



The European Organisation for Civil Aviation Equipment
L'Organisation Européenne pour l'Équipement de l'Aviation Civile

MINIMUM OPERATIONAL PERFORMANCE SPECIFICATION FOR MODE S MULTILATERATION SYSTEMS FOR USE IN ADVANCED SURFACE MOVEMENT GUIDANCE AND CONTROL SYSTEMS (A-SMGCS)

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FOREWORD

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2. EUROCAE is an international non-profit making organisation. Membership is open to European manufacturers of equipment for aeronautics, trade associations, national civil aviation administrations, users, and non-European organisations. Its work programme is principally directed to the preparation of performance specifications and guidance documents for civil aviation equipment, for adoption and use at European and worldwide levels.
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5. This document is compliant with the requirements of the surveillance function within EUROCAE ED-87C [2.] ("MASPS for Advanced Surface Movement Guidance and Control Systems, January 2015").
6. Copies of this document may be obtained from:

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CHAPTER 1

GENERAL

1.1 PURPOSE AND SCOPE

This EUROCAE Minimum Operational Performance Specification (MOPS) specifies the minimum performance requirements for a Multilateration (MLAT) System which is one of the co-operative sensors for use in Advanced Surface Movement Guidance and Control Systems (A-SMGCS).

Chapter 1 of this document provides the necessary information to understand the need for technical characteristics and tests of this MLAT System that are described in the following chapters. This chapter also describes the typical applications of the system and the operational objectives. Along with EUROCAE ED-87C [2.], *Minimum Aviation System Performance Specification for A-SMGCS*, the basis for performance criteria stated in Chapters 2 and 3 is explained. Definitions and abbreviations essential to the proper understanding of this document are also provided in Chapter 1.

Chapter 2 describes the different physical and technical components of the MLAT System and contains general design requirements for use as part of an A-SMGCS. Requirements in Chapter 2 are not necessarily tested during Factory Acceptance or Site Acceptance.

Chapter 3 contains the minimum operational performance requirements for the MLAT System, defining performance under all environmental conditions likely to be encountered.

Chapter 4 identifies requirements for testing performance characteristics of the MLAT equipment under environmental conditions representative of those that may be encountered in actual operations.

Chapter 5 describes recommended test procedures for demonstrating compliance with Chapters 2 and 3 in the factory.

Chapter 6 describes recommended test procedures for demonstrating compliance with the requirements of Chapter 2 and 3 for the installed MLAT System.

1.2 MOPS APPLICATIONS

The information contained in this document specifies desired system characteristics that should prove useful to designers, manufacturers and users of MLAT equipment.

It should be noted that this document provides the *minimum* operational performance specification for the MLAT System. These performance specifications are focused on the basic MLAT applications as a co-operative sensor in a multi-sensor A-SMGCS, as defined in EUROCAE ED-87C [2.]. Performance standards for functions or components that apply to capabilities that exceed the stated minimum requirements are identified as optional features.

Compliance with this MOPS document ensures that the MLAT will satisfactorily perform its intended function, as given in section 1.6, during surface movement operations.

Compliance with the MOPS does not necessarily constitute compliance with regulatory requirements. Any regulatory application of this document wholly or in part is the sole responsibility of the appropriate air traffic control authority.

As the measured values of the system performance characteristics may be a function of the method of measurement, standard test conditions and methods of testing are recommended in this document.

The word "equipment" as used in this document includes all components and units necessary for the MLAT System to correctly perform its function.

1.3 MANDATING AND RECOMMENDATION PHRASES

1.3.1 “Shall”

The use of the word “Shall” indicates mandated criteria; i.e. compliance with the particular requirement or specification is mandatory and no alternative may be applied.

1.3.2 “Should”

The use of the word “Should” (and phrases such as “It is recommended that ...”) indicates that, although the requirement or criterion is regarded as the preferred option, alternative requirements, specifications or criteria may be applied, provided that the manufacturer, installer or tester can provide information or data to adequately support and justify the alternative.

