129B (Technical specification for a 1090 MHz extended squitter ADS-B ground system).

The ATC tracking system is enhanced to be capable to process these partial (incomplete) measurements of ranges, range differences or angles directly.

PJ.14-W2-84b is part of a panel of surveillance solutions defined in the scope of PJ.14 that has to be performed to reach maturity TRL6 of this solution.

SESAR Solution ID	OI Steps ref. (coming from the Integrated Roadmap)	OI Steps definition (coming from the Integrated Roadmap)	OI step coverage	Source reference
PJ.14-W2-84b	POI-0058-SUR	Surveillance sensors for Multiple Remote Tower Controlled operations: This POI addresses the need for a low cost/tailored performance surveillance sensor for small and regional airports with Multiple Remote Tower Controlled	Fully	EATMA DS23 Draft

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		operations to improve situational awareness of ATCOs		

Table 3-1: SESAR Solution PJ14-W2-84b Scope and related OI steps

OI Steps ref.	Enabler[1] ref.	Enabler definition	Enabler coverage	Applicable stakeholder	Source reference
POI-0058-SUR	CTE-S10	The Multi Remote Tower Module is complemented with a cost efficient surveillance solution that integrates new combinations of Non Cooperative Surveillance Sensors and Cooperative Surveillance sensors. Data fusion of Electro-optical sensor, Mini-MLAT, non-rotating Mode S radar and ADS-B will be investigated.	Fully	Air Navigation Service Provider	EATMA DS23 Draft
	SVC-062	MultiRemoteTowerSensor: The MultiRemoteTowerSensor Service is used to provide multi-sensor track data to Multi Remote Tower Module.	Fully	Air Navigation Service Provider	EATMA DS23 Draft

Table 3-2: OI steps and related

3.3 Objectives of the CBA

This document provides the Cost Benefit Analysis (CBA) related to the deployment of the SESAR technological solution PJ.14-W2-84b that has been matured through validation activities at (partial)

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

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TRL6 level. The main purpose of this CBA is to facilitate and support better informed decision-making for key investment decisions. This is achieved by:

- identifying all costs and benefits per stakeholders,
- quantifying in economic terms the costs and benefits,
- calculating the economic value of the project,
- making a cash flow projection,
- Identifying the factors/assumptions having the most influence on the results

3.4 Stakeholders[2] identification

This section identifies the stakeholders' categories that are affected by implementing, operating and benefitting from the Solution PJ.14-W2-84b

Stakeholder	The type of stakeholder and/or applicable sub-OE	Type of Impact	Involvement in the analysis	Quantitative results available in the current CBA version
ANSP	Small and medium airport environment	Invest: Purchase, install and bring to operation MRT-SUR Enjoy benefit: lower total cost of ownership compared to reference (full A-SMGCS)	Yes	yes on both costs and benefits
Airport Operators			No	See remark below
Network Manager			No	
Scheduled Airlines (Mainline and Regional)			No	
Business Aviation			No	

[2] Note that the terminology used to describe AU stakeholders in the CBA differs from that associated with Enablers in the dataset. This is due to costing being provided for different types of aircraft regardless of the operations they perform.

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Rotorcraft			No	
General Aviation IFR			No	
General Aviation VFR			No	
Military – Airborne			No	
Military – Ground			Potentially yes Not assessed	There is no impact on these stakeholders. They have no results in the CBA.
Other impacted stakeholders (ground handling, weather forecast service provider, NSA….)			No	

Table 3-3: SESAR Solution PJ14-W2-84b CBA Stakeholders and impacts

All costs are attributed to ANSPs and no costs for Airport Operators. Considering the solution targets remote towers, one could consider to attribute costs to Airport Operators instead of ANSPs. However, surveillance infrastructure for MRTC is considered to fall under ANSPs responsibility since ANSPs are the ones introducing MRTC operations. If it would be the airports, multiple airports (maybe operated by the same airport operator) would have to form an MRTC cluster. But since it can be assumed that approach/departure + RWY and TWY is in most cases controlled by an ANSP (or at least a FIS) it is seen to be viable to assume ANSPs are the main and sole stakeholders.

3.5 CBA Scenarios and Assumptions

The CBA aims to provide results at ECAC level about the economic and financial viability of deploying the SESAR Solution PJ.14-W2-84b at European scale.

Scope: The assessment will consider airports applying Multi-Remote Tower Control operations. The assessment will cover the cost and benefits provided by Multi-Remote Tower -Surveillance sensor in comparison to the use of existing sensor technology (A-SMGCS).

The MRTC concept is developed by PJ.05-W2-35. The DFS MRTC concept in PJ.05-W2-35 considers the use of a dedicated surveillance sensor to ensure the ATCOs situational awareness.

This leads to the Primary underlying assumption: MRT requires a surveillance to ensure the situational awareness of an ATCO controlling multiple airports simultaneously.

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The basic approach followed in this CBA is consequently: Pj14.W2-84b as a technological solution compares cost between a 'classical' airport surveillance (A-SMGCS as per ED-87C), the only option currently available, against the cost for a specific new surveillance sensor addressing the needs of MRTC operations through a tailored performance, low cost.

Resulting Benefit is cost saving resulting from the cost difference between full A-SMGCS against MRT-SUR.

The Main KPI addressed by solution is CEF3.

It should be noted that as a technical solution PJ.14-W2-84b will not assess operational benefits resulting from MRTC operations.

