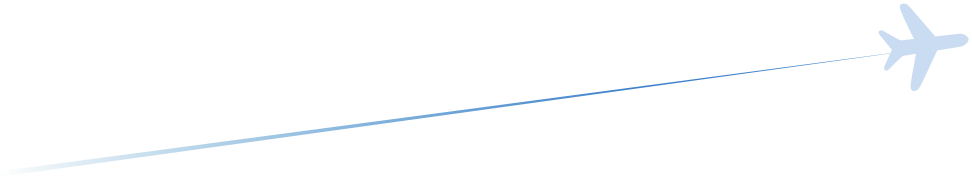

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Copyright Statement

NewSense

EVALUATION OF 5G NETWORK AND MMWAVE RADAR SENSORS TO ENHANCE SURVEILLANCE OF THE AIRPORT SURFACE

This Operational, security and safety Preliminary Requirements Analysis deliverable is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 893917 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document is the operational, security, and safety preliminary requirements analysis, D1.1, of the NewSense project. This deliverable provides applicable operational, security, and safety requirements that need to be considered in the solution design, and it also includes a preliminary requirements analysis.

The NewSense project aims at improving safety and efficiency of operations primarily in secondary airports, with innovative low-cost surface surveillance solutions using 5G and millimetre waves (mmWave) signals, widely used outside ATM, allowing the implementation of affordable Advanced-Surface Movement Guidance and Control Systems (A-SMGCS) and increasing the automation levels of Airport Collaborative Decision Making (A-CDM) milestones events detection.

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1 Introduction

1.1 Project overview

NewSense project aims at improving safety and efficiency of operations primarily in secondary airports with innovative low-cost surface surveillance solutions allowing the implementation of affordable Advanced-Surface Movement Guidance and Control Systems (A-SMGCS).

It also aims at developing gap-filler solutions that could be deployed at larger airports to cover up current system limitations such as coverage issues, to extend Air Traffic Controllers (ATCo's) situational awareness in the parking and apron areas, and to enable increase in automation levels through, for example, automated detection of Airport Collaborative Decision Making (A-CDM) milestones events.

The project has the following objectives:

- **Objective 1**: To propose an initial system design for an A-SMCGS system based on 5G Software Design Radio (SDR) receivers with 3D Vector antennas and relying on mmWave radar augmented with Artificial Intelligence (AI).
  - ✓ Identify and analyse the operational, technical performance, safety, and security requirements applicable to such system for use in an A-SMGCS from the existing standards.
  - ✓ Propose an initial system design and guidelines for building an A-SMCGS system based on NewSense sensors.
- **Objective 2**: To design a 5G-signal-based surveillance function for use in A-SMGCS including:
  - ✓ 3D vector antenna: source of Angle of Arrival (AOA) estimation.
  - ✓ A 5G positioning function identifying and calculating cooperative targets position using AOA and estimating Time of Arrival (TOA) from their transmitted 5G Radio Frequency (RF) signals.
  - ✓ A radar-like system relying on 5G signals to calculate all targets position from AOA and TOA of reflected 5G Base Station (BS) RF signals.
- **Objective 3:** To evaluate low-cost mmWave based radar as a non-cooperative surveillance solution for use in A-SMGCS.
  - ✓ Consolidate a preliminary mmWave technology capabilities assessment for use in A-SMCGS.
  - ✓ Provides an assessment of the mmWave radar augmented with AI to recognize target types from reflected mmWave radar signals.

As part of WP1, this document answers directly the objective 1, by identifying operational, performance, safety, and security requirements.

1.2 Document scope

This document D1.1 is the first deliverable of the NewSense WP1 (Assessment and Concept consolidation) that defines initial operational and safety requirements for the NewSense sensors that will be developed in WP2, WP3 and WP4.

The document D1.2 is the second deliverable within WP1 that will compile all the outcomes coming from WP2, WP3, and WP4 in order to consolidate a system design for building an A-SMCGS system based on NewSense sensors.

2 NewSense Concept

2.1 Introduction

As the ongoing growth of air traffic puts airports under pressure for greater capacity and increased safety, an important investment and research effort is aiming to develop A-SMCGS and equip airports with it. In the past ten years, most of the world's largest airports have initiated the implementation of an A-SMGCS Surveillance function together with the deployment of multilateration (MLAT) and surface movements radar (SMR).

However, regional airports could not afford the implementation of such surface surveillance technologies because of prohibitive infrastructure costs. The research effort is then focusing on alternative low-cost solutions that offer the sufficient surveillance level which is different for a small airport and a large airport. Additionally, an interest in the implementation of such low-cost technologies in large airports is increasing, as they could offer as gap-filler solutions to overcome the limitation of existing infrastructure especially in certain sections of the airport (stands, aprons, etc.)

The NewSense concept is a novel surveillance prototype suitable for any airport size. It relies on innovative and low-cost surveillance technologies solutions, developed outside the ATM domain, with the objective to overcome the limitations mentioned above.

The project will explore a long-term opportunity to position objects on the airport surface by using 5G based signals in addition to low-cost mmWave radar combined with AI.

In this document, the terms "cooperative" and "non-cooperative" will be used frequently, and their meaning needs to be clarified.

A cooperative target is defined in ED-87 [5] as "a target which is equipped with systems capable of automatically and continuously providing information including its identity to the A-SMGCS".

A non-cooperative target is defined in ED-87 [5] as "a target which is not equipped with systems capable of automatically and continuously providing information including its identity to the A-SMGCS".