1.3.3 “REQ”

The use of the label “REQ” (short for Requirement) is paired with a unique number and a “Shall” statement.

1.3.4 “REC”

The use of the label “REC” (short for Recommendation) is paired with a unique number and a “Should” statement.

1.3.5 “ORQ”

The use of the label “ORQ” (short for Optional Requirement) is paired with a unique number, a “Shall” statement. These requirements are not part of the minimum set of requirements necessary to claim compliance with ED-117A but they are applicable if that functionality of the system is explicitly required by the customer.

1.4 DEFINITIONS AND ABBREVIATIONS

1.4.1 Definitions

The following defined terms are used within the context of this document.

Some terms provided below are taken from existing ICAO documents, such as SARPS ANNEX 14 [10.], Doc 9830 A-SMGCS Manual [11.], Doc 9871 [16.] or ED-87 [2.].

Accuracy (ED-87 [2.])

The discrepancy between a measured/displayed value and a real/reference value.

Automatic Dependent Surveillance – Broadcast (ADS-B)

A means by which aircraft, aerodrome vehicles and other objects automatically transmit and/or receive identification, position, velocity and additional data in a broadcast mode via a data link.

ADS-B Message

A packet of information broadcast by an aircraft/vehicle. Each ADS-B Message contains a defined set of aircraft/vehicle parameters. Multiple messages may be used to transmit all required data. Message formats are link specific, as is the number of different messages required to provide a complete set of parameters.

Advanced Surface Movement Guidance and Control System (A-SMGCS)(Doc 9830 [11.])

Systems providing routing, guidance, surveillance and control to aircraft and affected vehicles. In order to maintain movement rate under all local weather conditions within the Airport Visibility Operational Level (AVOL) whilst maintaining the required level of safety.

Aerodrome (ICAO Annex 14 [10.])

A defined area (including any buildings, installations and equipment) intended to be used wholly or in part for arrival, departure and surface movement of aircraft.

Aircraft Address

A unique combination of twenty-four bits available for assignment to an aircraft for the purpose of air-ground communications, navigation and surveillance. Also referred as ICAO 24-bit Address or Mode S Address.

Aircraft Derived Data

Aircraft parameters that can be downlinked from aircraft via Mode S protocol to ground, providing information on the state of the aircraft and the intent of the pilot.

In Mode S EHS context called “Downlinked Aircraft Parameters” – for consistency this document only uses the term Aircraft Derived Data (ADD).

Aircraft Identification

The operational identification of the flight as used in the Item 7 of the ICAO flight plan. It is either the ICAO designator for the aircraft operating agency followed by the flight identification or the registration marking of the aircraft (when no flight plan is available or there is no aircraft operating agency designator).

Aircraft Stand Taxiway (ICAO Annex 14 [10.])

A portion of an apron designated as a taxiway and intended to provide access to aircraft stands only.

Apron Taxiway (ICAO Annex 14 [10.])

A portion of a taxiway system located on an apron and intended to provide a through taxi route across the apron.

Approach

The volume of airspace from the runway threshold out to a given distance and within the runway glide path. The extent of the approach volume is Aerodrome specific.

Apron (ICAO Annex 14 [10.])

A defined area on an Aerodrome intended to accommodate aircraft for the purposes of loading or unloading passengers, mail or cargo, fuelling, parking or maintenance.

Assurance Level (ED-109 [3.])

A measure of software assurance of ground based systems used for Communication, Navigation and Surveillance in an Air Traffic Management context (CNS/ATM).

Availability (ED-87 [2.])

The probability that a system or an item is in a functioning state at a given point in time.

Barometric Altitude (ICAO 9871)

Barometric altitude shall be interpreted as barometric pressure-altitude, relative to a standard pressure of 1 013.25 hectopascals (29.92 in Hg).