3.5.1 CBA Reference Scenario

The CBA reference scenario is represented by a 'classical' airport surveillance (A-SMGCS as per ED-87C), scaled to size of airport (small) with following details:

- Surveillance fully compliant with ED87C
- Airport MLAT compliant with ED-117
    - ADS-B included
    - Apron coverage
    - Fully redundant
    - MLAT typ. 10 … 15 Ground Stations (GS)
        - Assumed min. nr. Of GS: 10 GS
        - Cost per GS identical to ADS-B GS as per PJ.14-W2-84d (ADS-B GS is representative of a GS of a MLAT system)
- Airport SMR compliant with ED-116
- Sensor data processing system, SDPS

The scaling of the A-SMGCS to smaller airports is achieved through the number of MLAT Ground stations. On large an complex airports the amount of ground stations is significantly higher than the 10 which are considered herein to cover a small airport.

Per MRTC airport one system is required.

3.5.2 CBA Solution Scenario

The CBA solution scenario considers the MRT-SUR sensor developed by solution PJ14-W2-84b.

In context of the MRT-SUR the following is to be deployed:

- MRTC Cooperative Sub-Sensor:
    - Mini-MLAT / Validated ADS-B consisting of 4 to 6 GS, resulting in

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- Reduced Mini-MLAT redundancy
- ADS-B fully redundant
- RF Data Links to reduce infrastructure and operating cost (no lease line)

- MRTC Non-cooperative Sub-sensor:
  - Re-used cameras: the cameras are seen existing due to the general need for a visual reference in an RTC context. Consequently, RTC camera cost are not assessed.
  - MRT-SUR specific extensions are represented by an Object Detection Server,
  - The Object Detection SW (CAT015 Adapter)
  - The cost range varies whether Artificial Intelligence (AI) is included or not
- MRTC SDPS
  - The Sensor data processing system is comparable to existing solutions
  - On one hand fewer data are expected to be handled than in the reference scenario,
  - On the other hand, complexity is added due to new data handling like processing of partial positions and camera detected objects.
  - Same cost as for 'classical' SDPS
- Since the MRT-Sur is a surveillance sensor no human factors elements are included.
- procedures, standards or regulations need to be deployed in a particular operational environment with reference to the Solution's Enablers: New class of surveillance, extension of ED-87, ED-117 and ED-116 for new class of surveillance (A-SMGCS "light") envisaged and expected. These are considered as pre-requisites with respect to this CBAT.

Per MRTC airport one system is required.

Interdependencies with other solutions and agreement is reached on how to deal with them in the CBA:

PJ05 / Solution 35 covers the operational aspects of MRTC. A link is especially established to DFS in solution 35 due to the considered ground surveillance to ensure the ATCO situational awareness.

With the link to the operational project, a separation in the cost benefit assessments is performed, where PJ14 limits its assessment to the technological CBA for the surveillance

The Surveillance is seen as mandatory for MRTC (DFS solution).

Geographical scope: The solution is assumed to be deployed ECAC wide

MRTC is applicable to single RWY and simple TWY airport with max. ~60 k movements / year. A check with the OE airport database [11] for the number of airports in ECAC which are candidates for MRTC was performed. From OE Airport DB [11] the number of airports having a layout and traffic characteristics as stated above is approx. 1000. Further assumptions apply to determine the number of candidate airports for MRTC, these are given in section 3.5.3.

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Traffic evolution: The traffic evolution usually takes values from the latest STATFOR Long-term Forecast, which is used as input to define the Common Assumptions in [8]. However, with respect to MRT-SUR a max. number of 60000 movements per airport is applicable.

The time-horizon of the CBA including development, deployment and operational timeframes of the solutions is based on information as covered in EATMA and complemented with progress made by the solution in wave 2.

According to EATMA, DS23 draft the following dates apply:

V5 Start

31-12-2024

- Air Navigation Service Provider: 31-12-2024
  - Civil
  - Civil CNS Service Provider: 31-12-2024
  - Military
  - Military CNS Service Provider: 31-12-2024

IOC

31-12-2026

- Air Navigation Service Provider: 31-12-2026
  - Civil
  - Civil CNS Service Provider: 31-12-2026
  - Military
  - Military CNS Service Provider: 31-12-2026

The graphical representation of the timeline is provided in figure 3-1

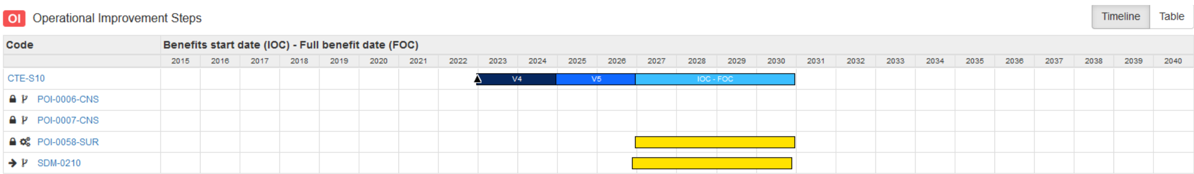

Figure 3-1: Timeline defined in EATMA

Considering the technological progress and progress made by standardisation to establish extended standards covering the MRT-SUR (WG-41 calls it “A-SMGCS light”) the timeline as shown in figure 3-2 will be taken into account for this CBA.