2.2 NewSense Overview

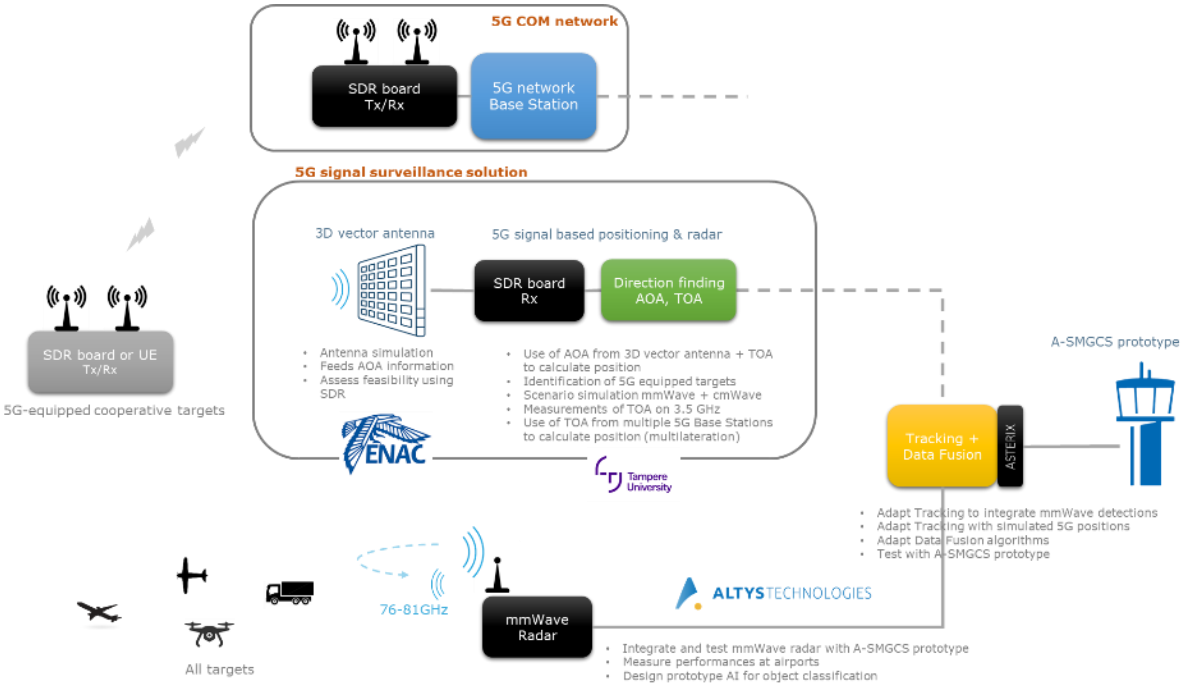

Figure 1 - The NewSense concept architecture diagram

The project will explore a long-term opportunity to position objects on the airport surface by monitoring 5G signals, assuming a large-scale 5G deployment in the next decades, with independent private 5G networks available at airports and with 5G equipment onboard aircraft. As such, the NewSense concept generates an opportunity for technological convergence with future datalink communications systems (c.f. SESAR 2020 project for use of 5G in CNS and mainly communication [2] [3]).

Additionally, the opportunity to use low-cost mmWave radar technology together with AI / Machine Learning will be investigated as a medium-term solution. MmWave radar will sensibly improve situational awareness over non-cooperative mobiles and enhance tracking function accuracy, as well as system redundancy, in all visibility conditions.

NewSense aims therefore to evaluate two surveillance solutions that aim to cover cooperative targets with 5G based signals and non-cooperative targets using mmWave radar as well as 5G based signals.

Innovative tracking and data fusion functions will be developed in NewSense to process information coming from the 5G surveillance solution and mmWave radar. The proposed interface for positioning data obtained from these two technologies will make possible to fuse them together and with existing surveillance solutions in order to obtain an assembled view.

2.2.1 5G-based signal surveillance solution

The NewSense 5G Signal Surveillance Solution relies on the combination of information essential to build a consolidated position information for each target operating on the airport surface. The concept implies calculation of the targets' positions by combining the AOA information obtained from an innovative 3D vector antenna, together with TOA information computed from the transmitted or reflected 5G signals.

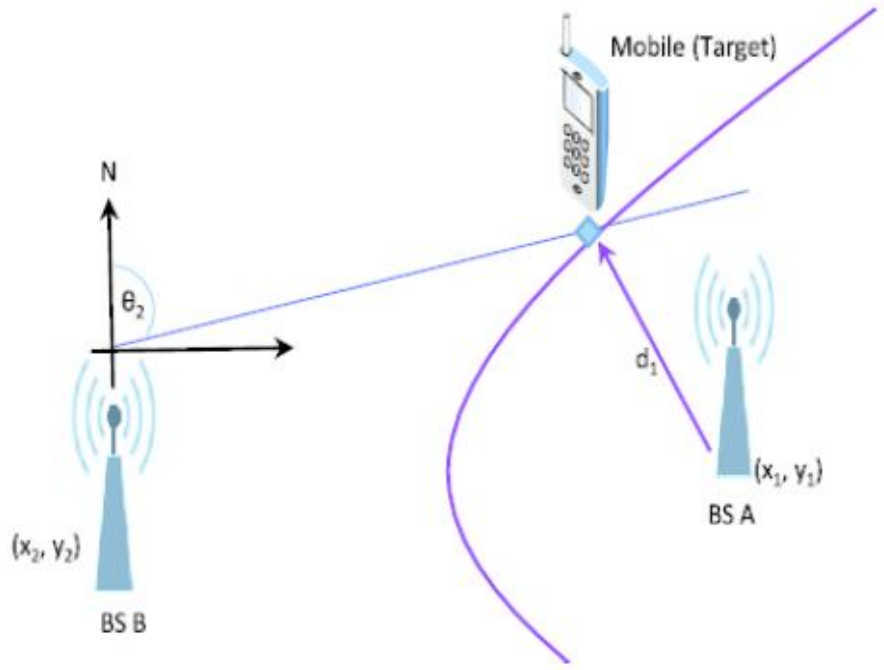

Figure 2 - Hybrid 5G signal TOA / AOA function

2.2.1.1 3D Vector antenna

The objective will be to design and study the performances of an RF device based on 3D direction finding with a vector antenna. This technology will be applied in the context of surveillance of cooperative targets by monitoring of 5G signals. The interest of this technology is to use the polarization diversity to resolve the 2D AOA of incoming electromagnetic fields. Consequently, the antenna size can be reduced while covering a 3D half-space.

2.2.1.2 5G-based positioning solution

The concept is to develop and evaluate a positioning system within the specifications of 5G New Radio (5G NR) for location estimation as part of a device tracking system on an airport, based on a single or several base stations.

5G signals transmitted by cooperative targets and received by the base station in combination with the 3D vector antenna will make possible the positioning of the transmitting source in what is called in 5G terminology an uplink (UL, i.e., signals from User Equipment (UE) to BS) configuration. In addition, the possibility of downlink (DL, i.e., signals from BS to UE) positioning directly at the cooperative target side will be investigated, based on the signal received by the cooperative target (e.g., the aircraft) from

the 5G base station(s). The cooperative targets do not necessarily need to be equipped with 3D vector antennas, as the 5G positioning can rely on either Angle of Arrival (AoA), or on the Angle of departure (AoD), depending on where the beamforming is possible (e.g., at target side, at the base station side, or at both sides).

