

D12.2.130 - PJ14-W2-84b - TRL6 Final TS/IRS– Multi Remote Tower Surveillance (MRT-SUR) module - Part II - Safety Assessment Report

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PJ.14-W2-I-CNSS

MULTI REMOTE SURVEILLANCE MODULE SURVEILLANCE

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Abstract

This document describes the safety activities performed for the SESAR Solution PJ.14-W2-84b – Multi Remote Tower Surveillance (MRT-SUR): SAP. It describes the safety assessment approach and activities performed as part of the MRT-SUR requirement derivation and validation. This document represents part II D12.2.130 - PJ14-W2-84b -TRL6 Final TS/IRS– Multi Remote Tower Surveillance (MRT-SUR) module.

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1 Executive Summary

This document contains the Technical Safety Assessment Report for the PJ.14-W2-84b Multi Remote Tower Surveillance module Technological Solution. The Safety Assessment Report (SAR) represents Part II of the TS/IRS document and presents the assurance that the Safety Requirements for the-TRL6 phases are complete, correct and realistic, thereby providing all material to adequately inform the PJ.14-W2-84b Multi Remote Tower Surveillance module Solution TS/IRS Part I.

In order to achieve this level of maturity the development within PJ.14-W2-84b of providing a surveillance for multi-remote tower (MRT-SUR) was performed. The goal of solution 84b is to provide an adequate and economically reasonable surveillance solution for Multi Remote Tower Control – Surveillance (CTE-S10). Depending on the operational concept as defined by PJ05 solution 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. With this operational background safety objectives were established in common safety workshops with DFS in PJ05 and technical safety requirements have been derived, which have flown into the TS/IRS part I as performance requirements to support the intended service.

As part of the technical validation the performance of the MRT-SUR for cooperative targets was validated by means of performance evaluations of target data recorded in real operational environment and in workshops with ATCOs in order to acquire the operational feedback with regard to the quality of the surveillance service with the background of enhancement of the ATCOs situational awareness when controlling multiple airports simultaneously from remote.

It should be considered that the surveillance service for non-cooperative targets could not be fully established since the non-cooperative sub-sensor based on camera target detection was not available. Therefore, the safety activities concentrated on the cooperative sub-sensor.

2 Introduction

2.1 Background

The goal of solution 84b is to provide an adequate and economically reasonable surveillance solution for Multi Remote Tower Control – Surveillance (CTE-S10). Depending on the operational concept as defined by PJ05 solution 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 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 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 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. Furthermore, the simulation and analysis infrastructure is upgraded to handle this new kind of data.

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

2.2 General Approach to Safety Assessment

This safety assessment is conducted as per the SESAR Safety Reference Material (SRM) which allows the derivation of:

- Technical Specification Safety Requirements (TSSR) specifying the functionality of the technological system for the intended uses (the WHAT) – in terms of equipment, performance and integrity/reliability.

- Technical Safety Requirement at Design level (TSRD) defining the design of the technological system (the HOW) in order to meet the TSSRs.

The activities followed the safety assessment plan [11] established by the solution.

2.3 Scope of the Safety Assessment

The aim of this SESAR technological solution is to provide a low-cost tailored performance surveillance to enable MRT-SUR services. The MRT-SUR surveillance sensor addresses small and regional airports providing air & ground situation for Multiple Remote Tower Controlled (MRTC) operations.

The system uses ADS-B and Mini-MLAT (secondary surveillance) and Video Camera (primary surveillance, dual use with remote tower camera) measurements.

With the specific objective to increase the maturity towards TRL6 a specific focus is laid on standardization including the establishment of a performance class below current A-SMGCS definitions (ED-87C) and definition of corresponding equipment standards in MLAT MOPS (ED-117).

2.4 Layout of the Document

- Chapter 1: Executive summary
- Chapter 2: Introduction
- Chapter 3: Setting the Scene of the Safety Assessment
- Chapter 4: Technical Safety Specification
- Chapter 5: Safe Design of the Technical System
- Chapter 6: Demonstration of achievability of the Technical System Safety Specification
- Chapter 7: Acronyms and Terminology
- Chapter 8: References

3 Setting the Scene of the Safety Assessment

3.1 Concept overview and scope of the change

MRT-SUR represents a technical solution enabling surveillance for multiple remote tower control. It is composed of an electro-optical sensor, non-rotating Mode-S ranging component as well as the data fusion component. In difference to what is currently understood as a surveillance layer, all three components are closely connected with one another to establish a surveillance layer.

For the provision of an MRT-SUR service, the established sensor technologies like a full MLAT or an SMR are not feasible choices due to the cost constraints.

In order to achieve a cost-efficient solution with a performance fitting its purpose the following sensor components are considered for MRT-SUR:

- **ADS-B** enables a cost efficient high-performance surveillance layer. This technology – at least if correct working – provides surveillance data with a sufficient accuracy and integrity for any MRT-SUR service. Unfortunately it cannot be assumed that all aircraft are appropriately equipped and hence mitigation strategies have to be applied to address these targets as well. These mitigations are seen to come by validated ADS-B from PJ.14-W2-84c Secured Surveillance and will be validated using the MRT-SUR test-bed as well.
- **Mini-MLAT & Non-rotating secondary ranging:** The terms mini-MLAT is used to indicate an MLAT system whose performance is below what is specified in current MOPS (ED-117, ref. [11]). This makes the sensor not suitable for applications related to A-SMGCS (ED-87C, ref. [12]); nevertheless, such a sensor adds value to the surveillance service.

The elementary building block of any (mini-) MLAT system is non-rotating secondary ranging. Unlike an MLAT system such a building block provides no direct position solution. Non-rotating secondary ranging can be operated in an active or a passive mode. Both modes have the provision of secondary data like barometric altitude in common.

- **Active Non-Rotating Secondary Ranging:** The elementary setup for active non-rotating secondary ranging consists of a 1030 MHz transmitter and a 1090 MHz receiver unit possible but not necessary at a different location. This arrangement is capable of measuring the range from transmitter to the target and back to the receiver. The antennas can be of omnidirectional characteristic or show some opening angle e.g. 180°. Due to the 1090 MHz receiver, this setup is potentially capable of providing ADS-B data. A potential jitter on the transponder delay has a direct impact on the active non-rotating secondary ranging. Due to the non-directional interrogation characteristic, this setup introduces a notable load on the 1030 MHz and 1090 MHz bands. Hence non-rotating secondary ranging should be operated as passive as possible.
- **Passive Non-Rotating Secondary Ranging:** The elementary setup of passive non-rotating secondary ranging consists of two 1090 MHz receiver units. This arrangement is capable of measuring a range difference in addition to secondary attributes like pressure altitude. This setup induces no additional HF load on the already overloaded 1090 MHz band. A potential jitter on the transponder delay has no impact on the passive non-rotating secondary ranging.

- **RTC camera system** provides the substitute of the view on the airport. It requires cameras of an appropriate performance. These cameras are reused as sensors relying on computer vision and target extraction mechanisms. Cameras have to be distinguished by the spectrum for which they are designed – mainly visual or infrared. Each of the technology has specific strengths and weaknesses – and a combination of both sources promises an additional gain in performance (with respect to accuracy, continuity and availability). Both sources are considered separate surveillance sources producing their own plots that are combined in a data fusion entity.
 - o The camera can provide target azimuth and elevation angle data.
 - o Besides the pure location of a detected target by an electro-optical sensor, the sensor provides additional information on the size of the detect target in the azimuth and elevation angle plane. These bounding boxes support a controller in its situational awareness with respect to the video stream
- **Data Fusion:** In the classic surveillance data processing a main purpose of the tracker is to combine several independent surveillance layers to a combined situation awareness picture. Depending on the connected sensors this picture might cover ground movements on an airport. For processing partial measurements – measurements which do not form an independent surveillance layer by themselves, the role of the tracker changes. The tracker can be considered as part of the sensor itself; without the tracker the data does not provide by itself a full position solution. The role of the tracker is threefold: correlation, update and initialization.

3.2 Stakeholders' expected benefits with potential Safety impact

In the context of the link to PJ.05-W2-35 Multiple Remote Tower and Remote Tower centre the aim of the MRT-SUR is to increase the situational awareness of an ATCO controlling multiple (small) airports from remote.