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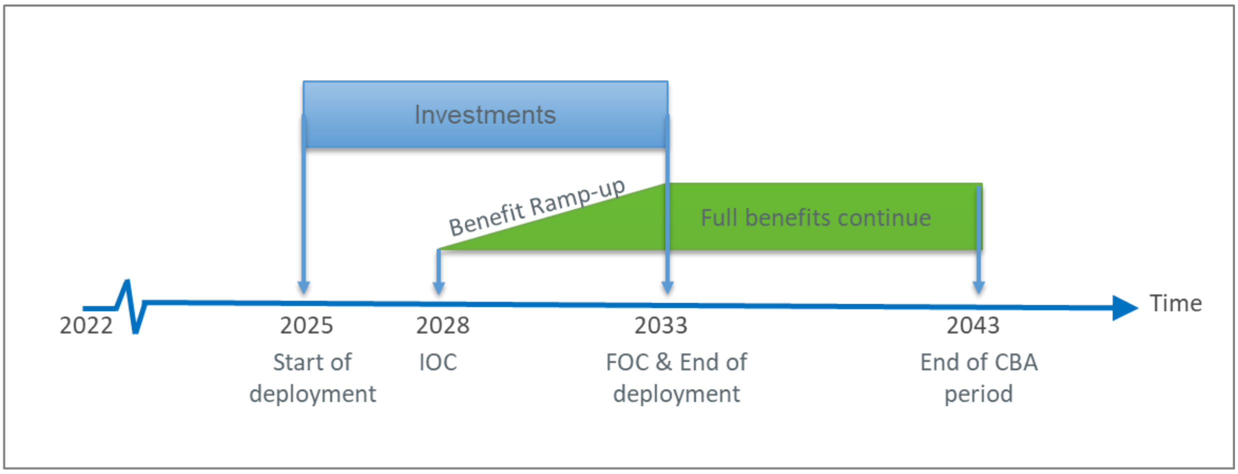

IOC – Initial Operational Capability
FOC – Full Operational Capability

Figure 3-2: Timeline considered for this CBA

Pre-requisite / Basic assumption:

- MRTC requires surveillance
  - MRTC with SUR provides enhanced situational awareness.
  - MRT-SUR provides tailored surveillance performance for MRTC application in referenced operational environment
  - Performance of MRT-SUR as defined by TS/IRS is sufficient to provide the intended surveillance service

Approx. 1000 airports (Medium/Small/Other) exist in ECAC which have the potential to be operated from remote.

These airports currently are operated with a local tower and fully rely on operation using visual cues from direct outside view.

These airports typically have no ground/airport surveillance sensors installed.

In context of deployment of MRTC operations to these airports, a ground surveillance (MRT-SUR) will be deployed.

Among the identified airports having a suitable airport layout and traffic characteristics, 50% are assumed to be candidate airports for implementation of RTC: 500.

- Rationale: Not every potential airport will vote for a RTC operation.

From these again 50% considered to be operated in MRTC cluster: 250

- Rationale: From those airports to be controlled from remote, not all airports will apply a multi-remote operation.

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Potentially the ratio RTC:MRTC would deviate from 50% : 50% more towards 20% : 80% since MRTC is expectedly more effective for ANSPs. Therefore the assumed 50% : 50% ratio is conservative and also the total number of airports is conservative

Assuming a linear growth rate the assumed yearly equipage increase is 10%/year, resulting in 25 airports / year.

An HW exchange occurs typically approximately every 10 years. This will not be further assessed, since it can be assumed that after this time a new development would have to be covered in order to handle obsolescence, add new / improved capabilities, apply modified / changed requirements etc.

3.5.3 Assumptions

Besides the key assumptions given already as part of the solution scenario, the following is assumed:

Following ref. [9] regarding the discount rate a value of 8% is considered. The discount rate will be subject to variation assessment.

The same discount rate is applicable to reference and solution scenario.

Since the solution scenario has less HW, savings will increase over time compared to reference scenario.

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4 Benefits

MRT-SUR increases safety through increased situational awareness of an ATCO controlling multiple airports simultaneously.

The primary assumption followed, foresees the mandatory use of a surveillance when conducting MRTC operations (as defined in the DFS concept).

Potential surveillance solutions are represented by an A-SMGCs in line with existing standard ED-87C or the specific solution dedicated to support MRTC operations, the MRT-SUR developed by PJ14-W2-84b, which provides a tailored performance for this operation is less costly than a full A-SMGCs.

The resulting benefit CEF3 in consequence results from cost savings when applying the MRT-SUR instead of a full A-SMGCs as surveillance sensor to support MRTC operations.

The Performance Framework **Error! Reference source not found.** defines CEF3 as "Technology cost per flight". This can be linked to investment costs (a stakeholder needs to buy a new component to deploy the solution) and/or to operating costs (the running costs of the new component). A solution needs to identify if both components of the costs are applicable.

In case of the MRT-SUR the main benefit results from lower investment cost, but since less equipment is used, the operating costs are also lower than with a traditional A-SMGCs.

MRTC is a new operation not yet deployed. In most cases the envisaged small and medium airports currently have no airport/ground surveillance means deployed. Tower operation is performed locally mainly based on visual cues. Since currently no surveillance is available, the deployment will occur in a forward-fit manner. No reduction / exchange of surveillance infrastructure is expected and in consequence no removal cost will apply.

Therefore, the resulting cost savings from using MRT-SUR instead of A-SMGCs will be fully converted into benefit.

The model within this CBAT compares the cost between the reference and the solution scenario as follows:

CAPEX = Investment future stations

OPEX = + Maintenance systems

Total Cost = CAPEX + OPEX

Avoided Total Cost undiscounted = Total Cost Ref. – Total Cost sol.