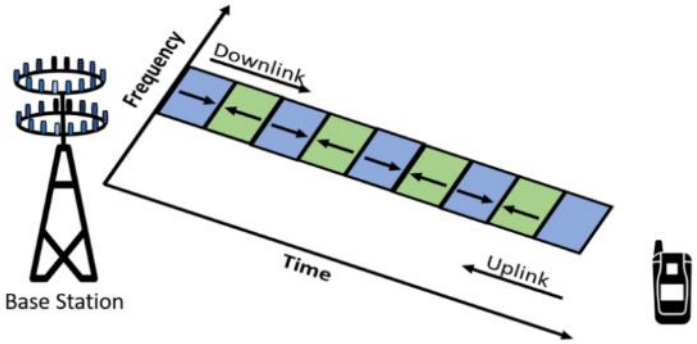

Figure 3 - 5G – uplink, downlink signals (TDD mode)

For non-cooperative targets on the airport surface, their position will be estimated from reflected 5G signals, with reflections received by the base stations (called next generation Node B (gNB) in 5G terminology).

Figure 4 - Terminology evolution from 1G to 5G

Target's classification will be investigated based on highly accurate Doppler measurements, or so-called micro-Doppler radar/detection. Drones equipped with 5G modems will be of particular interest due to their higher velocities and higher altitude fluctuations.

2.2.2 mmWave surveillance solution combined with AI

5G millimeter wave (mmWave) technology is commonly used outside the ATM domain, especially in automotive and industrial sectors (autonomous systems, robotics, etc.). It is used in the scope of NewSense project to cover non-cooperative targets on the airport surface.

The choice of using mmWave signals in the NewSense project is to overcome other technologies limitation such as cameras and LIDAR that have insufficient positioning performances in inclement weather conditions and low visibility conditions. In fact, mmWave signals offers a more favourable

characteristics than optical sensors (camera, LIDAR) in bad light and weather conditions. In addition, mmWave radars offer a high angular, range and direction resolution.

However, there is a limitation in current mmWave radar devices which is their inability to recognize objects. The NewSense project will introduce the use of AI techniques to automatically process radar signal reflections and classify object types.

2.2.3 Data Fusion

The data fusion module is responsible of the aggregation of redundant and complementary information coming from different positioning sensors. The redundancy will be managed by considering the reliability and integrity of position data provided by each source of information dynamically (which are expected to indicate the level of confidence).

The data fusion module inputs will be the mmWave sensors output and the 5G positioning solution output. Additional existing surveillance solutions such as ADS-B and camera could be used if they are used during the development study. In fact, these sensors could be used to validate results obtained from 5G based signals and mmWave surveillance solutions. They could be also used to train the AI model combined with mmWave signals reflection in case of insufficient data capable to characterize targets type.

3 NewSense A-SMGCS Requirements

3.1 Introduction

The purpose of this section is to make a preliminary analysis to identify A-SMGCS operational, security and safety requirements that the sensors developed in the scope of the NewSense project should comply with.

This preliminary analysis will be used as input for the sensors assessment and development during WP2, WP3, and WP4 and will be a reference during the final phase of the project that consists of proposing a system design that consolidates results obtained from technical WP listed above.

A-SMGCS requirements have been standardised into several recent standards including the EUROCAE document ED-87 MAPS for ASMCG-S [5]and the EUROCONTROL document Specification for A-SMGCS Services [4] and older documents such as the ICAO Doc 9830 A-SMGCS Manual [8]. These standards have been taken as input for the elaboration of NewSense A-SMGCS requirements taking into consideration only requirements that could be related to or impacted by the use of NewSense sensors.

3.2 NewSense A-SMGCS Concept

3.2.1 A-SMGCS Definition

A-SMGCS is defined in ICAO Manual [5] with different levels of implementation starting from level 1 (providing improved situational awareness to controller) to level 4 (providing more advanced functions such as conflict resolutions, automated planning, and guidance, etc.).

EUROCONTROL has opted for a Service definition of the A-SMGCS, and it is defined in [4] as:

“An A-SMGCS is a system that supports surface movement operations in all weather conditions at an aerodrome based on defined operational procedures. It consists of **the Surveillance Service** that provides the position, identification and tracking of mobiles and can include a combination of the following services.

- **The Airport Safety Support Service** that provides the functions: Runway Monitoring and Conflict Alerting (RMCA), Conflicting ATC Clearances (CATC), Conformance Monitoring Alerts for Controllers (CMAC).
- **The Routing Service** that generates ground trajectories for mobiles.
- **The Guidance Service** that provides the functions: Automated Switching of Taxiway Centreline Lights (TCL), Automated Switching of Stop Bars and Automated Activation of Advanced-Visual Docking Guidance Systems (A-VDGS).”

The Surveillance Service is the minimum service that should be provided by an A-SMGCS as it improves the airport traffic situational awareness on the airport surface and in the approach volume via a Human Machine Interface (HMI) showing aircraft and mobiles present on the coverage zone with identification, position and tracking information. This corresponds to the level 1 of A-SMGCS implementation as defined in ICAO Manual [8].