The MRT-SUR service provision is strictly limited to low up to medium density single runway airports.

With respect to other use the solution will provide surveillance for small and regional airports where today no surveillance is available.

The MRT-SUR concept can be applied to each single runway and low traffic density airport since it applies to small and other aerodrome environments.

The surveillance can also provide benefits in non-remote operations through the increased situational awareness and through enabling the use of safety nets.

Enabling of increased situational awareness of ATCO/AFISO through the cost-effective / tailored performance surveillance sensor is in line with the high level SESAR goals of a safety increase.

3.3 Intended Operational use of the Technological Concept

3.3.1 Intended use identified from SESAR Operational Solutions

The intended use of the MRT-SUR is described in the solution PJ.14-W2-84b technical OSED, which is included in the TS/IRS as Appendix C [9].

A brief summary is given below.

3.3.1.1 Operational Concept

The (single) remote tower concept (RTC) approach does not change the requirements on the surveillance; it provides only a substitute of the view of the airport for the controller by electro-optical means. The operation is still based on outside view and VHF communication.

Depending on the specific local implementation Multi remote tower applications in solution PJ05 for up to three small aerodromes simultaneously may require some additional surveillance to enhance ATCOs situational awareness. Due to the limited traffic, which can be served by multi remote tower the cost aspect is a central point.

Low-Cost Tailored-Performance

For MRT a change in the operational procedures appears likely, but this requires an appropriate surveillance. MRT is the game changer for the required surveillance service. Cost is a main driver for the MRT-SUR; otherwise a full A-SMGCS would be the first choice. The provided performance must match the intended application. Hence the procedures might have to be adapted to the limited performance of the provided surveillance service.

ADS-B has without any doubt the potential to establish a surveillance service more than capable for any applications in the context of MRT. But it cannot be assumed that ADS B will be available for all targets on the airport – not even for all aircraft. Therefore, when using ADS-B as the source of surveillance data it is also of the utmost importance to address the non-ADS B targets. In the foreseeable future especially for VFR traffic the presence of an ADS-B transmitter cannot be expected. These targets might be surveyed with a different performance. Also the procedures in handling these objects might be different.

Partial Confirmation of Other Surveillance Layer

In the past it was common practice that each sensor provides a new surveillance layer. This might be considered as the very definition of a surveillance layer – back in the old days when a rotating radar was the only available surveillance technology for ATC applications. It might still be stated that at least a new surveillance layer is provided by each sensor, reflecting the currently ongoing discussion on the nature of a surveillance layer. In the past it was always differentiated between a primary and a secondary surveillance layer; no hybrid version exists so far.

A sensor providing confirmation on a target detected by another sensors is adding significant value to the surveillance service and not necessarily establishing a new surveillance layer at all. A partial confirmation of e.g. an ADS-B report can be done by video sensor – in the azimuth and elevation angle domain – as well as by ranging conducted by non-rotating Mode-S ranging. For a full confirmation, the additional sensor would necessarily form an additional surveillance layer.

Performance Enhancement for Other Surveillance Layer

Even partial measurements can be used to locally enhance the performance of another sensor. A long range radar provides a full position solution, but due to the limited update period of up to 12 s, a target detected by solely one such sensor cannot be resolved in its manoeuvres as precisely as it can be done using a fast rotating airport surveillance radar of less than half the update period, e.g. 5 s.

The task of the additional incomplete sensor is not to establish an additional surveillance layer, but to upgrade an existing one. With respect to redundancy no additional layer is formed. If the upgrading sensor is down, a basic surveillance service is still available. If the main sensor is down, no surveillance layer at all is available.

Combination of Partial Sensors to form an Additional Surveillance Layer

A partial sensor is by definition not forming an additional surveillance layer. But the combination of two or more partial sensors could potentially generate performance equivalent to a fully fledged surveillance layer. These partial sensors can be of the same type but at different locations e.g. two video sensors covering the same part of an airport, but with different view angles or of different kind potentially located even nearby one another e.g. a combination of video and non-rotating Mode-S ranging.

It is not necessary that the newly established surveillance layer is pure with respect to its technology – opening the door for primary-secondary hybrid surveillance layers.

The establishment of an additional surveillance layer by the combination of several partial measurements is characterized by the capability to initialize and sustain a track on its own.

Map Based Enhancements

By constraining the position of a target e.g. assuming the target is located on the ground. It might even be assumed that the target is located somewhere on the taxiway network – further reducing the dimensions of the target locations. While such an approach might work rather well on a limited and well-defined space like the apron, due to the missing dimension, it nevertheless results in a substitute and not a true measurement – with the potential danger of misinterpreting the intention of the target. While a false alarm may limit the acceptance of the system, a missing alarm might be critical.

3.3.1.2 Operational Services

The operational services intended to be covered by MRT-SUR are:

- MRT-SUR-DISP (Display): is related to the support of situation awareness to the ATC controller by means of the MRT-SUR providing air & ground situation for information purposes in contrast to a control tool. The distinction follows from the reduced performance of the MRT-SUR in comparison to a full A-SMGCS system.
- MRT-SUR-EVE (Event): is related to the support of event generation by the MRT-module (as developed in Pj05), e.g. pending clearances, in the context of MRT by providing an appropriate surveillance service. The MRT-SUR provides surveillance data with a performance such that he MRTM is enabled to perform this service.
- MRT-SUR-ROUT (Routing): is related to the support of conformance monitoring of routing in the context of MRT by providing an appropriate surveillance service. The MRT-SUR-ROUT service in the context of MRT provides a reduced service due to be reduced performance of MRT-SUR compared to a full A-SMGCS surveillance.
- MRT-SUR-ASSS (Airport Safety Support Service) is related to the support of safety-nets in the context of MRT by providing an appropriate surveillance service. The safety-net service in the context of MRT may, due to the reduced performance, need to differ significantly from a safety-net service based on an A-SMGCS system on a medium to large airport. The Airport

Safety Support Service must address the implications of a limited performance of MRT-SUR-ASSS in comparison to an A-SMGCS system.

- MRT-SUR-AUG (Augmentation): is related to the video stream augmentation in the context of MRT by providing an appropriate surveillance service. The detected target, represented by coordinates and bounding boxes are augmented by secondary surveillance data. Therefore, a link from the track report to the original sensor surveillance data has to be provided.
- MRT-SUR-PTZ (Pan-tilt-zoom camera): is related to the support of a pan-tilt-zoom camera control in the context of MRT by providing an appropriate surveillance service. Smooth zooming and panning on a moving target are facilitated by position and at least velocity of the target as provided by MRT-SUR.

3.3.1.3 Operational environment

The current usage of the MRT concept shall be limited to single runway airports with simple taxiway layout and low traffic density (~60k movements per year).

Airport and airspace characteristics

MRT-SUR is applicable to airports where currently no surveillance especially no ground surveillance is used. The airports in general are suitable for scheduled (using mainline aircraft) and unscheduled (incl. general aviation) air traffic. Airspace users are all types of aircraft flying IFR and VFR.

The MRT-C concept applies to small and other aerodrome environments.

Aerodrome Layout:

- Basic Airport
- Max. simple airport
- Single RWY, simple TWY system

The airspace is classified so that all traffic (IFR and VFR) is controlled (ICAO Airspace Class C and D).

Traffic density

Light (L): No more than 15 movements per runway or typically less than 20 total aerodrome movements; (per hour)

Duration of operation: Considered airports: 50000 ... 60000 movements per year => ~7 movements per hour

Transponders

The usage of Mode-S transponders is seen as a pre-requisite. It is assumed that approx.. 80% of the traffic uses Mode-S with extended squitter, ADS-B.

Non transponder equipped aircraft (either on the ground or in the air) or vehicles are for MRT-SUR addressed by video sensors.

Operation under Low visibility conditions

Navigation infrastructure may be deployed and operations under low visibility conditions may be applicable. Under such conditions specific operational procedures may be applied (e.g. fixed taxi routes, procedures for traffic separation), which normally would limit airport capacity. This is not an issue for the considered class of airports.

Surveillance coverage

The surveillance service of MRT-SUR might only be provided for parts of an airport and its surroundings. Furthermore the designated performance may vary significantly for different parts of the airport and its surrounding. It covers the approach region and airport ground (RWY, TWY, Apron (optional)) as information tool. For the supporting services (EVE, ROUT, ASS, AUG, PTZ) the service volume is related to the RWY, TWY and optionally Apron.