Cartesian Coordinates

Coordinates X, Y, Z in a local 3D *Cartesian Coordinates* system with an origin at a system *Reference Point* defined in WGS-84 [12.] coordinates, where:

- X and Y-axes define a plane which is tangential to the WGS-84 [12.] Ellipsoid at the location of the origin.
- Y-axis points to the geographical north at the origin.
- X-axis is perpendicular to the Y-axis and points to the geographical east at the origin.
- Z-axis is perpendicular to the X, Y plane and points away from the centre of the Earth.

NOTE: *This 3D Cartesian Coordinates system is consistent with the 2D-system that is defined in the ASTERIX Category 020 Standard document [6.]*

The system *Reference Point* is defined in WGS-84 coordinates [12.] and may be published in ASTERIX Category 019 [5.] using data items I019/600 and I019/610.

Continuity of Service

The ability of a system or an item to perform its required function without unscheduled interruption throughout the duration of the intended operation.

Coverage Volume (ED-87)

The geographic volume of interest on and around the Aerodrome, within which the system must provide the required surveillance performance capabilities. This volume may be divided further into sub-volumes.

Data Driven Mode

A system output mode in which the successful determination of a Target position leads to an immediate Target Report output.

Detection

Multilateration: A successful decoding of a target transmission at a sufficient number of sensors to allow calculation of the multilateration position in at least the lateral dimension.

ADS-B: A successful decoding of a target transmission.

Downlink (ICAO)

A term referring to the transmission of data from an aircraft to the ground. Mode S air-to-ground signals are transmitted on the 1 090 MHz reply frequency channel.

Enhanced Surveillance

A service that adds the Downlinked Aircraft Parameters (DAPs), as defined within the Mode S specific services protocol, to Mode S Elementary Surveillance. Originally a term mainly used in Mode S Radar; the same mechanism can also be applied to multilateration. It involves addressed interrogation of individual targets to acquire Aircraft Derived Data (ADD) in return. The main parameters are aircraft selected altitude, roll angle, true track angle, track angle rate, ground speed, magnetic heading, indicated airspeed and vertical rate. For the purpose of A-SMGCS, other parameters may be more relevant, e.g. aircraft dimensions and antenna reference points.

Extended Squitter

A long squitter message (DF = 17, 18 or 19) that transponders transmit automatically, without needing to be interrogated by radar, to send information to other aircraft or ground stations.

False Target Report

Any spurious Target Report or a real Target reported to be at a position more than a certain distance from its true position at the time of position measurement.

Geometric Dilution of Precision (GDOP)

The ratio between the three-dimensional position error and the TOA measurement accuracy in the receiving stations contributing to the MLAT position, under the assumption that this measurement error has equal statistics for all contributing receiving stations.

NOTE: *The GDOP describes the influence of the geometrical configuration of the MLAT System and the related target on the position accuracy for a given target position.*

Identity

Operational identification of an aircraft, consisting of either Aircraft Identification (ACID) or SSR Mode A code.

Integrity

An attribute of a system or an item indicating that it can be relied on to perform correctly on demand. It includes the ability of the system to inform the user in a timely manner of any performance degradation.

Manoeuvring Area (ICAO Annex 14 [10.])

That part of an aerodrome to be used for take-off, landing and taxiing of aircraft, excluding Aprons.

Mode A/C

For the purpose of this document, Mode A/C is taken as referring to non-Mode S SSR transactions. Where specific Mode A or Mode C transactions are involved, these are identified individually.

NOTE: *Non-Mode S SSR is also known as ATCRBS (Air Traffic Control Radar Beacon System).*

Mode S

A selective addressing mode of the Secondary Surveillance Radar (SSR) system that operates using addressed interrogations on 1030 MHz and transponder replies on 1090 MHz. Mode S also supports a two-way data link and an ADS-B service known as Extended Squitter.

Movement Area (ICAO Annex 14 [10.])

That part of an aerodrome to be used for take-off, landing and taxiing of aircraft, consisting of the Manoeuvring Area and the Apron(s).

Multilateration

The process of determining the target location in two (or three) dimensions by solving the mathematical intersection of multiple hyperbolae (or hyperboloids). It is based on the TDOA principle, the Time Difference Of Arrival of a message from a transponder at several different receivers.