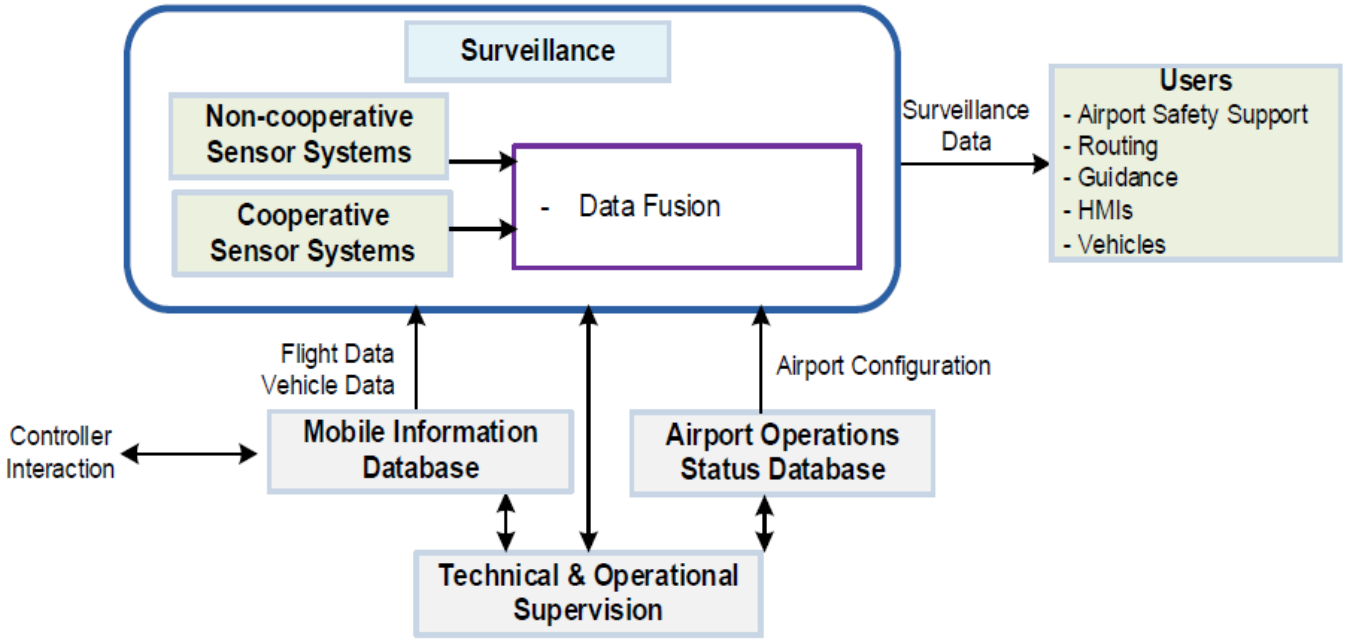

Figure 5 - Surveillance Service Architecture (from EUROCONTROL [4])

3.2.2 NewSense A-SMGCS

NewSense project aims to evaluate the use of 5G-based signal and mmWave radar, commonly used outside the ATM domain, as alternative low-cost surveillance sensors for use in A-SMGCS. In order to focus on the project main objective and as the maturity level in the NewSense project is TRL1, the research effort will not focus on the implementation of an A-SMGCS solution, but on the assessment of the operational, safety, and security performances obtained from the use of non-cooperative and cooperative NewSense sensors in an A-SMCGS low-cost solution. However, a system design will be proposed at the end of the NewSense project to put forward an A-SMGCS solution that integrates NewSense sensors and satisfies the minimum requirements necessary for an A-SMGCS.

Setting-up an A-SMGCS and its various services is a local decision based on the needs of an aerodrome and any national or regional mandates. For this reason, the proposed system design should consider the feed-back and needs expressed by the NewSense Advisory Board (e.g. ANSPs, airport operators) in order to select appropriate A-SMGCS services and local rules.

3.3 NewSense A-SMGCS Requirements

NewSense A-SMGCS requirements detailed in following sub-sections will focus on the minimum operational, performance, safety and security requirements applicable to NewSense sensors (5G-based signals and mmWave radar) for use in an A-SMGCS, by pointing applicable requirements from existing standards [4] [5] [6] or by identifying new requirement when applicable.

The standard requirements which are completely independent of the choice of surveillance sensors and their use in A-SMGCS (e.g. HMI implementation aspects, alerts management, guidance and routing services implementation and system monitoring, etc.) will not be assessed in following sub-sections as they are already detailed in existing standards [4] [5] [6] and that is not the purpose of this preliminary requirement analysis directly linked to the impact of using NewSense sensors in an A-SMGCS solution.

3.3.1 Operational Requirements

The operational requirements listed in this section refer to commonly applied requirements in an A-SMGCS independently of the airport parameters (visibility conditions, traffic density, local rules, airport map complexity, etc).

As stated in section 3.2.1 , the Surveillance Service is the minimum service that should be provided by an A-SMGCS. Surveillance Service requirements that have been identified in the EUROCONTROL Specification for A-SMGCS Services shall be considered in the design of the NewSense A-SMGCS solution. These requirements mainly relate to covering all targets type (cooperative and non-cooperative), providing the position, identification, speed and heading of mobiles, etc. within the coverage volume.

NEWSENSE-A-SMGCS-Req-01
NewSense A-SMGCS **shall** be compliant with the general “shall” requirements as defined in the EUROCONTROL Specification for A-SMGCS Services [4]. These requirements are listed in Appendix A.

The Coverage Volume is defined in [5] as the geographic volume on and around the airport within the A-SMGCS must provide the required surveillance performance capabilities. It includes:

- Runway(s) final approach
- Initial Climb out
- Manoeuvring area
- Apron taxiways and aircraft stand taxi lanes
- Stands

The coverage of NewSense sensors should be evaluated and results should be considered in the final system design. Complementary sensors or external procedures for non-covered areas could be proposed if necessary.

NEWSENSE-A-SMGCS-Req-02
NewSense A-SMGCS **shall** identify and position all mobiles on the airport surface within the targeted Coverage area.

As NewSense sensors can work independently of weather and visibility conditions, they should offer an augmented situational awareness in low visibility conditions.

NEWSENSE-A-SMGCS-Req-03
NewSense A-SMGCS **shall** support surface movement operations in all weather conditions.

NEWSENSE-A-SMGCS-Req-04
NewSense A-SMGCS **shall** provide a visual presentation of the airport surface augmented in low visibility conditions.

The need for a continuous availability should be considered in the design of the NewSense A-SMGCS solution. In case of service loss or unscheduled break, the downtime shall be short and without impact on flight operations or safety. Sensor's redundancy in critical areas that need to be covered by more than one sensor should be also assessed to avoid service loss if case of equipment failure.

NEWSENSE-A-SMGCS-Req-05
NewSense A-SMGCS **shall** provide a continuous service with relevant fallback procedures in case of service unavailability or equipment failure.

The simultaneous use of two independent type of sensors, i.e., 5G and mmWave, allows NewSense A-SMGCS to be compliant with this requirement.

3.3.2 Performance Requirements

The evaluation of the surveillance solution performances is very important because it is the major source of information on which the performance of the A-SMGCS depends. In this section, performance requirements are not sensors specific. However, they could concern some sensors and not others, depending on the type of the target (cooperative or non-cooperative) or the area of interest that could be covered by a certain type of sensors only.

Minimum surveillance performance requirements for the A-SMGCS have been defined in the ED-87 [5]. Recommended performance levels are location dependant: they have been defined according to the area in the Coverage Volume (cf. 3.3.1) and are given in Appendix B.

In ED-87 [5], performance requirements should be measured at the output of the Surveillance Service of the A-SMGCS. When applied to the output of the A-SMGCS, these performance parameters are not sensor specific, as it is applied to the output of the data fusion system that has as input different sensors types. However, as the aim of NewSense project is to evaluate the use of new surveillance sensors for A-SMGCS, performance requirements will be defined at the output of each sensor. This approach is applied also in some EUROCAE standards: In ED-117 [8] , performance requirements are applied to the output of the MLAT system (cf. Figure 6) and in ED-116 [7] performance requirements are applied at the output of the SMR sensor systems.