The core region for MRT-SUR applications is the runway including the adjunct holding positions.

The final approach covers approximately 10 NM from the runway threshold till the threshold. Although the final approach has to be already covered by an additional sensor infrastructure – typically a rotating sensor most likely not directly located at the airport itself. Especially for a long range radar (LRR) the performance might be far from optimal due to local obstacles. The task of MRT-SUR in the approach region is to enhance the already present surveillance layer and not to establish an additional independent one.

For the last mile of the final approach, a video camera can support the surveillance, especially for non-cooperative confirmation – including confirmation on the barometric altitude.

Although not of the same importance for MRT-SUR, the coverage of the taxiways is structurally similar to the coverage of the runway. Depending on MLAT ground station siting the geometries may become worse and the accuracy decreases. Focus of site selection will be on providing an appropriate coverage for the runway.

The importance of covering also the aprons is smaller compared to the taxiways or the runway. Especially the video sensor might have a limited performance at the aprons due to the large target extent. Non-rotating Mode-S ranging can generate additional data like magnetic heading to augment even ADS-B data.

Surveillance performance

For MRT-SUR not all targets might be addressed with the same performance. A potential lack on performance is addressed on the procedure level. Unequal sensor performance is caused by different transponder equipment.

Performance requirements have been established and are given in the TS/IRS. The performance indicators are based on the performance requirements from the ED-87C potentially suitable to address the specific circumstances of MRT-SUR.

The actual performance values to support MRT-C operations were derived based on a safety assessment which is described herein. The derivation is based on operational needs expressed by PJ05. In consequence multiple sessions were performed with PJ05 member DFS to quantify safety objectives as basis for the technical performance.

3.3.2 Other intended use outside SESAR

MRT-SUR can provide surveillance for Small and Regional airports in general. Surveillance can also provide benefits in non-remote operations through the increased situational awareness and through enabling the use of safety nets.

The solution developed in Pj14-W2-84b may support these applications - surveillance sensor addressing small and medium airports - as well.

3.4 Relevant applicable standards

General:

- ICAO A-SMGC Manual, [2]

Equipment:

- ED-87C Minimum Aviation System Performance Specification (MASPS) for A-SMGCS: [3]
 - o Full A-SMGCS: not applicable in terms of performance, since MRT-SUR is intended to be used as info-tool and not as control tool
 - o New performance class intended to be established
 - o Is in the scope (terms of reference) of EUROCAE WG-41: A-SMGCS light
- ED-117 Minimum Operational Performance Specification for Mode S Multilateration Systems for Use in Advanced Surface Movement Guidance and Control Systems (A-SMGCS): [4]
 - o Covers airport MLAT for use as control tool
 - o Not directly applicable in terms of performance since MRT-SUR is info tool
 - o Used as frame for cooperative sub-sensor
- ED-116 Minimum Operational Performance Specification for Surface Movement Radar Sensor System: [5]
 - o Used to establish a frame for performance metrics for the re-used cameras with object detection as non-cooperative surveillance layer

Safety:

- o ED-109 Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems [12]
- o ED-163 Safety, Performance and Interoperability Requirements Document for ADS-B Airport Surface Surveillance Application (ADS-B-APT) [6]
- o ED-153 GUIDELINES FOR ANS SOFTWARE SAFETY ASSURANCE [8]

4 Technical Safety Specification

4.1 Overview of activities performed

The following activities were performed in the context of the safety assessment:

- Safety Plan
- Common safety workshops with DFS PJ05.
- Quantification of performance specification (TSSRs) based on safety objectives flown into in intermediate TS/IRS [9]
- Technical validation to confirm performance using real prototype installed at airport of Erfurt
- Safety Assessment Report

4.2 Technical Specification Safety Requirements – TSSR (functionality and performance)

4.2.1 TSSR from SESAR operational solution intended use and/or relevant standards

Applicable is the PJ05 SAR from wave 1 [13] and the draft of the D12.2.130 - PJ14-W2-84b -TRL6 Final TS/IRS– Multi Remote Tower Surveillance (MRT-SUR) module - Part II - Safety Assessment Report [14].

4.2.1.1 Pre-existing hazard

Pre-existing hazards allocated with the intended operation were identified based on provided surveillance services as defined in technical OSED (Appendix of TS/IRS) with cross checks against PJ05 wave 1 SAR, ref. [13] and wave 2 SAP, ref. [14].

Inputs provided by PJ05 form the basis for the derivation of safety objectives for the technical system, its performance needs and the technical safety assessment incl. derivation of the design assurance level.

These are primarily related to the influence surveillance has on Runway / Taxiway system, i.e. separating the aircraft:

- Hazards related to collision (aircraft, ground vehicle, obstacle)
- Hazards related to wrong routes and wrong RWY direction (wrong RWY is of lower importance at small airports – i.e. single RWY airports)

With relevance for MRT-SUR from PJ05 are following hazards:

- CFIT
- Mid Air Collision
- Runway accident

- Runway excursion
- Taxiway accident
- Taxiway excursion

Table 4-1: Pre-Existing operational hazards from PJ05

Pre-existing Hazards to be mitigated by the AT services remotely provided using MRT		Leading to (type of accident)	AIM Model Used
Hp#1	Situation in which A/C trajectories can lead to mid-air collision	Mid Air Collision	MAC-TMA
Hp#2	Situation leading to collision with an obstacle, ground vehicle, another aircraft on apron or taxiway	Taxiway Collision	TWY-Col
Hp#3	Situation leading to collision with an obstacle, ground vehicle, another aircraft on the runway	Runway Collision	RWY-Col
Hp#4	Another aircraft or vehicle inside the Obstacle Free Zone – OFZ	Runway Collision	RWY-Col
Hp#5	Missed approach	Mid Air Collision	MAC-TMA
Hp#6	Situation leading to Wake vortex encounter in final approach	Wake Turbulence Accident	WV-FAP
Hp#7	Situation leading to Controlled Flight into Terrain	Controlled Flight into Terrain	CFIT
Hp#8	Bird close to/in path of aircraft or animal on the runway	Bird-strike Animal-strike	RWY-Col
Hp#9	Adverse weather conditions like violent winds or severe crosswind	Hard landing, runway excursion, Landing accident	RWY-EXC
Hp#10	Snow/slush on the runway	Loss of control on the runway, Landing accident	RWY-EXC
Hp#11	Low runway surface friction	Runway excursion (veer-off, overrun) Landing accident	RWY-EXC
Hp#12	Runway undershoot	Off-runway touchdown, Landing accident	None
Hp#13	Aircraft using a closed taxiway	Taxiway Collision	TWY-Col
Hp#14	Aircraft landing in/taking off from a wrong/closed runway	Runway Collision (wrong/closed RWY in which an A/C, vehicle, obstacle is present) Landing accident (closed runway)	RWY-Col

		because of maintenance: RWY surface not operational)	
Hp#15	Another aircraft or vehicle inside landing-aid protection area during CATII/III instrument approach	Landing accident	RWY-EXC
Hp#16	Foreign Object Debris within the Runway protected area	(Loss of control on the runway) Landing accident	RWY-EXC
Hp#17	Aircraft attempt to land with undercarriage retracted	(Gears-up landing) Landing accident	RWY-EXC
Hp#18	Loss/interruption of ATC services (to one or more aerodromes)	All types of accidents	None
Hp#19	Aircraft entering a restricted area (airspace)	Airspace infringement	MAC-TMA

4.2.1.2 Impact assessment of the change

Success approach:

- Assumption: the MRT-SUR works with its nominal performance
- This operation is strongly linked to the nominal conditions as assessed by Pj05

Table 4-2: Safety Requirements from PJ05 for success case, ref. [14] with relation to MRT-SUR

SRD-31	Surveillance data shall be provided to ATCO to support tasks for all aerodromes. Air surveillance data is mandatory while ground surveillance is optional	Pack	SRS-01 SRS-02 SRS-03 SRS-04 SRS-05 SRS-06 SRS-07 SRS-08 SRS-09 SRS-10 SRS-026 SRS-027 SRS-029 SRS-030 SRS-31 SRS-32 SRS-61 SRS-65
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From technical perspective the nominal condition of the surveillance is linked to the nominal performance of the surveillance sensor.