Avoided total cost discounted = Discount rate x Avoided Total Cost undiscounted

Cumulative Net Benefit undiscounted = Cumulative Sum(Avoided Total Cost undiscounted) over the years

Cumulative Net Benefit discounted = Cumulative Sum(Avoided Total Cost discounted) over the years

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Table 4-1 provides the deployment scenario, i.e. number of installations considered in this CBAT.

The only involved stakeholder, investing, deploying, operating and benefitting MRT-SUR, are ANSPs who introduce MRTC operations. As outlined before airports are considered not to have costs in this CBAT.

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Table 4-1: Deployment Scenario

Data Base

		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
MRT Growth Factor (linear)		0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
		Number of existing stations per year																			
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Reference Scenario	**A-SMGCS**	0	25	50	75	100	125	150	175	200	225	250	250	250	250	250	250	250	250	250	250
		Number of stations to deploy each year																			
			25	25	25	25	25	25	25	25	25	25	0	0	0	0	0	0	0	0	0
		Number of existing stations																			
		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Solution Scenario	**MRT-SUR**	0	25	50	75	100	125	150	175	200	225	250	250	250	250	250	250	250	250	250	250
		Number of stations to deploy each year																			
			25	25	25	25	25	25	25	25	25	25	0	0	0	0	0	0	0	0	0

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Performance Framework KPA[3]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year N	Year N+x	Year N+y
Cost Efficiency	ANS Cost efficiency	**CEF2** Flights per ATCO-Hour on duty	Nb	ATCO employment Cost change	€/year	N/A	*N/A*	*N/A*
				Support Staff Employment Cost Change	€/year	N/A	N/A	N/A
				Non-staff Operating Costs Change	€/year	N/A	N/A	N/A
		CEF3 Technology cost per flight	EUR / flight	G2G ANS cost changes related to technology and equipment	€/year	See Charts NPV in Section 7.	See Charts NPV in Section 7	See Charts NPV in Section 7
	Airspace User Cost efficiency	**AUC3** Direct operating costs for an airspace user	EUR / flight	Impact on direct costs related to the aeroplane and passengers. Examples: fuel, staff expenses, passenger service costs, maintenance and repairs, navigation charges, strategic delay, landing fees, catering	€/year	N/A	N/A	N/A

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

Performance Framework KPA[3]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year N	Year N+x	Year N+y
		AUC4 Indirect operating costs for an airspace user	EUR / flight	Impact on operating costs that don't relate to a specific flight. Examples: parking charges, crew and cabin salary, handling prices at Base Stations	€/year	N/A	N/A	N/A
		AUC5 Overhead costs for an airspace user	EUR / flight	Impact on overhead costs. Examples: dispatchers, training, IT infrastructure, sales.	€/year	N/A	N/A	N/A
Capacity	Airspace capacity	**CAP1** TMA throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
		CAP2 En-route throughput, in challenging airspace, per unit time	% and # movements	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
			% and # movements	Strategic delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
	Airport capacity	**CAP3** Peak Runway Throughput (Mixed mode)	% and # movements	Value of additional flights	€/year	N/A	N/A	N/A
	Resilience	**RES4a** Minutes of delays	Minutes	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A

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Performance Framework KPA[3]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year N	Year N+x	Year N+y
		RES4b Cancellations	% and # movements	Cost of cancellations	€/year	N/A	N/A	N/A
		Diversions	% and # movements	Cost of diversions	€/year	N/A	N/A	N/A
Predictability and punctuality	Predictability	**PRD1** Variance of Difference in actual & Flight Plan or RBT durations	Minutes^2	Strategic delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
	Punctuality	**PUN1** % Departures < +/- 3 mins vs. schedule due to ATM causes	% (and # movements)	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
Flexibility	ATM System & Airport ability to respond to changes in planned flights and mission	**FLX1** Average delay for scheduled civil/military flights with change request and non-scheduled / late flight plan request	Minutes	Tactical delay cost (avoided-; additional +)	€/year	N/A	N/A	N/A
						N/A	N/A	N/A
Environment	Time Efficiency	**FEFF3** Reduction in average flight duration	% and minutes	Strategic delay: airborne: direct cost to an airline excl. Fuel (avoided-; additional +)	€/year	N/A	N/A	N/A
	Fuel Efficiency	**FEFF1**	Kg fuel per movement	Fuel Costs	€/year	N/A	N/A	N/A

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Performance Framework KPA[3]	Focus Area	KPI/PI from the Performance Framework	Unit	Metric for the CBA	Unit	Year N	Year N+x	Year N+y
		Average fuel burn per flight						
	Fuel Efficiency	**FEFF2** CO2 Emissions	Kg CO2 per movement	CO2 Costs	€/year	N/A	N/A	N/A
Civil-Military Cooperation & Coordination	Civil-Military Cooperation & Coordination	**CMC2.1a** Fuel saving (for GAT operations)	Kg fuel per movement	Fuel Costs	€/year	N/A	N/A	N/A
		CMC2.1b Distance saving (for GAT operations)	NM per movement	Time Costs	€/year	N/A	N/A	N/A

Table 4-2: Results of the benefits monetisation per KPA

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5 Cost assessment

5.1 ANSPs costs

5.1.1 ANSPs cost approach

Cost in CBA is considered as full system cost consisting of all involved sub-sensors

The considered cost categories are:

- HW
- Siting / configuration
- Training
- Operating cost
    - Direct
        - Maintenance
    - Non-direct
        - Power
        - Lease-line / Network
        - Licensing

Following cost composition is considered:

- Total Non-Recurring Cost (NRC): HW + installation
- Operating cost: considered as percentage of Non-Recurring Cost (NRC): covering indirect and direct operating cost and called 'Maintenance cost' in CBA
- For MRT-SUR the resulting total operating cost percentage of NRC is presumably lower than for A-SMGCS due to simplified data connection, lower site consumption, lower power consumption etc.
- The same percentage of NRC for the total operating cost is assumed for both, reference and solution scenario, to be conservative.
- *Environmental footprint: Qualitatively it can be stated that:*
    - *MRT-SUR requires less GS, no additional SMR site*
    - *Resulting in less power consumption which is furthermore decreased since less heat is produced and less air conditioning is required,*
    - *Lower site/soil/land usage*
    - *In consequence, the MRT-SUR is advantageous compared to full A-SMGCS regarding environmental impact and additional benefits will result*
    - *No monetary assessment for the environmental impact will be conducted*

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The cost figures were established based on expert judgement with representatives from involved stakeholders (manufacturers and ANSP).

5.1.2 ANSPs cost assumptions

Costs for investment were collected based on knowledge and experience of contributing manufacturers (Frequentis, Thales) and ANSP (DFS).

5.1.3 Number of investment instances (units)

Airport				Terminal Airspace				En-route			
HC	HS	LC	LS	VH	H	M	L	VH	H	M	L
0		250									

Table 5-1: Number of investment instances - ANSPs

5.1.4 Cost per unit

For detailed cost composition see CBAT-model provided in sect. 6, ANSP Source tab and ANSP Scenario tab.

Cost per unit for reference scenario (A-SMGCS)

Cost category	Airport				Terminal Airspace				En-route			
	HC	HS	LC	LS	VH	H	M	L	VH	H	M	L
Pre-Implementation Costs Implementation costs			3 M€									
Operating costs			0.21 M€									

Table 5-2: Cost per Unit A-SMGCs – ANSP

Cost per unit for solution scenario (MRT-SUR)

Cost category	Airport				Terminal Airspace				En-route			
	HC	HS	LC	LS	VH	H	M	L	VH	H	M	L
Pre-Implementation Costs Implementation costs			1.61 M€									
Operating costs			0.11 M€									

Table 5-3: Cost per Unit MRT-SUR – ANSP

5.2 Airport operators costs

There are no associated costs of the solution

5.2.1 Airport operators cost approach

There are no associated costs of the solution

5.2.2 Airport operators cost assumptions

There are no associated costs of the solution

5.2.3 Number of investment instances (units)

There are no associated costs of the solution

5.2.4 Cost per unit

There are no associated costs of the solution

5.3 Network Manager costs

There are no associated costs of the solution

5.3.1 Network Manager cost approach

There are no associated costs of the solution

5.3.2 Network Manager cost assumptions

There are no associated costs of the solution

5.3.3 Network Manager cost figures

There are no associated costs of the solution

5.4 Airspace User costs

There are no associated costs of the solution

5.4.1 Airspace User cost approach

There are no associated costs of the solution

5.4.2 Airspace User cost assumptions

There are no associated costs of the solution

5.4.3 Number of investment instances (units)

There are no associated costs of the solution

5.4.4 Cost per unit

There are no associated costs of the solution

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5.5 Military costs

There are no associated costs of the solution

5.5.1 Military cost approach

There are no associated costs of the solution

5.5.2 Military cost assumptions

There are no associated costs of the solution

5.5.3 Number of investment instances (units)

There are no associated costs of the solution

5.5.4 Cost per unit

There are no associated costs of the solution

5.6 Other relevant stakeholders

There are no associated costs of the solution

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6 CBA Model

For the PJ14-W2-84b Solution, an ad-hoc CBAT model has been developed to integrate the specific requirements of the project. This model made by the members of the solution includes the established assumptions, as well as the computations, data and sources that have been used in the assessment. The model followed the methodology for ad-hoc CBAT model taken by solution PJ14-W2-84d [12].

D12.2.500-PJ14-W2-84b -TRL6_CBAT-Mu

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7 CBA Results

Table 7-1: CBA Results

Value	Unit	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Discount Factor	-	1,0	0,9	0,9	0,8	0,7	0,7	0,6	0,6	0,5	0,5	0,5	0,4	0,4	0,4	0,3	0,3	0,3	0,3	0,3
CAPEX PV	MEUR	0,0	34,8	34,8	34,8	34,8	34,8	34,8	34,8	34,8	34,8	34,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
CAPEX NPV	MEUR	0,0	32,2	29,8	27,6	25,5	23,7	21,9	20,3	18,8	17,4	16,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Avoided Total Cost undiscounted	MEUR	0,0	37,2	39,6	42,0	44,5	46,9	49,3	51,8	54,2	56,6	59,1	24,3	24,3	24,3	24,3	24,3	24,3	24,3	24,3
Avoided Total Cost discounted	MEUR	0,0	34,4	34,0	33,4	32,7	31,9	31,1	30,2	29,3	28,3	27,4	10,4	9,7	8,9	8,3	7,7	7,1	6,6	6,1
Cumulative PV	MEUR	0,0	37,2	76,8	118,8	163,3	210,2	259,6	311,4	365,6	422,2	481,3	505,6	529,9	554,3	578,6	602,9	627,2	651,6	675,9
Cumulative NPV	MEUR	0,0	34,4	68,4	101,8	134,5	166,4	197,5	227,7	257,0	285,3	312,7	323,1	332,8	341,7	350,0	357,7	364,8	371,3	377,4

Table 7-1 provides the results of the CBAT. The rows provide the values as explained in the Benefit determination methodology provided in Chapter 4. Until 2034 capital expenditures are present due to the investment into new stations to equip 25 airports per year. From 2035 onwards no new equipment will be installed. But the maintenance of the deployed base still results in cost savings from lower operating cost for the solution scenario. The CAPEX in table 7-1 represents the delta between the CAPEX for reference and solution scenario. The resulting avoided cost represent the resulting benefit due to cost savings when applying the solution instead of the reference scenario.