Following the same logic as in ED-87 [5], the surveillance performance requirements in this document focus on the ground part of the aerodrome (i.e. manoeuvring area, apron taxiways and aircraft stand taxi lanes and stands) as airborne related requirements are covered by existing standards for the Approach Control Service.

According to ED-87 (section 3.3.20), some performance parameters given in the table in Appendix B are reduced for non-cooperative surveillance solution (e.g. Probability of Target Report (PTR) and Probability of False Target Report (PFTR)) and others apply only to cooperative targets (mainly identification related requirements). For these reasons, performance requirements for NewSense surveillance system will be assessed depending on the target type (i.e. cooperative or non-cooperative).

3.3.2.1 Performance requirements for cooperative surveillance system

Requirements defined in this section will be applied only to the 5G based surveillance solution as mmWave radar is not a cooperative surveillance system.

EUROCAE has defined performance requirements for Mode S Multilateration (MLAT) Systems in ED-117 [8]. This is an interesting point of view for the definition of NewSense surveillance system performance requirements for cooperative sensors as the objective is to replace costly surveillance cooperative technologies such as MLAT with low-cost cooperative technologies (i.e. 5G based signal surveillance solution).

EUROCAE ED-117 [8] MLAT Performance requirements are compliant with the requirements of the surveillance function within EUROCAE ED-87 (cf. Appendix B) and are given in the table below:

Performance Parameter	Manoeuvring Area	Apron Taxiways and Taxi Lanes	Stands
PTR Probability of Target Report (update rate)	≥ 95 % (1 s)	≥ 70 % (1 s)	≥ 90 % (5 s)
PFTR Probability of False Target Report	≤ 10^{-4} per Target Report		
PID Probability of Identification (see Note 1)	Mode S Address: ≥ 99% Mode A Code: ≥ 97% Aircraft ID: ≥ 97%		
PFID Probability of False Identification	≤ 10^{-4} per Target Report		
RPA Reported Position Accuracy (see Notes 2,3,4)	≤ 12 m (95 %)	≤ 20 m (95%)	≤ 25 m (95%)
TRUR Target Report Update Rate	≥ 1 Hz	≥ 1 Hz	≥ 0.2 Hz
IRTOP Identification Renewal Time Out Period	≤ 30 s		
PLG Probability of Long Horizontal Gaps	Gaps ≥ 3 s: PLG ≤ 10^{-3} per Target Report	Gaps ≥ 3 s: PLG ≤ 10^{-2} per Target Report	Gaps ≥ 15 s: PLG ≤ 10^{-3} per Target Report
TRIT Target Report Initiation Time	≤ 3 s	≤ 6 s	≤ 13 s
System Capacity	300 Targets		
Latency	≤ 0.5 s		
Time Synchronisation	+/- 0.1 s		
Switchover Time	≤ 3 s		
Failure Report Time	≤ 10 s		

Figure 6 - ED-117 MLAT Performance Requirements Table

In the scope of NewSense project, performance requirements for the 5G surveillance solution will be measured at its output. Requirement values will be based on those used for MLAT system as defined in ED-117 and when not applicable, they will be based on performance requirements defined in ED-87 (cf. Appendix B)

Only the performance parameters that are derived from sensors performances, and therefore could be assessed in the scope of NewSense project, will be considered. The other performance parameters are not applicable or not measurable within the scope of NewSense as they apply to the operational system.

Considered performance parameters are listed below.

- Probability of Target Report (PTR):

In ED-117 [8], the PTR is defined as: the probability that each target is reported at each update at the output of the surveillance solution.

NEWSENSE-A-SMGCS-Req-06
The 5G surveillance solution **shall** achieve the PTR value for each respective area, as specified in Table 1.

- Probability of False Target Report (PFTR)

In ED-117 [8], the PFTR is defined as the probability to detect a target which does not reflect an actual target or which position is more than a certain distance from its real position.

NEWSENSE-A-SMGCS-Req-07
The 5G surveillance solution **shall** achieve the PFTR value for each respective area, as specified in Table 1.

- Probability of Identification (PID)

In ED-117 [8], the PID is defined as the probability that the correct identity of a target is reported at the output of the Surveillance element for each Target Report.

NEWSENSE-A-SMGCS-Req-08
The 5G surveillance solution **shall** achieve the PID value for each respective area, as specified in Table 1.

- Probability of False Identification (PFID)

In ED-117 [8], the PFID is defined as the probability that the identity reported at the output of the Surveillance system is not the correct target identity.

NEWSENSE-A-SMGCS-Req-09
The 5G surveillance solution **shall** achieve the PFID value for each respective area, as specified in Table 1.

- Reported Position Accuracy (RPA)

In ED-117 [8], the RPA is defined as the difference between the reported position of the Target and the Target Position Reference Point (TPRP) at the time of the target report.

The TPRP is the mid-point of the geometric centreline of a target.

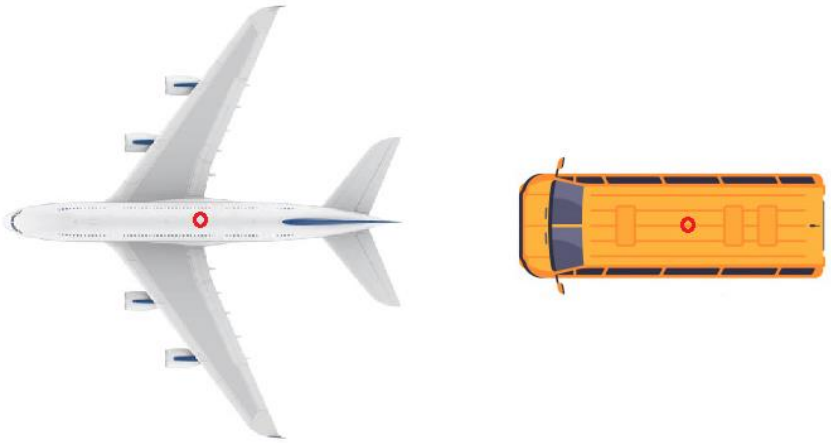

Figure 7 - TPRP for an aircraft and a vehicle

NEWSENSE-A-SMGCS-Req-10
The 5G surveillance solution **shall** achieve the RPA value for each respective area, as specified in Table 1.

- Target Report Update Rate (TRUR)

In ED-117 [8], the TRUR is defined as the frequency with which target reports are output from the surveillance system.

NEWSENSE-A-SMGCS-Req-11
The 5G surveillance solution **shall** achieve the TRUR value for each respective area, as specified in Table 1.