In this regard following characteristics are important:

- Nominal Coverage
- Nominal accuracy
- Nominal update rate

Failure approach:

Table 4-3: Safety Requirements from PJ05 for failure approach, ref. [14] with relation to MRT-SUR

SRD-70	In case surveillance function is available in the MRTM position, but the function is lost or the information provided is inappropriate and detected, relevant fallback procedures shall be applied	Pack	Mitigation mean identified from the hazard assessments of former project phases.
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From technical perspective, failures cover non-nominal conditions, i.e. conditions where the nominal performance is not achieved.

- Reduced coverage
- Missing updates
- Erroneous positions (low accuracy)
- Ghost targets

4.2.1.3 Setting of Quantitative Safety Objectives based on intended operation

Based on the identified technical mitigations, define safety objectives and compare against performance requirements in TS/IRS: establish safety requirements

From safety workshop with DFS (PJ05):

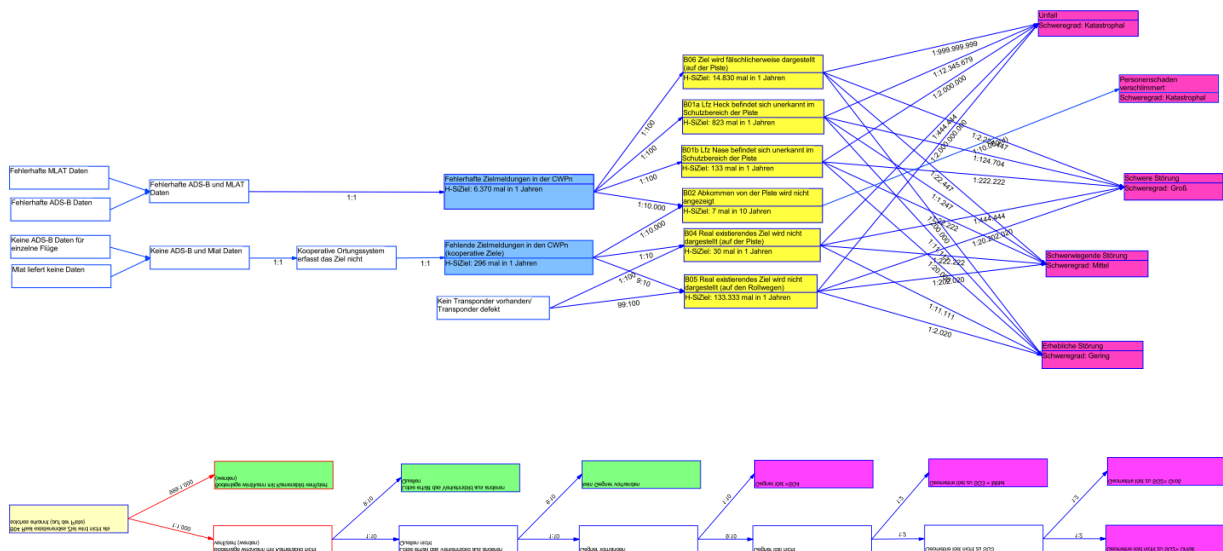


Figure 4-1: Safety objectives related to MRT-SUR established during safety workshops with DFS PJ05

The relevant risks are:

- B06: Target is erroneously displayed (on RWY)

- B01a: Aircraft tail penetrates RWY sensitive or critical zone and condition is not detected
- B01b: Aircraft nose penetrates RWY sensitive or critical zone and condition is not detected
- B02: Runway excursion is not recognized
- B04: Real existing target on runway is not displayed
- B05: Real existing target on taxiway is not displayed

Link to operational impact, assessment of risks can be linked to following basic technical events:

- R001: Erroneous target data displayed in CWP: Linked to B06; B01a; B01b; B02
- R002: Missing target data in CWP: Linked to B02; B04; B05
- R003: No Transponder, transponder malfunction: Linked to B04; B05

Risks R001 and R002 are tied to Mini-MLAT and ADS-B. These Sub-sensors need to provide target data to allow the tracker to generate an output data towards CWP.

These risks are split as follows:

- R001-1: Erroneous MLAT Data of a non-ADS-B, Mode-S target leading to erroneous target data output to CWP
- R001-2: Erroneous ADS-B Data leading to erroneous target data output to CWP
- R002-1: Missing MLAT Data for a non-ADS-B, Mode-S target leading to erroneous target data output to CWP
- R002-2: Missing ADS-B Data leading to erroneous target data output to CWP

R003 is solely linked to the camera: when transponder is not working, only the camera can provide target information (without target identification).

4.2.1.4 Derived (performance) target requirements

Safety target for cooperative sub-sensor from DFS Safety assessment workshop:

- R001: Erroneous target position reported on CWP: $6370/y \Rightarrow 2 \times 10^{-4}/s$
 - o Misleading information is defined as: Erroneous target position report on CWP: Misleading position error
 - o Involved technical performance parameters:
 - Probability of misleading information: Probability of false and ghost target
 - Threshold for position deviation – leading to nominal accuracy

- Update rate
- Latency
- Allocation to Probability of misleading information: $PMI < 2 \times 10^{-4}/s$:
- could be split between ADS-B & MLAT based on traffic mix – but not considered for the following, what is conservative since for ADS-B, the validated ADS-B from solution 84c is considered, which applies target validation using MLAT-like technologies based on partial positions.
- Missing target position on CWP for cooperative targets: $1 \times 10^{-5}/s$
 - Missing target report in MRT-SUR context is defined as no target report for more than 30 s (track drop). Background: the tracker applies extended coasting.
 - The 30 s time-out criterion is established by extended coasting, which is the max. time a track is kept in SDPS with ‘frozen position’
 - Involved technical performance parameters
 - Probability of long gap
 - Probability of false identification
 - Update rate
 - Probability of long gap ($PLG > 30 s$) $< 1 \times 10^{-5}/s$

To cross check the safety target as defined in the safety workshop an assessment based on traffic density is performed:

- Number of movements: 60000/year $\Rightarrow \sim 7$ Movements / h
- Percentage of time operating near threshold: 10% of total taxi time
- Total taxi time: 20 min
- Time near threshold: 2 min = 180 s
- Time near threshold per hour: $7 \times 180 s = 1260 s$
- $\Rightarrow PMIP = 0.73 [1/h] / 1260 [s/h] = 5.8 \times 10^{-4} / s$
- $\Rightarrow PMIP$ of $2 \times 10^{-4} / s$ compared to the defined target of $1 \times 10^{-5}/s$. Therefore, the defined target is conservative! (based on the assessment using traffic density, even more traffic could be handled)

4.2.2 TSSR from other intended use

No detailed assessment for other intended use is performed. In a scenario where an ATCO controls a single airport, the performance requirements are seen to provide potential to be less stringent than in a multi-remote control scenario. Therefore it is conservative to apply the same performance requirements in these scenarios as well.

4.3 Technical Specification Safety Requirements - TSSR (Required Performance for Safe Operation)

4.3.1 TSSR from SESAR operational solution intended use and/or relevant standards

Assessment addresses solely SUR not visual reference. Visual reference is addressed in operational context by PJ05.

The assessment is performed for most demanding service provided by the MRT-SUR. The dimensioning service is MRTM conformance monitoring (MRT-SUR-ROUT), especially related to observation of the RWY holding points.

Driver for nominal performance is performance of SUR for cooperative targets (Mini-MLAT & ADS-B).

Camera with object detection to address non-transponder – similar to role of SMR.

- Airports can be operated with failed SMR using the cooperative sensor as info-tool. For MRT-SUR the SUR-sensor generally is considered as info-tool.
- Unavailability of SUR-sensor:
 - o MRTC (video view still available) still feasible when object detection fails
 - o MRT-SUR also available when environmental conditions do not allow for object detection by camera.
 - o Non-transponder:
 - Non-transponder aircraft with missing object detection by camera have to be handled by a fallback to conventional operational procedures (e.g. VHF COM and pilot reported position, etc.). Potentially with reversion to single remote airport operation for the respective airport. But this would have to be addressed by the operational project PJ05.
 - Objects on movement area: as with current operations: under LVP no traffic other than aircraft are allowed.
- Redundancy: overlapping of cameras -> provides level of redundancy. Camera failures to be addressed by PJ05 since visual cues will be missing
- PFA: Object detection is fused with secondary SUR data -> false detections will be recognized and removed

- Update rate by camera: very high UR – supports recognition of target false positions in MSDF
- Accuracy: EL, AZ with high accuracy supports accurate position output after MSDF
- Latency: low

4.3.1.1 Availability:

The existing standards ED-117 (MLAT MOPS) & ED-142 (WAM MOPS) defining requirements for the use of the surveillance sensor as control tool, require that the surveillance system's inherent availability has to be at least 99.99%. These standards require that the system's MTBCF is at least 10,000 hours and it should be noted that this refers to the loss of service.