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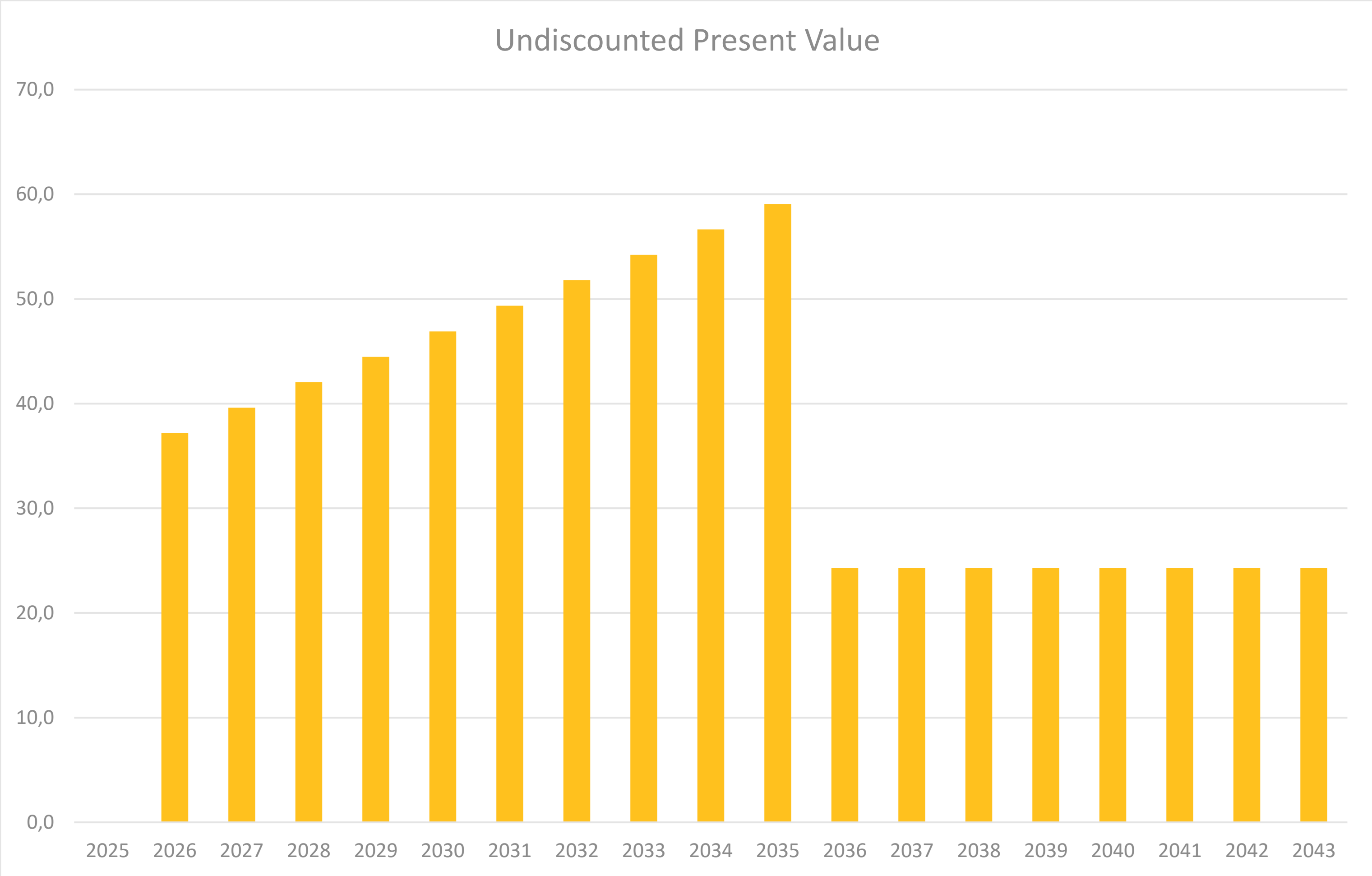

Figure 7-1: Undiscounted Present Value y-axis, M€) over years (x-axis)