- Identification Renewal Time-out Period (IRTOP)

In ED-117 [8], the IRTOP is defined as the elapsed time after which the output of valid identification data in a Target Report for a specific Target will be terminated due to a lack of renewed identification data.

This parameter is applicable only if interrogations will be used by the surveillance system.

NEWSENSE-A-SMGCS-Req-12
The 5G surveillance solution **shall** achieve the IRTOP value for each respective area, as specified in Table 1.

- Probability of Long Horizontal Gaps (PLG)

In ED-117 [8], the PLG is defined as the probability of target reporting gaps exceeding an operationally acceptable duration once a target has been initiated and reported.

NEWSENSE-A-SMGCS-Req-13
The 5G surveillance solution **shall** achieve the PLG value for each respective area, as specified in Table 1.

- Target Report Initiation Time (TRIT)

In ED-117 [8], the TRIT is defined as the elapsed time from the first available signal of a target within the Coverage Volume to the output of the first target report from the surveillance system.

NEWSENSE-A-SMGCS-Req-14
The 5G surveillance solution **shall** achieve the TRIT value for each respective area, as specified in Table 1.

Performance requirements for the 5G solution given in Table 1 are defined for each aera within the ground part of the aerodrome (i.e. manoeuvring area, apron taxiways and aircraft stand taxi lanes and stands). If these requirements could not be achieved using a single 5G base station, a network of 5G base stations shall be deployed to cover all aeras.

NEWSENSE-A-SMGCS-Req-15
The 5G surveillance solution **shall** deploy enough 5G base stations to achieve performance requirements defined in Table 1.

Performance requirements for the 5G surveillance solution are given in the table below.

Performance Parameter	Manoeuvering Area	Apron Taxiways and Taxi Lanes	Stands
PTR Probability of Target Report (update rate)	≥ 95 % (1 s)	≥ 70 % (1 s)	≥ 90 % (5 s)
PFTR Probability of False Target Report	≤ 10^{-4} per Target Report		
PID Probability of Identification	≥ 99% (If interrogations will be used, this value could be reduced to 97% in order to protect the spectrum from over-interrogations)		
PFID Probability of False Identification	≤ 10^{-4} per Target Report		
RPA Reported Position Accuracy	≤ 12 m (95 %)	≤ 20 m (95 %)	≤ 25 m (95 %)
TRUR Target Report Update Rate	≥ 1 Hz	≥ 1 Hz	≥ 0.2 Hz
IRTOP Identification Renewal Time-out Period	≤ 30 s		
PLG Probability of Long Horizontal Gaps	Gaps ≥ 3 s: PLG ≤ 10^{-3} per Target Report	Gaps ≥ 3 s: PLG ≤ 10^{-2} per Target Report	Gaps ≥ 15 s: PLG ≤ 10^{-3} per Target Report
TRIT Target Report Initiation Time	≤ 3 s	≤ 6 s	≤ 13 s

Table 1 - Performance requirements for the 5G surveillance solution

3.3.2.2 Performance requirements for non-cooperative surveillance system

Requirements defined in this section will be applied to mmWave radar solution for all targets and to the 5G based surveillance solution for non-cooperative targets that are not equipped with a 5G transmitter.

EUROCAE has defined performance requirements for SMR sensor systems for use in A-SMGCS in ED-116 [7]. This is an interesting point of view for the definition of NewSense surveillance system performance requirements for non-cooperative sensors as the objective is to replace costly surveillance non-cooperative technologies such as SMR with low-cost cooperative technologies (i.e. mmWave radar and 5G surveillance solution).

EUROCAE ED-116 [7] MLAT Performance requirements are compliant with the requirements of the surveillance function within EUROCAE ED-87 (cf. Appendix B). All identification related requirements (e.g. PID, PFID, IRTOP) that are defined in ED-87 are not applicable to non-cooperative surveillance.

In the scope of NewSense project, performance requirements for non-cooperative surveillance systems (i.e. mmWave radar and 5G surveillance solution) will be measured at their outputs. Requirement values will be based on those used for SMR system as defined in ED-116.

Only performance parameters that are derived from sensors performances and therefore could be assessed in the scope of NewSense project, will be considered. The other performance parameters are not applicable or not measurable within the scope of NewSense as they apply to the operational system.

Considered performance parameters are listed below.

- Detection Sensitivity:

In ED-116 [7], the Detection Sensitivity is defined as the probability that all types of vehicle, aircraft and obstacle are detected per scan, whether moving or stationary, having an equivalent Radar Cross-Section (RCS) of at least 1 m^2, everywhere within the specified coverage area.

NEWSENSE-A-SMGCS-Req-16
NewSense non-cooperative surveillance solutions **shall** achieve the Detection Sensitivity value as specified in Table 2.

- False Alarm Rate of Target Detection

The False Alarm Rate of Target Detection is the probability to detect a target which does not reflect an actual target or which position is more than a certain distance from its real position.

NEWSENSE-A-SMGCS-Req-17
NewSense non-cooperative surveillance solutions **shall** achieve the False Alarm Rate of Target Detection value everywhere within the specified coverage area as specified in Table 2.

- Data Renewal Rate

In ED-116 [7], the Data Renewal Rate is defined as the frequency at which the radar shall perform a complete scan of the entire specified coverage area and provide a new set of data.

NEWSENSE-A-SMGCS-Req-18
NewSense non-cooperative surveillance solutions **shall** achieve the Data Renewal Rate value as specified in Table 2.

- Targets Dynamics

In ED-116 [7], the Targets Dynamics is defined as the speed range of targets that should be detected within the specified coverage area.

NEWSENSE-A-SMGCS-Req-19
NewSense non-cooperative surveillance solutions **shall** detect targets with speed in the Targets Dynamics range as specified in Table 2.

- Displacement Detection

The Displacement Detection is the minimum target displacement that should be detected by the radar in any direction anywhere within the specified coverage area.

NEWSENSE-A-SMGCS-Req-20
NewSense non-cooperative surveillance solutions **shall** detect a minimum target displacement as specified in Table 2.

- Targets Classification

Targets Classification is the output information that will be used by the A-SMGCS to discern the various types of target (i.e., Aircraft, vehicle, man, etc.) within the specified coverage area.

NEWSENSE-A-SMGCS-Req-21
NewSense non-cooperative surveillance solutions **shall** output the Targets Classification information specified in Table 2.

- Target Discrimination Distance

The Target Discrimination Distance is the minimum distance that separates two targets that should be distinguished and resolved by the radar in any direction within the specified coverage area.