With respect to MRT-SUR and its involved sub-sensors as an info-tool no quantitative availability figures are defined. The required availability for MRT-SUR is tentatively defined to be 99.5%. No detailed availability assessment is performed for MRT-SUR.

However, with respect to system availability the following considerations apply:

Redundancy considerations

The mini-MLAT does not provide redundancy providing tolerance to the fault of a component and still maintaining the full service.

With respect to the Mini-MLATs ground stations (GS) there is however, a degradation path which allows to tolerate GS faults and still allowing to provide cooperative SUR service:

1. Normal:
 - 5 operating ground stations
 - System provides MLAT & validated ADS-B,
2. GS degradation, #GS ≥ 3 :
 - System provides degraded MLAT & validated ADS-B;
 - min. # of GS for MLAT position is 3;
 - However, if one GS fails the Mini-MLAT coverage, PU and accuracy will decrease
 - ADS-B coverage may (slightly) decrease
3. GS degradation, #GS ≥ 2 :
 - System provides ADS-B, ADS-B can still be validated.
 - A Mini-MLAT position is not available anymore.
 - Depending on which GS fails coverage will decrease
 - if Tower antennas still available, no reduction in coverage, but limitation in validation capability
 - if (at least one) airport antenna still available, reduced coverage, but still validation capability.
4. GS degradation, #GS = 1:
 - System provides unvalidated ADS-B
 - Validation is not feasible anymore
 - Coverage and PU decrease
5. #GS = 0:

- No cooperative SUR service anymore

The GS themselves are not redundant (no dualized GS, no battery backup)

The Data Link is not redundant but provides a degradation capability due to dual Base-station.

Synchronisation of the ground stations, which is essential to allow the Mini-MLAT to localize targets

- Primary and secondary synchronization are available
- Primary synch is dualized: a fault on the sync master site will not impact system performance since the second sync site can take over.
- Secondary: only if Primary Synch becomes totally unavailable, secondary synch (GPS) will be used.
- There is a time coasting period (~6 minutes) after which timing accuracy will degrade and hence localization accuracy will degrade
- When Primary Synch is available a degradation or unavailability of GNSS will have no impact.
- For security:
 - Potential jamming 1090 MHZ could affect Primary-Synch. The secured SUR (sol 84c) provides Jamming detection, so that awareness is given and with respect to synch corrective actions can be performed.
 - Potential jamming on GNSS L1 could affect time synchronization. The secured SUR (sol 84c) provides jamming detection and executive GNSS monitoring to handle time synch errors due satellite faults, local multipath and jamming and maintain timing accuracy.

Central processing providing control & monitoring is not redundant. But it provides internal redundancy allowing for re-configuration and resulting in a MTBF of the central processing exceeding 5000 h.

4.3.1.2 Accuracy

Accuracy

Accuracy: Ref. [2] generally states that 20 m (longitudinal) surveillance accuracy result in significant improvements in system performance and allow more time for reaction to avoid a conflict.

A more comprehensive analysis is performed to establish an accuracy requirement for MRT-SUR, which translates directly into a required accuracy for the cooperative sub-sensor. The required accuracy is derived from longitudinal RWY holding point scenario as given in ref. [2].

The derivation of the accuracy requirement for cooperative sub-sensor based on derived PMPI.

For PMPI a misleading position is defined to exceed 45 m (criterion based on ED-163, ref. [6]).

Calculation of frequency of excess of MI-threshold is shown in Figure 4-2 and 4-3 for various THR_MI values. The difference between both figures is that the assessment as Figure 4-2 is related to excess rates, while Figure 4-3 is related to probability to exceed the misleading information threshold.

The limit value of $2 \times 10^{-4}/s$, which is the target value for PMPI is shown as red line (not to exceed criterion)

- ⇒ For 45 m limit is fulfilled with a nominal accuracy of 12.7 m (1 sigma). Assuming gaussian distributed errors, an accuracy requirement of 25.4 m (95%) will result. Conservative: **25 m (95%)**
- ⇒ This value is conservative. With the looser PMPI of $5.8 \times 10^{-4} /s$ from the traffic density consideration a required accuracy of 14 m (1 sigma) => **28 m (95%)** will result.

TSSR-01: The MRT-SUR shall provide a nominal accuracy (95%) for cooperative Mode-S equipped targets located on the airports manoeuvring area of 25m.

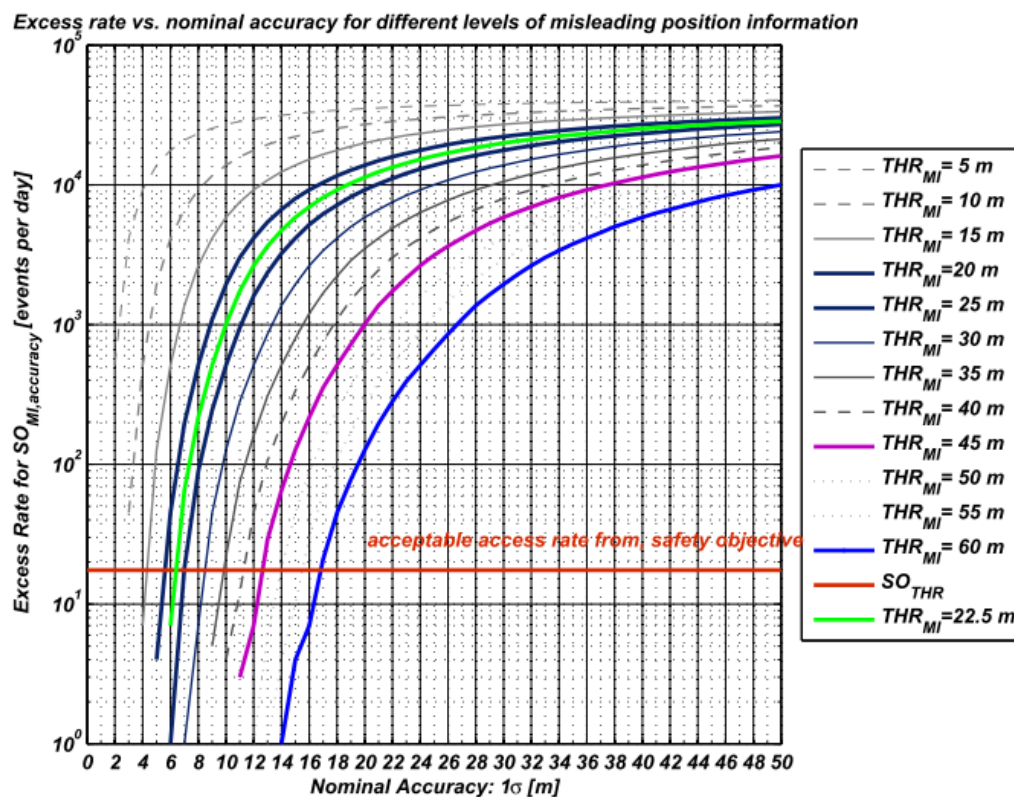


Figure 4-2: Derivation of nominal accuracy based on max. Excess rate safety objective