Multilateration (MLAT) System

A group of equipment configured to provide position and identification derived from Mode S or Mode A/C transponder signals using Time Difference of Arrival (TDOA) techniques.

Multipath

The phenomenon whereby signals arrive at the antenna of a sensor by more than one route.

NOTE: *Multipath can create a number of different interference effects to the detriment of Multilateration performance. Where the path length differences are very large or where the direct (line-of-sight) path is obscured Multipath can create False Targets.*

Non-transponder Device

A device capable of broadcasting 1090 Extended Squitter (DF18) that is not part of a Mode S transponder.

Reliability

The ability of a system or an item to perform a required function under specified conditions, without failure, for a specified period of time.

Requirement

An identifiable element of a function specification that can be validated and against which an implementation can be verified.

Squitter

A spontaneous transmission generated at a pseudo-random rate or on an event-driven basis by a Mode S transponder without the need to be interrogated.

Stand (ICAO Annex 14 [10.])

A designated area on an Apron intended to be used for the parking of an aircraft.

Surveillance (ED-87)

A function of the system that provides identification and accurate positional information on aircraft, vehicles and objects within the required area.

System Capacity (ICAO)

The maximum number of simultaneous movements of aircraft and vehicles that the system can safely support, within an acceptable delay, commensurate with the runway and taxiway capacity at a particular aerodrome.

Target

Any vehicle or aircraft equipped with a Mode S, Mode A/C transponder or Non-transponder Device, which has been turned on and is functioning in compliance with its Minimum Operational Performance Specification.

Target Identification

The correlation of a known aircraft or vehicle identifier with target data.

Target Report

A data record containing all relevant information pertaining to a target detected by the MLAT System.

Target Reference Point

The position of the transponder antenna from which all multilateration position information is measured.

Time of Arrival (TOA)

The time a transmission from a target is received at any sensor receiver.

Time Difference of Arrival (TDOA)

The difference in relative time that a transmission from the same Target is received at different sensor receivers.

Update

A renewal of Target Reports relating to all Targets under Surveillance.

Uplink (ICAO)

A term referring to the transmission of data from the ground to an aircraft. Mode S ground-to-air signals are transmitted on the 1030 MHz interrogation frequency channel.

Verification

The evaluation of an implementation of requirements to determine that they have been met.

1.4.2**Acronyms**

Acronym	Description
2D	Two Dimensional, x and y
3D	Three Dimensional, x, y and z
ACAS	Airborne Collision Avoidance System
ACID	Aircraft Identification
ADD	Aircraft Derived Data
ADS-B	Automatic Dependent Surveillance - Broadcast
AL	Assurance Level
ASTERIX	All-purpose Structured EUROCONTROL Surveillance Information Exchange
ASX	A synonym for ASTERIX
ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System

Acronym	Description
ATM	Air Traffic Management
AVOL	Airport Visibility Operational Level
BDS	Binary Data Section
CAT	Category (in the context of ASTERIX categories)
CMS	Control and Monitoring System
CNS	Communications, Navigation and Surveillance System
DAP	Downlink Aircraft Parameter
DF	Downlink Format
DGPS	Differential GPS
DPR	Data Phase Reversals
EC	European Commission
EHS	Enhanced Surveillance
ELM	Extended Length Messages
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
ETSI	European Telecommunications Standards Institute
EU	European Union
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAT	Factory Acceptance Test
FRT	Failure Report Time
GBS	Ground Based System
GDOP	Geometric Dilution of Precision
GNSS	Global Navigation Satellite System
Hz	Hertz
ICAO	International Civil Aviation Organisation
ID	Identifier
IEC	International Electrotechnical Commission
IRTOP	Identification Renewal Time Out Period
ITU	International Telecommunication Union