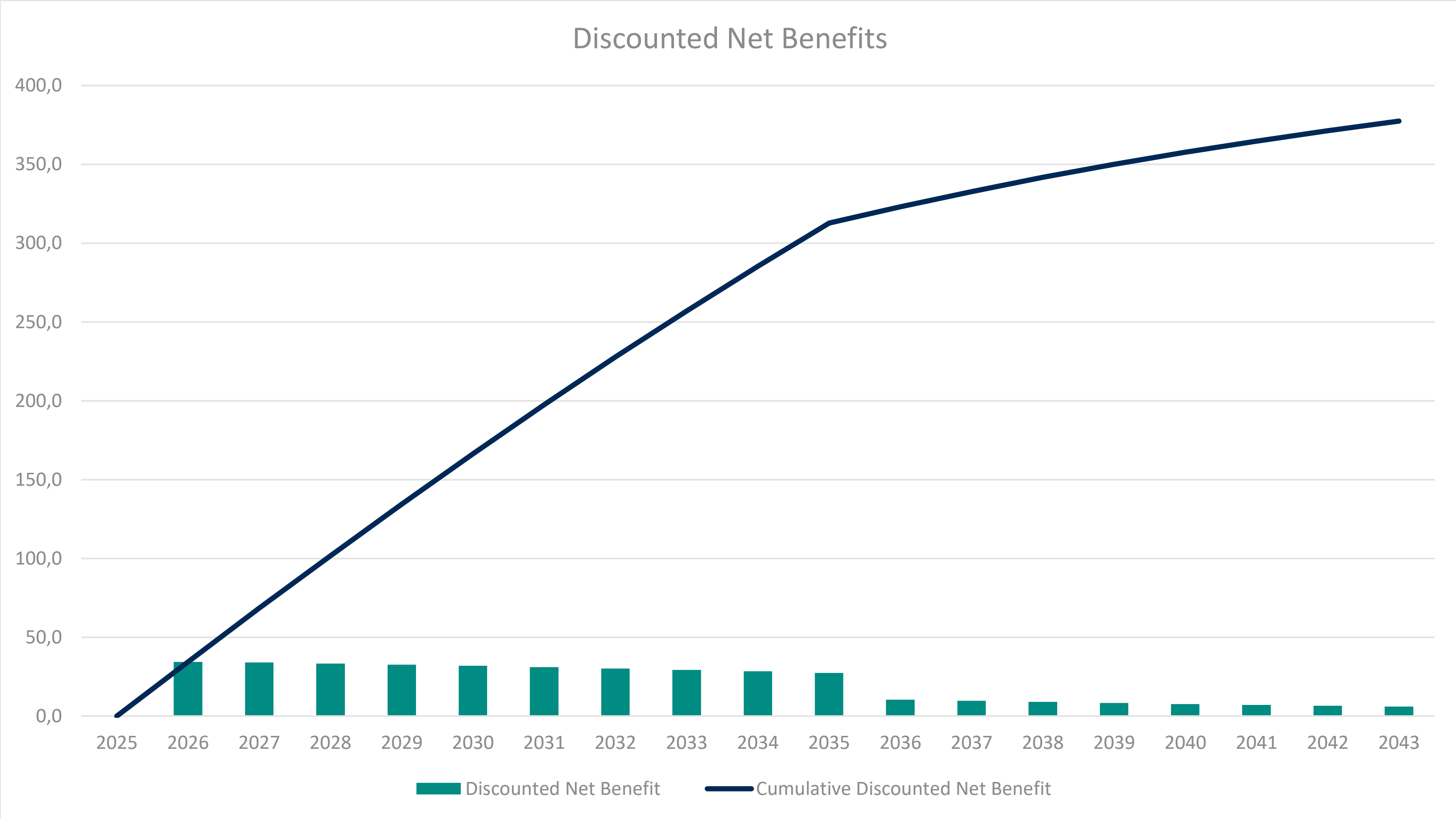

Figure 7-2 Net Benefit Value (y-axis, M€) over years (x-axis)

8 Sensitivity and risk analysis

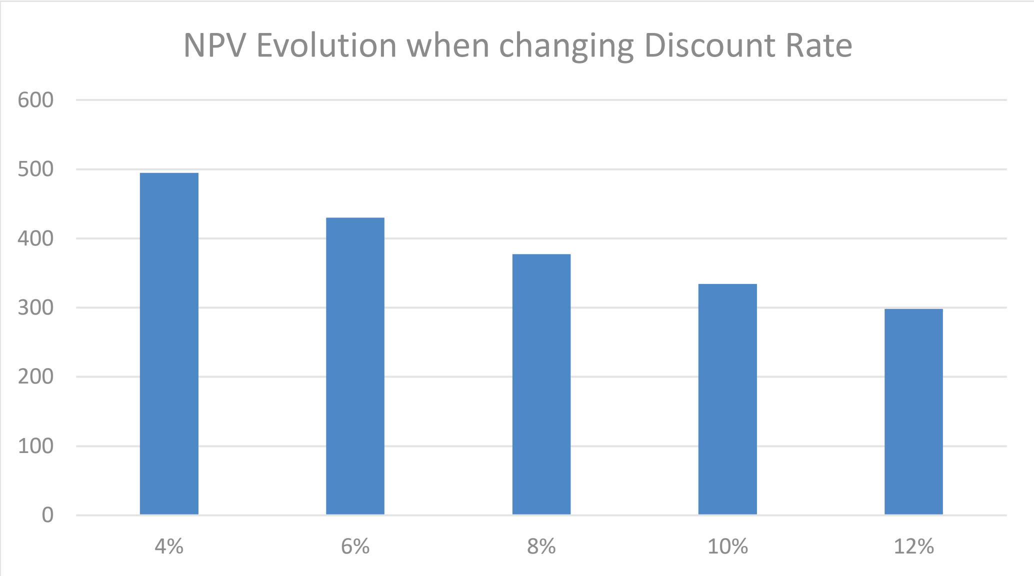

Figure 8-1: NPV variation (M€) for different discount rates in percentWith increasing discount rate the NPV will decrease.