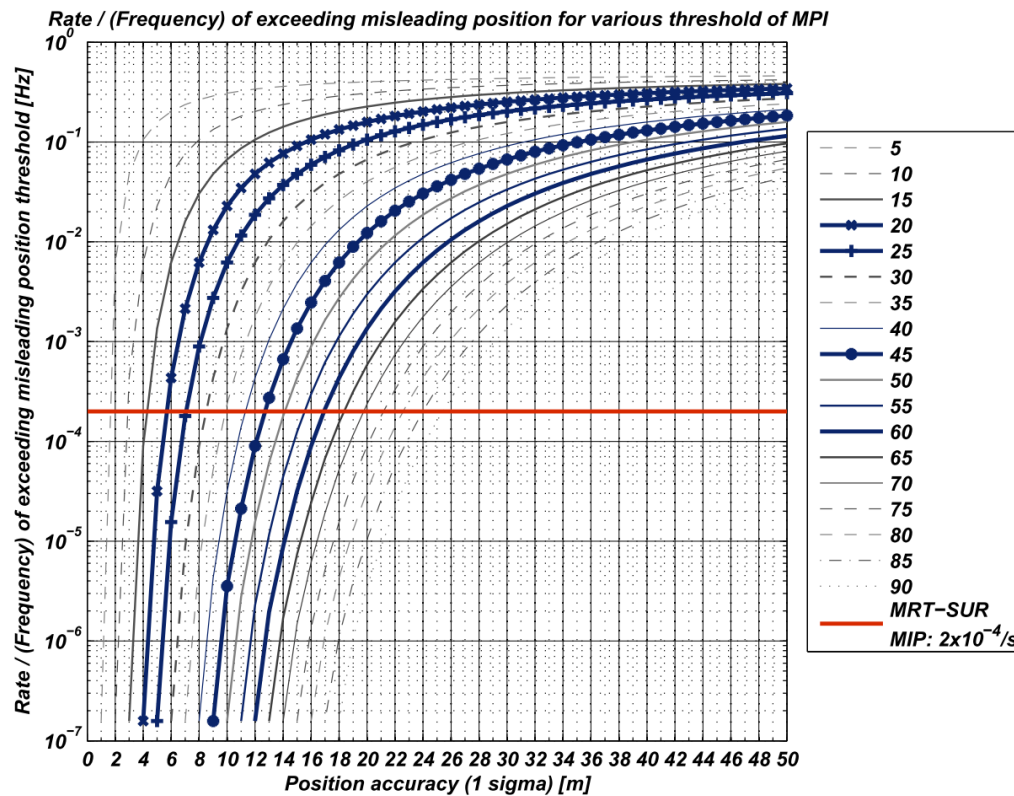


Figure 4-3: Derivation of nominal accuracy based on probability to exceed misleading information

4.3.1.3 Update Rate

Update rate of 1 s defined based on expert judgement. The update rate is a trade-off between accuracy and update rate. It is set to minimize time delays in detecting an erroneous position.

TSSR-02: The MRT-SUR shall provide a nominal update rate for cooperative Mode-S equipped targets located on the airports manoeuvring area of 1s

4.3.1.4 Latency:

System Data Latency and Communications Delay

In EUROCAE the following references are relevant:

- ED-117A [S8] section 3.3.13 "Latency",
- ED-142 [S10] section 3.3.11 "Processing delay".

The WAM application allows for a maximum data latency of 1.0 second with 0.5 second maximum contribution apportioned to the communications infrastructure.

The Airport MLAT application allows for a maximum data latency of 0.5 s with 0.25 s maximum contribution apportioned to the communications infrastructure.

TSSR-03: The Data latency as the time from output MLAT to Display shall be 1 s max.

4.3.1.5 Probability of update

The defined nominal position update once per second is intended to be given during 95% of the time, the MRT-SUR outputs target data.

TSSR-04: The nominal update rate shall be achieved for 95% of the time the MRT-SUR outputs target data.

4.3.1.6 Probability of long gaps

For MRT-SUR a long gap is defined as losing track (track drop). With the MRT-SUR's extended coasting this relates to a gap larger than 30 s.

The safety target for the missing output of target data on the CWP of 296 events per year as defined during the safety workshop with DFS (PJ05) translates into a PLG of $2.8 \times 10^{-4}/30$ s, which in turn can be linked to $1.7 \times 10^{-3}/5$ s.

The requirement for Mini-MLATs PLG on the manoeuvring area is conservatively set to **$1 \times 10^{-3}/5$ s**.

TSSR-05: The probability of long gap (PLG) shall be less than 1×10^{-3} per 5 s interval for the time data for a Mode-S equipped target is provided.

4.3.1.7 Performance in approach region

The requirements driving the performance of the MRT-SUR are related to the airport manoeuvring area, these are the most demanding ones.

The MRT-SUR is intended to cover the approach/departure region to allow a smooth transition between air surveillance, typically provided by long range radar or WAM and the airport surveillance provided by MRT-SUR.

With respect to approach region a performance as defined for a WAM in medium density TMA was identified to fulfil the needs.

TSSR-06: In approach region the performance for a Mode-S equipped target in line with the performance parameters PU, PLG, Accuracy PLFG, PID, PFID, update rate and communication delay shall be compliant with an intermediate density TMA.

4.3.2 TSSR from other intended use

No detailed derivation for other intended use is performed, since the dimensioning case for the MRT-SUR performance is the support of operations where multiple towers are remotely controlled. A single (remote) tower operation is less demanding in terms of enhancement of ATCOs situational awareness. Therefore, these operations are seen to be feasible to be safely conducted using a SUR-Sensor fulfilling the MRT-SUR performance specification.

4.4 Process assurance of the Technical Safety Specification

Derivation of system safety/design assurance levels following definitions in ED-109, ref. [12] / (ED-153, ref. [8]) leads the design assurance level for the MRT-SUR and its sub-sensors in support to a later industrialisation.

Criticality of the functions is Minor.

This Minor criticality leads to DAL: Level D (ED-012 / DO-178) or Level AL5 (ED-109).

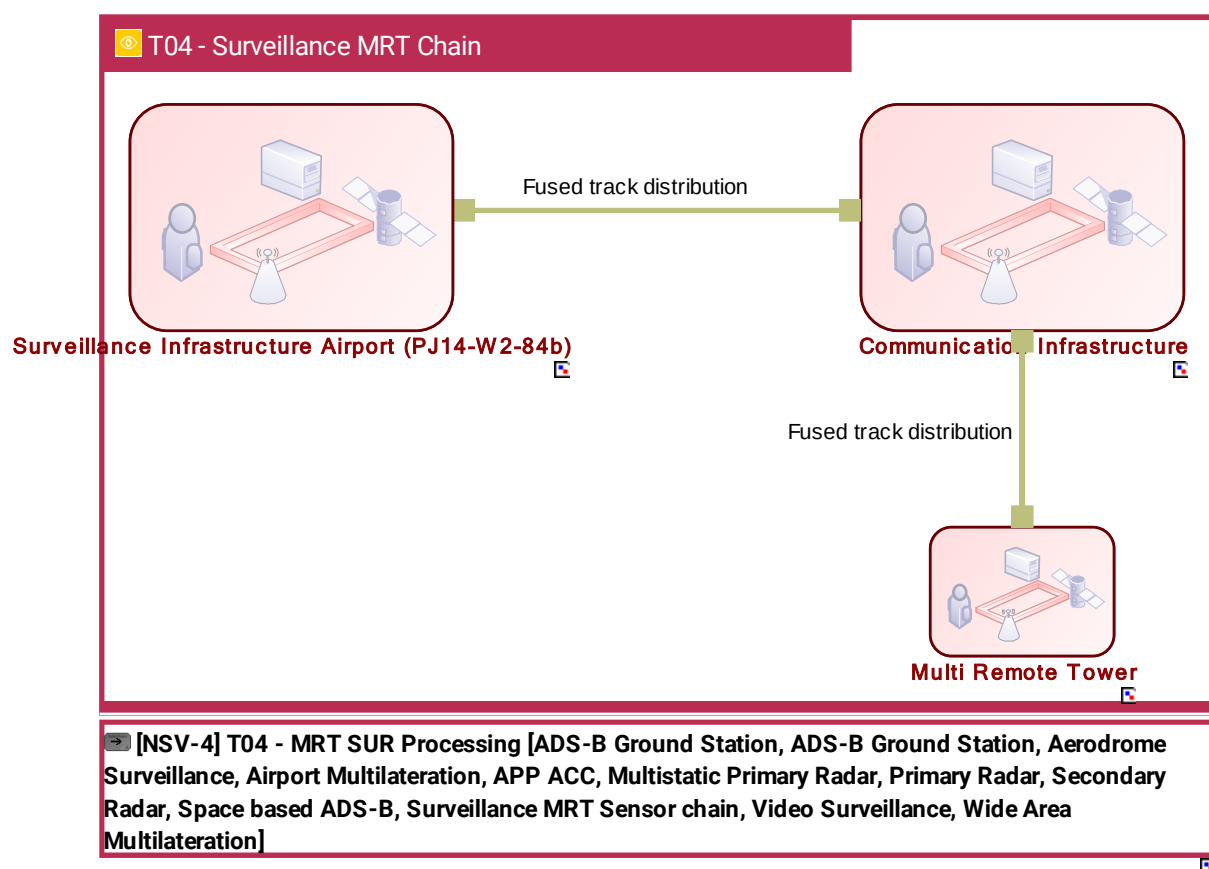
5 Safe Design of the Technical System

5.1 Overview of activities performed

The design of the prototype was performed based on the requirements defined in the intermediate TS/IRS.