NEWSENSE-A-SMGCS-Req-22
NewSense non-cooperative surveillance solutions **shall** achieve the Target Discrimination Distance value as specified in Table 2.

- Reported Position Accuracy (RPA)

The RPA is defined in 3.3.2.1.

NEWSENSE-A-SMGCS-Req-23
NewSense non-cooperative surveillance solutions **shall** achieve the RPA value as specified in Table 2.

Performance requirements for the NewSense non-cooperative surveillance solution given in Table 2 are applicable to all the ground part of the aerodrome. If these requirements cannot be met using a single non-cooperative sensor (e.g. one mmWave radar), a network of sensors shall be deployed to cover all target areas (i.e. manoeuvring area, apron taxiways and aircraft stand taxi lanes and stands).

NEWSENSE-A-SMGCS-Req-24
NewSense non-cooperative surveillance solutions **shall** deploy, if necessary, a network of non-cooperative sensors to achieve performance requirements defined in Table 2.

Performance requirements for the NewSense non-cooperative surveillance solutions are given in the table below.

Performance Parameter	Value/Type
Detection Sensitivity	≥ 90 %
False Alarm Rate of Target Detection	10^{-4}
Data Renewal Rate	1 second
Targets Dynamics	0 to at least 250 knots
Displacement Detection	7.5 m
Targets Classification	Target size
Target Discrimination Distance	30 m
Reported Position Accuracy (RPA)	≤ 7.5 m (95%)

Table 2 - Performance requirements for the NewSense non-cooperative surveillance

3.3.3 Safety Requirements

The performance of the Airport Safety Support Service (cf. 3.2.1) depends on the input data received from other A-SMGCS services including the Surveillance Service.

In this section, we are focusing on the impact of using NewSense sensors on safety requirements as defined in ED-87 [5]. Safety functions (detection of alert situation, runway monitoring, conflict detection, etc.) should be assessed against the expected surveillance performance to determine how they can be implemented.

In fact, if the safety function relies on the position of a target (e.g. alert raised when an aircraft crosses a line), it will be limited by the accuracy of detection of that target. The integrity of target position is also very important in the generation of alerts because false target reports may lead to false alerts generated by the Airport Safety Support Service. In addition to that, the number of target reports may also to be higher than rates required by the Surveillance service to achieve the required probability of detection of alerts.

Safety requirements depend on the set of alerts and rules that should be implemented in the A-SMGCS which is depending on local rules and operational needs. The requirements defined for the Surveillance service in Table 1 and Table 2 could be sufficient to achieve the required safety requirements or they might need to exceed defined minimum requirements.

In the scope of NewSense project, we are targeting to achieve the safety performances that drive from the surveillance performance parameters defined in Table 1 and Table 2.

NEWSENSE-A-SMGCS-Req-25
NewSense A-SMGCS **shall** achieve the safety performances that drive from the surveillance performance parameters defined in Table 1 and Table 2.

Safety requirements as defined in ED-87 [5] depend also on the system availability and reliability and especially the availability and reliability of input data from the data fusion system that derives from Surveillance sensors.

- Availability

In ED-116, availability is defined as the probability that a system or an item is in a functioning state at a given point in time. Availability requirements listed below derive from ED-116.

NEWSENSE-A-SMGCS-Req-26
NewSense Surveillance system **shall** be able to operate 24 hours throughout the year and its availability, allowing for necessary maintenance, shall be 99.9%.

NEWSENSE-A-SMGCS-Req-27
NewSense Surveillance sensors **shall** be installed and configured so that essential maintenance can be performed without interrupting the system.

- Reliability:

In ED-116, reliability is defined as the ability of a system or an item to perform a required function under specified conditions, without failure, for a specified period of time. Reliability requirements listed below derive from ED-116.

NEWSENSE-A-SMGCS-Req-28
NewSense Surveillance system **shall** be designed, as a minimum, to meet a failure rate of 10^{-4} per operational hour.

NEWSENSE-A-SMGCS-Req-29
NewSense Surveillance sensors **shall** be designed with a dual redundant configuration to minimise signal points of failure. Automatic or manual changeover **shall** be performed within three seconds in case of equipment failure or maintenance operation.

3.3.4 Security Requirements

As specified in ICAO doc [6], all ground modules (including surveillance sensors) for an A-SMGCS should be sited within the aerodrome boundary for security and maintenance reasons. In the scope of NewSense project, 5G and mmWave sensors will to be deployed on the airport surface.

NEWSENSE-A-SMGCS-Req-30
NewSense Surveillance sensors **shall** be deployed on the airport surface for security and maintenance reasons.

The choice, the electronic design (e.g. maximum input and output powers, filters, etc.), the bandwidth and the signal processing chain (e.g. response to non-coherent signals) of NewSense Surveillance sensors should limit the effectiveness of jamming attacks such as deception jamming and noise jamming.

NEWSENSE-A-SMGCS-Req-31
NewSense Surveillance sensors **shall** be robust against jamming techniques such as deception jamming and noise jamming.

4 References

[1] NewSense Grant Agreement Description of Action - GA- 893917-NewSense

[2] FACT (Future All Aviation CNS Technology) SESAR 2020 project: Test Nokia 4G/5G Connectivity for Controller to Pilot Data Communications

[3] SESEAR solution PJ.14-W2-61 – Hyper Connected ATM (Industrial Research) – To explore the concept of an enlargement of the Future Communication Infrastructure (FCI) through integration of open network services and commercial public radio.

[4] EUROCONTROL Specification for Advanced-Surface Movement Guidance and Control System (A-SMGCS) Services, Edition: 2.0, Edition date: 22 April 2020, Reference nr: EUROCONTROL-SPEC-171

[5] EUROCAE ED-87 – Minimum Aviation System Performance Specification (MASPS) for A-SMGCS, revision D, June 2019

[6] ICAO Doc 9830 - Advanced-Surface Movement Guidance and Control System (A-SMGCS) Manual, 2004

[7] ED-116 – MOPS for Surface Movement Radar Sensor Systems for use in A-SMGCS, January 2004

[8] ED-117A – MOPS for Mode S Multilateration systems for use in A-SMGCS

Appendix A EUROCONTROL A-SMGCS Surveillance Service Requirements

ASMGCS-[SURV]-[010] The Surveillance Service shall include at least one cooperative sensor and at least one non-cooperative sensor.

ASMGCS-[SURV]-[020] The Surveillance Service shall provide the identification, position and tracking of mobiles within a predefined Coverage Volume.