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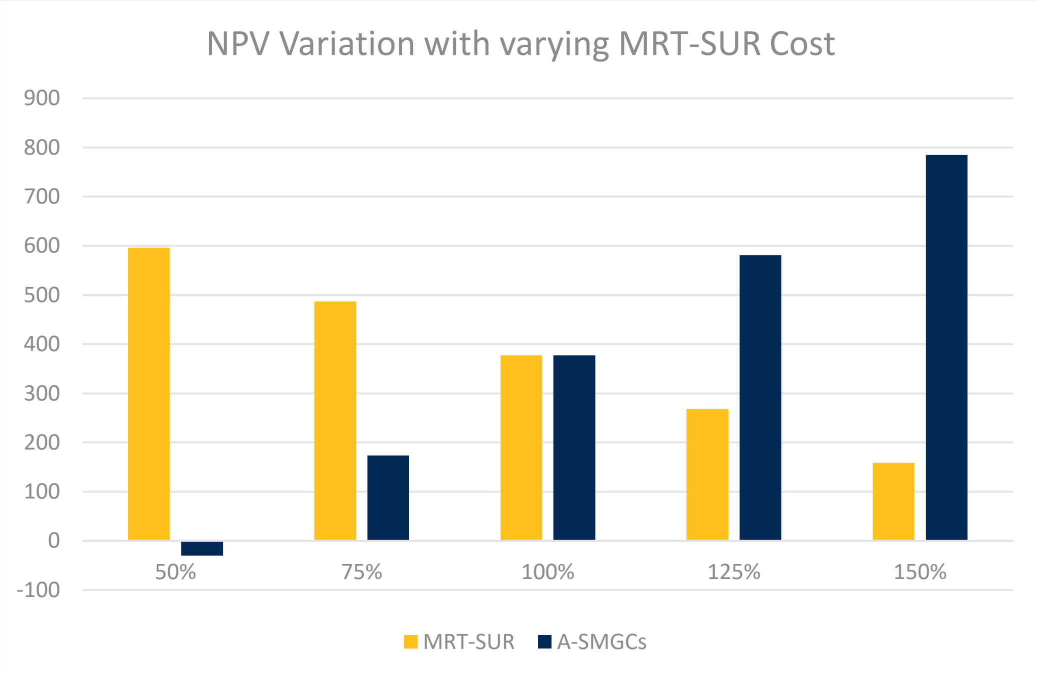

Figure 8-2: NPV variation (M€) for MRT-SUR cost variation in percent

Analyzing the benefits of the solution scenario, the NPV (by applying the improvements), are obtained by subtracting the investment with these improvements (MRT-SUR) from the investment that would be made if these improvements were not there (A-SMGCS).

It provides a comparison of the saving by applying the solution with the solution investment compared against investment without the solution. By increasing the solution cost the benefit decreases (yellow bars). By increasing the solution cost, the difference reduces and there are lower avoided costs so the NPV will reduce. However, without the MRT-SUR solution A-SMGCs would have to be deployed resulting in increased cost when the price of A-SMGCS is increased (blue bars).

9 Recommendations and next steps

The present CBA was established from the perspective of a technological solution. It compares the cost of surveillance sensor implementations in context of the introduction of Multi-Remote Tower Control. The primary underlying assumption is that a surveillance is needed when applying MRTC operations.

The resulting benefit is cost saving resulting from applying MRT-SUR compared to state-of-the-art existing technology, i.e. A-SMGCs as defined by ED-87C.

Based on the performed analysis significant cost-savings would result by applying the solution scenario compared to the reference scenario. This holds also true if influencing factors (discount rate, cost per unit estimate, number of units) vary.

In consequence the recommendation towards operational projects aiming on implementation of MRTC is to consider the MRT-SUR as surveillance sensor instead of a ‘classic’ A-SMGCs, when a surveillance is deemed necessary in order to ensure the situational awareness of an ATCO controlling multiple airports simultaneously from remote.

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10 References and Applicable Documents

10.1 Applicable Documents

[1] SESAR Project Handbook; SJU, ed. 02.02.00, June 2020

[2] Guidelines for Producing Benefit and Impact Mechanisms; EUROCONTROL, ed. 03.00.01, October 2014

[3] Methods to Assess Costs and Monetise Benefits, EUROCONTROL, ed. 00.02.02, October 2014

[4] SESAR Cost-Benefit Analysis Model[4], s7.3.8, February 22

[5] Standard Inputs for Cost-Benefit Analyses, EUROCONTROL, ed. 8.0, January 2018

[6] ATM CBA Quality checklist, SESAR2020 PJ19.04, ed. 5.1, May 2020

[7] Methods to Assess Costs and Benefits for CBAs, SESAR2020 PJ19.04, May 2020

10.2 Reference Documents

[8] Common assumptions

[9] European ATM Master Plan Portal https://www.atmmasterplan.eu/

[10] Performance Framework

[11] Airport OE_December 2017 Version (1.0)

[12]CBAT Model solution PJ14-W2-84d

[4] This reference is no more accessible from Programme library but it is now available in ATM Performance Assessment Community of Practice.

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11 Appendix

Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs, source reference *[10]*

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

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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: 2 minute time window for 70% of flights actually arriving at gate		Variance of actual and reference business trajectories	PRD1	Variance of differences between actual and flight plan or Reference Business Trajectory (RBT) durations
	PA2 - 3-6% reduction in flight time	Environment	Fuel efficiency	(FEFF3)	Reduction in average flight duration
	PA3 - 5-10% reduction in fuel burn			FEFF1	Average fuel burn per flight
Environment	PA8 - 5-10% reduction in CO_2 emissions			(FEFF2)	CO_2 Emissions
Safety	PA9 - Safety improvement by a factor 3-4	Safety	Accidents/incidents with ATM contribution	<SAF1>	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

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[13] **Table 11-1: Mapping between ATM Master Plan Performance Ambition KPAs and SESAR Performance Framework KPAs, Focus Areas and KPIs**

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