Acronym	Description
LVD	Low Voltage Directive
MASPS	Minimum Aviation System Performance Specification
MHz	Megahertz
MLAT	Multilateration
MOPS	Minimum Operational Performance Specification
MTBCF	Mean Time Between Critical Failures
MTTR	Mean Time to Repair
NTP	Network Time Protocol
PFD	Probability of False Detection
PFID	Probability of False Identification
PFTR	Probability of Target Report
PID	Probability of Identification
PLG	Probability of Long Horizontal Gaps
PPS	Pulse Per Second
PTR	Probability of Target Report
REQ	Requirement
RF	Radio Frequency
RMA	Reliability, Maintainability and Availability
RPA	Reported Position Accuracy
RR	Reply Request
RTCA	Radio Technical Commission for Aeronautics
SARPS	Standards and Recommended Practices
SLM	Standard Length Messages
SMR	Surface Movement Radar
SNMP	Simple Network Management Protocol
SPR	Synch Phase Reversal
SSR	Secondary Surveillance Radar
TCAS	Traffic Alert and Collision Avoidance System
TDOA	Time Difference of Arrival
TOA	Time of Arrival
TOO	Targets of Opportunity
TRIT	Target Report Initiation Time

Acronym	Description
TRUR	Target Report Update Rate
UF	Uplink Format
UPS	Uninterruptible Power Supply
UTC	Universal Time Coordinated
WAM	Wide Area Multilateration
WG	Working Group
WGS	World Geodetic System

1.5

REFERENCES

1.5.1

Normative references

The following documents are incorporated by reference.

1. EUROCAE ED-73E: Minimum Aviation System Performance Specification for Secondary Surveillance Radar Mode S Transponders, (May 2011)
2. EUROCAE ED-87C: Minimum Aviation System Performance Specification for Advanced Surface Movement Guidance and Control Systems (January 2015)
3. EUROCAE ED-109A: Guidelines for Communication, Navigation, Surveillance and Air Traffic Management (CNS/ATM) Systems Software Integrity Assurance (January 2012)
4. EUROCONTROL Standard Document for Surveillance Data Exchange, Part 7: Category 010 Transmission of Monoradar Surface Movement Data (March 2007)
5. EUROCONTROL Standard Document for Surveillance Data Exchange, Part 18: Category 019 Multilateration System Status Messages (December 2010)
6. EUROCONTROL Standard Document for Surveillance Data Exchange, Part 14: Category 020 Multilateration Target Reports (March 2015)
7. EUROCONTROL Specification for Surveillance Data Exchange, Part 12: Category 021 ADS-B Target Reports (June 2015)
8. EUROCONTROL Specification for Surveillance Data Exchange, Part 26: Category 025 CNS/ATM Ground System Status Reports (November 2015)
9. ICAO Annex 10 Volume IV (Surveillance and Collision Avoidance Systems), fifth edition (July 2014)
10. ICAO Annex 14 Aerodromes, fifth edition (July 2009)
11. ICAO Doc. 9830 AN/452 Advanced Surface Movement Guidance and Control Systems, A-SMGCS Manual (First Edition 2004)
12. ICAO Doc. 9674-AN/946, World Geodetic System 1984 (WGS-84) Manual (2002)
13. ETSI EN 300 019 parts 1-1, 1-2, 1-3 and 1-4
14. EUROCAE ED-129B: Technical Specification for an 1090 MHz Extended Squitter ADS-B Ground System (April 2016)
15. EUROCAE ED-142: Technical Specification for Wide Area Multilateration (WAM) Systems (September 2010)
16. ICAO Doc. 9871 AN/464: Technical Provisions for Mode S Services and Extended Squitter
17. Directive 2014/53/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment.

18. Directive 2014/30/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to electromagnetic compatibility.
19. Directive 2014/35/EU of the European Parliament and of the Council on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits.

1.6 SYSTEM DESCRIPTION

1.6.1 MLAT Applications and Operational Objectives

The MLAT System is a ground based co-operative sensor system which detects stationary and moving Targets on the surface or in the vicinity of the Aerodrome. In the context of this document this data is destined to supply a multi-sensor Data Fusion System of an A-SMGCS.