5.2 Design Model of the Solution Technical System

The design model for solution PJ.14-W2-84b is covered in EATMA. It is provided in the solutions TS/IRS part I and also provided in the following figure.



The fused track contains the aircraft position reports and target information.

5.2.1 Description of the Technical System Design Model

As laid out in the SAM in case the safety assessment refers to an EATMA model developed by the Project/Solution, no particular description is needed.

5.3 Deriving Technical Safety Requirements at Design level for Normal and Abnormal conditions

5.3.1 Technical Safety Requirements at Design level for Normal and Abnormal conditions

Table 5-1 provides the consolidated list of Technical Safety Requirements at Design level (functionality and performance) for Normal and Abnormal conditions of operations derived by mapping the Technical Specification Safety Requirements (TSSRs) documented in section 4.2 onto the related elements of the Design Model, i.e. the safety related requirements as defined in the solutions TS/IRS.

These requirements cover the entire sensor performance. Detailed requirements with respect to the cooperative sub-sensor as backbone of the MRT-SUR are provided in 5-2.

Table 5-1: Derived Technical Safety Requirements for the overall MRT-SUR

Technical Safety Requirement ID [Design Model element]	Technical Safety Requirement description (functionality & performance)	Derived from TSSR (ID)
REQ-14.84b-TS-MRTS.0021	The MRT-SUR sensor shall be sufficient to support the following intended operational services: - Provide ground situation in terms of an information tool: MRT-SUR-DISP - Support the generation of trigger events (MRT-SUR-EVE): - o (optional: notification of arrival) - o landing clearance - o landing reminder - Support the conformance monitoring (MRT-SUR-ROUT) for following cases: - o Runway Incursion, - o Conformance Monitoring (TWY), - o Conflict Detection - Provide video stream augmentation (MRT-SUR-AUG) by - o Adding secondary surveillance data to a detected primary target represented by coordinates and bounding box - Support the control of a Pan-Tilt-Zoom (PTZ) camera through	TSSR-01, TSSR-02, TSSR-03, TSSR-04, TSSR-05
REQ-14.84b-TS-MRTS.0094	The performance of the MRT-SUR shall be in line with the operational need to generate trigger following events as follows: • Event: Landing Clearance: - o Location: Approach path – Threshold (THR) - o Required performance:	TSSR-01, TSSR-02, TSSR-03, TSSR-04, TSSR-05

	▪ SUR data stability (predictability): Speed vector < 20 m/s (90%) or < +/- 25% of the actual speed (the higher value applies) • <i>Note Derived value</i> ▪ SUR update rate: 0.2 ... 0.5 Hz (5 s ... 2 s) • <i>Note: as per draft ED-142A</i> ▪ SUR data delay: < 2 s • <i>Note: Derived value</i> ▪ SUR data probability of update: 96.5% (5 s) ... 90% (2 s) • <i>Note: as per draft ED-142A</i> ▪ SUR data accuracy: 130 ... 160 m (95%) • <i>Note: as per draft ED-142A</i> ▪ Identification: 96.5% • <i>Note: as per draft ED-142A</i> • Event: Landing Reminder: ○ Location: Approach path– Threshold (THR) ○ Required performance ▪ SUR data stability (predictability): Speed vector < 20 m/s (90%) or < +/- 25% of the actual speed (the higher value applies) ▪ SUR update rate: 0.2 ... 0.5 Hz (5 s ... 2 s) ▪ SUR data delay: < 2 s ▪ SUR data probability of update: 96.5% (5 s) ... 90% (2 s) ▪ SUR data accuracy: 130 ... 160 m (95%) ▪ Identification: 96.5% <i>Note: The purpose of this requirement is to define the locations and needed performance to perform the intended operation.</i>	
REQ-14.84b-TS-MRTS.0095	The performance of the MRT-SUR shall be in line with the operational need to detect the following non-conformances: • Non-Conformance: Runway Incursion: ○ Location: RWY holding point ○ Required performance ▪ SUR data stability (predictability): Speed vector < 5m/s (90%) or < +/- 10% of the actual speed (the higher value applies) • <i>Note: as per ED-87C</i> ▪ SUR update rate: 1 Hz • <i>Note: as per ED-87C</i> ▪ SUR data delay: <= 0.5 s • <i>Note: as per ED-87C</i> ▪ SUR data probability of update: 90% (1 s) • <i>Note: as per ED-87C</i> ▪ SUR data accuracy: 25 m (95%)	TSSR-01, TSSR-02, TSSR-03, TSSR-04, TSSR-05

	• <i>Note: Derived from initial safety considerations</i> ▪ Identification: 1E-4 • <i>Note: as per ED-87C</i> ▪ Probability of false target report: 2E-4 per target report • <i>Note: Derived from initial safety considerations</i> • Non-Conformance: Conformance Monitoring Taxiway route (TWY) ○ Location: Taxiway (TWY) ○ Required performance: ▪ SUR data stability (predictability): speed vector < 7.5m/s (90%) or < +/- 15% of the actual speed (the higher value applies) • <i>Note: Derived</i> ▪ SUR update rate: 1 Hz • <i>Note: as per ED-87C</i> ▪ SUR data delay: <= 0.5 s • <i>Note: as per ED-87C</i> ▪ SUR data probability of update: 90% (1 s) • <i>Note: as per ED-87C</i> ▪ SUR data accuracy: 40 m (95%) • <i>Note: Derived from initial safety considerations</i> ▪ Identification: 1E-4 • <i>Note: as per ED-87C</i> ▪ • Non-Conformance: Conflict Detection (aircraft separation violation on taxiway system) ○ Location: Taxiway ○ Required performance: ▪ SUR data stability (predictability): speed vector < 7.5 m/s (90%) or < +/- 15% of the actual speed (the higher value applies) ▪ SUR update rate: 1 Hz ▪ SUR data delay: < 0.5 s ▪ SUR data probability of update: 90% ▪ SUR data accuracy: 40 m ▪ Identification: 1E-4 <i>Note: The purpose of this requirement is to define the locations and needed performance to perform the intended operation.</i>	
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REQ-14.84b-TS-MRTS.0096	The performance of the MRT-SUR shall be in line with the operational need to control a Pan-Tilt-Zoom (PTZ) camera of the MRTM ○ Location: Follow selected target on the airport ○ Required performance ▪ SUR data stability (predictability): Speed vector < 5m/s (90%) or < +/- 10% of the actual speed (the higher value applies) ▪ SUR update rate: 1 Hz ▪ SUR data delay: < 1 s ▪ SUR data probability of update: 90% (1 s) ▪ SUR data accuracy: 40 m (95%) <i>Note: The purpose of this requirement is to define the locations and needed performance to perform the intended operation.</i>	TSSR-01, TSSR-02, TSSR-03, TSSR-04, TSSR-05
REQ-14.84b-TS-MRTS.0097	The MRT-SUR shall support object bounding as follows: - High quality of object bounding - Cooperative Targets based on MLAT/ADS-B with size provided by Video - Targets only ,on ground' (especially non-cooperative) Performance metrics - SUR data stability: high - SUR update rate: 1 Hz - SUR data delay: < 1s - SUR data probability of update: 90% - SUR data accuracy: 40 m (95%) - SUR data probability of false target report: 2E-4 per target report <i>Note: The purpose of this requirement is to define the locations and needed performance to perform the intended operation.</i>	TSSR-01, TSSR-02, TSSR-03, TSSR-04, TSSR-05

5.4 Technical Safety Requirements at design level addressing Internal System Failures

5.4.1 Design analysis with respect to internal system failure conditions

Design analysis addressing MRT-SUR internal failures was performed for the cooperative sub-sensor based on the analysis provided in section 4.2.