ASMGCS-[SURV]-[030] The Surveillance Service shall be designed to minimise the following effects:

- Radio interference, including that produced by standard navigation, telecommunications and radar facilities (including airborne equipment).
- Signal reflections and shadowing caused by aircraft in flight, vehicles or aircraft on the ground, buildings, snow banks or other raised obstacles (fixed or temporary) in or near the aerodrome environment.

ASMGCS-[SURV]-[040] The Surveillance Service shall be designed to operate in meteorological conditions applicable to the aerodrome or any state of the aerodrome resulting from adverse weather.

ASMGCS-[SURV]-[050] The Surveillance Service shall use transponder signals for the purpose of determining the location and identity of cooperative aircraft.

Note: The transponder operating procedures for Flight Crew are normally published in the AIP.

ASMGCS-[SURV]-[060] The Surveillance Service shall use transmitter signals for the purpose of determining the location and identity of cooperative vehicles.

ASMGCS-[SURV]-[070] The HMI shall display every mobile in the correct position with respect to the aerodrome layout and other traffic.

ASMGCS-[SURV]-[080] The Surveillance Service shall calculate the current speed and heading of mobiles within the Coverage Volume.

ASMGCS-[SURV]-[090] The Surveillance Service should ensure a seamless transition is provided between the surveillance from the approach radar and the surveillance from the A-SMGCS.

ASMGCS-[SURV]-[100] The HMI shall allow the manual assignment of an identification label to a non-identified target.

ASMGCS-[SURV]-[110] The Surveillance Service may provide the Actual Landing/In-Block/Off-Block/Take-Off Time (ALDT/AIBT/AOBT/ATOT) to external systems.

Appendix B EUROCAE ED-87 Surveillance Performance Requirements

PERFORMANCE PARAMETER	Manoeuvring area	Apron taxiways and aircraft stand taxi lanes	Stands
PTR (3.3.6.1) (see NOTE 19 and NOTE 20) Probability of Target Report (update rate)	≥ 99% (1 s)	≥ 90% (1 s)	≥ 95% (5 s)
PFTR (3.3.6.2) (see also NOTE 20) Probability of False Target Report	≤ 10^{-4} per report	≤ 10^{-4} per report	≤ 10^{-4} per report
PID (3.3.7.2) (see also NOTE 22) Probability of Identification	≥ 99.9%	≥ 99.9%	≥ 98%
PFID (3.3.7.3) (see also NOTE 22) Probability of False Identification	≤ 10^{-4} per identified report	≤ 10^{-4} per identified report	≤ 10^{-4} per identified report
RPA (3.3.8) (see also NOTE 23) Reported Position Accuracy	≤ 12 m (95%)	≤ 20 m (95%)	≤ 25 m (95%)
TRUR (3.3.9) (see also NOTE 21) Target Report Update Rate	≥ 1 Hz	≥ 1 Hz	≥ 1 Hz
RVA (3.3.10) (see also NOTE 21) Reported Velocity Accuracy	< 5m/s (90%) or < +/- 10% of the actual speed (the higher value applies)	< 5m/s (90%) or < +/- 10% of the actual speed (the higher value applies)	Not applicable.
TDL (3.3.11) Target Display Latency	≤ 0.5 s	≤ 0.5 s	≤ 0.5 s
PRTOP (3.3.12.1) (see also NOTE 21) Position Renewal Time Out Period	≤ 4 s	≤ 4 s	≤ 10 s
IRTOP (3.3.12.2) (see also NOTE 22) Identification Renewal Time Out Period	≤ 30 s	≤ 30 s	≤ 30 s
TC/GAPS (3.3.13) Track Continuity	Gaps > 5s: TC :≤ 10^{-6} per Target Report 3s ≤ Gaps ≤ 5s: TC: ≤ 10^{-3} per Target Report	Gaps > 5s: TC: ≤ 10^{-5} per Target Report 3s ≤ Gaps ≤ 5s: TC: ≤ 10^{-3} per Target Report	Gaps > 5s: TC: ≤ 10^{-3} per Target Report
TRIT (3.3.14) (see also NOTE 21) Target Report Initiation Time	≤ 5 s	≤ 8 s	≤ 15 s
TRPR (3.3.15) Target Report Position Resolution	≤ 1 m	≤ 1 m	≤ 1 m
TRVR (3.3.16) Target Report Velocity Resolution	≤ 0.25 m/s per cartesian velocity component	≤ 0.25 m/s per cartesian velocity component	≤ 0.25 m/s per cartesian velocity component
TRTR (3.3.17) Target Report Time Resolution	≤ 0.1 s	≤ 0.1 s	≤ 0.1 s
TCA (3.3.19) (See also NOTE 24) Target Course Accuracy	+/-15° (90%)	+/-15° (90%)	+/-30° (90%)

Figure 8 EUROCAE ED-87 Surveillance Performance Requirements table [5]

Appendix C Acronyms

A-CDM	Airport Collaborative Decision Making
ADS-B	Automatic Dependent Surveillance-Broadcast
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
AOA	Angle of Arrival
AOD	Angle of departure
A-SMGCS	Advanced-Surface Movement Guidance and Control System
ATC	Air Traffic control
ATCO	ATC Officer
ATM	Air Traffic Management
A-VDGS	Advanced-Visual Docking Guidance Systems
BS	Base Station
CATC	Conflicting ATC Clearances
CMAC	Conformance Monitoring Alerts for Controllers
cmWave	Centimetre wave
DL	Dowlink
GA	Grant Agreement
gNB	Next Genration NodeB
HMI	Human Machine Interface
ICAO	International Civil Aviation Organization
IRTOP	Identification Renewal Time-out Period
LIDAR	Laser Imaging, Detection And Ranging
MLAT	Multilateration
mmWave	Millimetre Waves
NR	New Radio
RCS	Radar Cross-Section
RF	Radio Frequency
RMCA	Runway Monitoring and Conflict Alerting
PFID	Probability of False Identification
PFTR	Probability of False Target Report
PID	Probability of Identification

PLG	Probability of Long Horizontal Gaps
PTR	Probability of Target Report
RPA	Reported Position Accuracy
SDR	Software Design Radio
SJU	Sesar Joint Undertaking
SMR	Surface Movements Radar
TCL	Taxiway Centreline Lights
TDD	Time Division Duplexing
TOA	Time of Arrival
TPRP	Target Position Reference Point
TRIT	Target Report Initiation Time
TRL	Technology readiness level
TRUR	Target Report Update Rate
UE	User Equipment
UL	Uplink
WP	Work Package


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