As a sensor in an A-SMGCS, an MLAT combined with a primary sensor, such as Surface Movement Radar (SMR), can provide sufficient information to unambiguously identify and track aircraft and/or vehicles.

1.6.2 Operating Principles of the System

1.6.2.1 Multilateration Principles

An MLAT System works by placing a number of receivers and/or receiver/interrogators in precisely surveyed locations in or around an Aerodrome. The system uses the spontaneous Mode S “squitter” transmission and asynchronous transponder replies as well as the responses to interrogations elicited by the MLAT System. The system does not require any additional aircraft equipment to be installed.

Multilateration is the process of determining the Target location in two (or three) dimensions by solving the mathematical intersection of multiple hyperbolae (or hyperboloids). It is based on the Time Difference of Arrival (TDOA) principle, the time difference between the “arrivals” of one transponder’s signal received at several receivers.

The system detects each transponder signal at multiple receiver locations. The signal is either time-stamped locally and then sent to the Central Processing System (CPS), or sent directly to the CPS to be time-stamped centrally. At the CPS, the difference in signal arrival time at each receiver location is used to estimate the transponder antenna location. Data from three receivers permits the system to determine a two-dimensional (2D) position estimate. Data from a fourth receiver is required to determine a three-dimensional position (3D) estimate. Alternatively, a 3D positional estimate can be calculated using only three receivers when altitude can be ascertained from an outside source (such as Mode C code or ‘on ground’ bit from the aircraft transponder).

The position accuracy and the probability of detection of the Multilateration solution depend on a number of factors, including:

- Accurate time stamping and correct decoding of received signals.
- The position of the receivers with respect to the Target, i.e. the Geometric Dilution Of Precision (GDOP).
- The number of receivers.

The Multilateration principle depends on each ground station's ability to determine the precise time of arrival and correctly decode received signals. Aerodromes are generally quite difficult environments for wave propagation and reflection of signals (Multipath propagation) occurs all the time due to the presence of many objects of sufficient size. Overlapping signals can impact both time-stamping precision and decoding quality, particularly when the overlapping signal has similar level and short delays compared to the original signal. This is typically true for reflected signals. Various signal processing, message processing and position estimation techniques can be used to minimise the effects of garbled or reflected signals.

The accuracy of the position calculation is also highly dependent on the GDOP. The locations of the receivers can be favourable or unfavourable for a given Target location.

An unfavourable location can result in high GDOP values which will greatly increase the positional error even if the TDOA accuracy is maintained. Wider angular separation between the receivers used to calculate Target position will result in lower GDOP values and better positional accuracy. Hence, the location of receiver stations is important for the overall system performance.

The number of receivers is determined according to the Aerodrome layout and the required Coverage Volume. Additional receivers are sometimes needed to overcome the effects of shadowing by buildings and Multipath, and enhance the overall positional accuracy.

1.6.2.2 Target Identification

The Identity of a Target is obtained as follows:

The ICAO 24-bit Mode S Address is integrated in the Mode S squitter message and is therefore acquired by the MLAT System.

The Mode S Address is used by the MLAT System to interrogate aircraft selectively in order to obtain:

- The Aircraft Identification, when reported by the Mode S transponder.
- The Mode A code.
- The Mode C altitude.

NOTE: *The 24-bit Mode S Address shall be one of more than 16,000,000 Mode S Addresses allocated by ICAO to the State of Registry or common mark registering authority and assigned uniquely to individual aircraft.*

1.6.2.3 Interrogations

Multilateration Systems can be operated in either passive or active configurations. In the passive form, Multilateration can rely on the reception of 1090 MHz signals being broadcast from aircraft transponders. This includes ACAS transmissions, ADS-B broadcasts and Mode S / SSR replies originating from other active on-board transmitting devices. In this mode of operation certain data items, in particular height, identity and EHS parameters may not be available at sufficient rates to support the required MLAT System performance.