5.4.2 Technical Safety Requirements at design level addressing internal system failures

Table 5-2: Derived Technical Safety Requirement addressing the cooperative sub-sensor

Technical Safety Requirement ID	Technical Safety Requirement description (functionality & performance)	Derived from TSSR (ID) or Common cause failure
REQ-14.84b-TS-MRTS.0014	The ADS-B sub-sensor shall provide performance in line with EUROCAE ED-129B	TSSR-01, TSSR-02, TSSR-03, TSSR-04, TSSR-05
REQ-14.84b-TS-MRTS.0018	The performance of the mini-MLAT of the MRT-SUR sensor in support of services related to on-airport locations shall be as follows: • Probability of Update: ○ Manoeuvring Area: $\geq 95\%$ (1 s) ○ Taxiways and Taxi Lanes: $\geq 70\%$ (1 s) • Probability of Long Gaps: ○ Manoeuvring Area: $PLG(5\text{ s}) \leq 1E-3$ per Target Report ○ Taxiways and Taxi Lanes: $PLG(5\text{ s}) \leq 1E-2$ per Target Report • Position Accuracy: ○ Manoeuvring Area: 25 m (95%) ○ Taxiways and Taxi Lanes: 40 m (95%) • Probability of False and Ghost Detection: ○ $2E-4$ per TargetReport • Probability of Identification ○ Mode S Address: $\geq 99\%$ ○ Aircraft ID: $\geq 97\%$ • Probability of False Identification: $2E-4$ per Target Report • Target Report Update Rate: 1 s • Ground Processing & Communication Delay: $\leq 0.5\text{ s}$ <i>Note: the performance is linked to support the intended operational service expressed in REQ-14.84b-TS-MRTS.0021.</i>	TSSR-01, TSSR-02, TSSR-03, TSSR-04, TSSR-05

REQ-14.84b-TS-MRTS.0098	The performance of the mini-MLAT of the MRT-SUR sensor in support of services related to approach region shall be as follows: • Probability of Update: 90% (2 s) • Probability of Long Gaps: PLG(15s) $\leq 1E-3$ per Target Report • Position Accuracy: 160 m (95%) • Probability of False and Ghost Detection: 0.06% • Probability of Identification: 96.5 % • Probability of False Identification: $2E-4$ per Target Report • Target Report Update Rate: 2 s • Ground Processing & Communication Delay: ≤ 2 s <i>Note: the performance is linked to support the intended operational service expressed in REQ-14.84b-TS-MRTS.0021.</i>	TSSR-06
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Table 5-3. Additional TSRDs (functionality & performance) to mitigate functionality hazards

5.5 Realism and testability of the Safe Design

TVALP Part I provides the results of the technical validation. During the technical validation the performance of the MRT-SUR for cooperative targets was demonstrated. The performance assessment was conducted using the validated surveillance performance monitoring tools developed by solution PJ.14-W2-84e.

With respect to the non-cooperative sub-sensor the finally achieved maturity might be limited since the non-cooperative sub-sensor was not available for the technical validation, as described in the TVALP. In consequence the safety aspects related to non-cooperative targets were not feasible to be validated based on real operation.

With respect to the operational assessment addressing suitability of the sensors performance to conduct the intended operation a workshop with ATCOs was performed to capture their operational feedback.

5.6 Process assurance of the Safe Design

The developments performed by the partners followed internal quality assurance processes.

6 Demonstration of achievability of the Technical System Safety Specification

The MRT-SUR and the derived performance metrics developed and obtained within this solution PJ.14-W2-84b demonstrated to be mature enough to achieve a partial maturity level TRL6 for the MRT-SUR using only a cooperative sub-sensor to provide input data for targets on airport.

The performed validation showed that it is feasible to develop a cost-efficient surveillance sensor related to operations on small and regional single RWY and simple TWY airports with a tailored performance such that the situational awareness of ATCOs controlling multiple of such airports simultaneously is ensured. This statement is seen to hold true even if the non-cooperative sub-sensor of the MRT-SUR was not assessed.

7 Acronyms and Terminology

Term	Definition
ADD	Architecture Definition Document
ATCO	Air Traffic Controller
ATM	Air Traffic Management
AWP	Analysis Working Position; a DFS in-house product to display plot and tracks.
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.
CNS	Communication Navigation Surveillance
E-ATMS	European Air Traffic Management System
E-OCVM	European Operational Concept Validation Methodology
EXE	Exercise
FAF	Final Approach Fix
FAT	Factory Acceptance Test
IRS	Interface Requirements Specification
INCS	Independent non-cooperative Surveillance
INTEROP	Interoperability Requirements
LRR	Long Range Radar
MLAT	Multi Lateration

MRT	Multi Remote Tower
MRT-SUR	Multi Remote Tower Surveillance
MTBF	Mean Time Between Failures
MTBCF	Mean Time Between Critical Failures
OFA	Operational Focus Areas
OSED	Operational Service and Environment Definition
OTQC	Online Tracking Quality Control
POD	Probability of detection
PTZ	Pan Tilt Zoom Camera
RTC	Remote Tower Control
SAC	System Area Code
SAT	Site Acceptance Test
SESAR	Single European Sky ATM Research Programme
SIC	System Identification Code
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SPR	Safety and Performance Requirements
SUT	System Under Test
TS	Technical Specification
TVALP	Technical Validation Plan
TVALR	Technical Validation Report
VALP	Validation Plan
VALR	Validation Report
VALS	Validation Strategy
VP	Plan
VR	Report
VS	Strategy

WAM Wide Area Multilateration

Table 7-1: Acronyms

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
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
Incomplete Measurement	See Partial Measurement	Term introduced in this solution
Mini-MLAT	A mini-MLAT is a MLAT with a performance below what is specified in ED-117 (MLAT)	Term introduced in this solution
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
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-located receivers. It can be based on Mode-A/C or Mode-S signals.	Term introduced in this solution
Synthetic data	Any production data applicable to a given situation that are not obtained by direct measurement	McGraw-Hill Dictionary of Scientific and Technical Terms

Table 7-2: Glossary of terms

8 References

Safety

- [1] (EU) No 2017/373 laying down common requirements for service providers and the oversight in air traffic management/air navigation services and other air traffic management network functions, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011 and (EU) No 1035/2011 and amending Regulation (EU) No 677/2011 (and associated AMC and GM)
- [2] ICAO Doc 9830 MANUAL ON ADVANCED SURFACE MOVEMENT GUIDANCE AND CONTROL SYSTEMS (A-SMGCS), 2004
- [3] ED87C Minimum Aviation System Performance Specification (MASPS) for A-SMGCS
- [4] ED117 Minimum Operational Performance Specification for Mode S Multilateration Systems for Use in Advanced Surface Movement Guidance and Control Systems (A-SMGCS)
- [5] ED116 Minimum Operational Performance Specification for Surface Movement Radar Sensor System
- [6] EUROCAE ED 163 Safety, Performance and Interoperability Requirements Document for Ads-B Airport Surface Surveillance Application (ADS-B-APT)
- [7] EUROCAE ED-109 SOFTWARE INTEGRITY ASSURANCE CONSIDERATIONS FOR COMMUNICATION, NAVIGATION, SURVEILLANCE AND AIR TRAFFIC MANAGEMENT (CNS/ATM) SYSTEMS
- [8] ED-153 GUIDELINES FOR ANS SOFTWARE SAFETY ASSURANCE
- [9] D12.2.120 - PJ14-W2-84b -TRL6 Intermediate TS/IRS– Multi Remote Tower Surveillance (MRT-SUR)
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- [12] ED-109 Software Integrity Assurance Considerations for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems
- [13] Pj05 SAR Wave 1
- [14] Draft SESAR Solution PJ.05-W2-35-SPR-INTEROP/OSED for V3 – Part II – Safety Assessment Report (not yet submitted)
- [15] ED-012 SOFTWARE CONSIDERATIONS IN AIRBORNE SYSTEMS AND EQUIPMENT CERTIFICATION

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