The above limitation can be addressed by using Multilateration in an active configuration. In the active form, the MLAT Systems utilise 1030 MHz Transmitting Units (Mode S / SSR interrogators) for Mode S interrogations to obtain information not available by passive reception, such as Mode A code and Mode C Barometric Altitude. The downlink of specific aircraft parameters, e.g. aircraft dimensions, position of antennas, etc., is also possible through interrogations.

Whilst interrogations provide a degree of autonomy and improved performance, the interrogations introduce a load upon the 1030/1090 MHz channel capacity and contribute to transponder occupancy. Congestion of the 1030/1090 MHz spectrum and excessive transponder occupancy are major issues facing European surveillance infrastructure and are problems which should be addressed whenever possible.

A complete list of interrogation formats is described in ICAO Annex 10 Volume IV [9.].

1.6.2.4 Synchronisation

An MLAT System requires two types of time synchronisation:

- 1) Receiver Synchronisation.
- 2) Synchronisation to an external time source.

1.6.2.4.1 Receiver Synchronisation

Given that an MLAT System relies on Time Difference of Arrival in order to calculate a Target position, it is necessary that the TOAs of the Target signal at the different receivers be synchronised to each other. There are a number of commonly accepted methods for synchronising the TOAs:

- Use of a common signal received at multiple receivers: an MLAT System may have one or more Reference Transmitters or Transponders to provide receiver synchronisation. By receiving the same signal at multiple receivers and by knowing the precise transmitter location, the MLAT System can determine the time differences between the receivers and compensate for these differences when performing the TDOA calculation.
- Use of a central clock: with this method, the Target signals received by all receivers are time-stamped centrally at the Central Processing System. This method removes the need to compensate for time differences between receivers.
- Use of GNSS: this is similar to the first method but, in this case, the common signal may be the 1 PPS GNSS receiver signal. Additional precision can be achieved through synchronisation to a common transmitting satellite (known as the Common View method).

The accuracy of this component is essential as it directly relates to position accuracy.

1.6.2.4.2 Synchronisation to External Time Source

Given that an MLAT System is typically part of a larger A-SMGCS, the MLAT Target Reports need to be synchronised to the A-SMGCS time. This is typically accomplished by incorporating a UTC time reference capability within the MLAT System, or by synchronising the MLAT System time to an external time reference through the usage of protocols such as the Network Time Protocol (NTP).

1.6.3 Components of the Multilateration System

The MLAT System consists of the following components:

- Sensors:
 - o Receivers installed in or around the Coverage Volume;
 - o Interrogators installed in or around the Coverage Volume;
- Sensor Antennas,
- A Central Processor System associated to the sensors;
- A synchronisation system for the TDOA if necessary;
- An inter-modules communication system;
- An interface to the A-SMGCS multi-sensor Data Fusion system;
- Control and Monitoring System (CMS) to provide technical supervision;
- Lightning protection system;
- Uninterruptible Power Supply (UPS);
- Optional transponder or transmitter or Non-Transponder devices for system integrity verification and/or for time synchronisation.

Other components which should be considered in defining a complete sensor system are:

- Obstruction Lights.

NOTES: Transmitters, Reference Transponders and Non-transponder Devices are normally installed in and/or around the Coverage Volume, in line of sight of one or more ground stations. The transmitted signals can also be utilised for the TOA measurement synchronisation within the ground stations.

1. Non-Transponder device:
 - Squittering exclusively DF18.
2. Transponder device:
 - Squittering DF11/17 (or DF19) and
 - responding to interrogations with (DF4/5).
3. Transmitter:
 - Interrogating aircraft transponders (UF4/5),
 - may be squittering DF18.

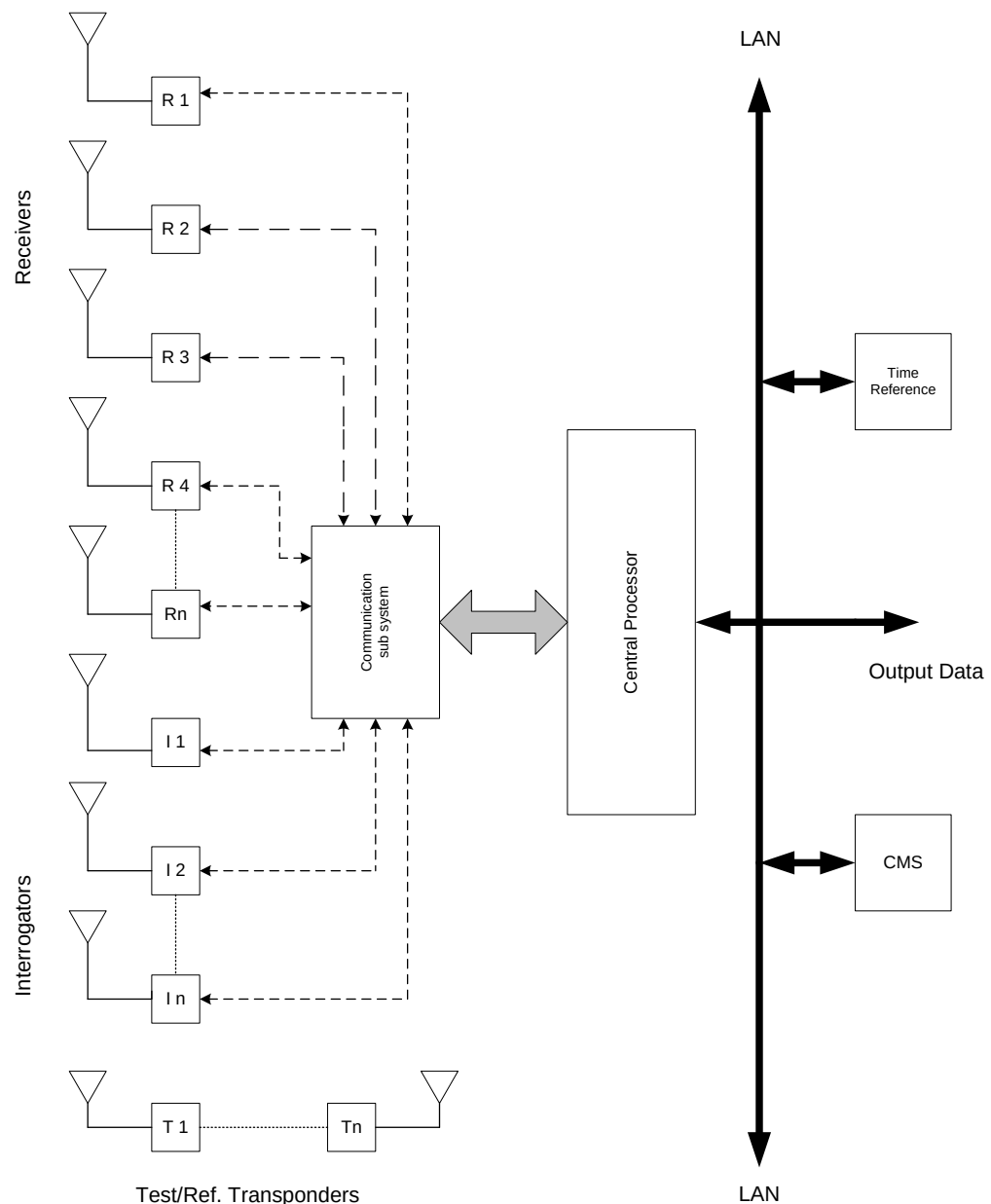


FIGURE 1-1: EXAMPLE BLOCK DIAGRAM PRESENTING THE BASIC COMPONENTS OF THE MLAT SYSTEM

1.6.4 Siting of MLAT Equipment

The installed receivers / interrogators constitute the “sensors”. The sensors are installed around the Aerodrome in as many locations as required to meet the required Coverage Volume. Consideration should be given to sites with available main power and communications.

The antenna associated with each sensor must have clear line of sight to the transponder antennas of those aircraft and vehicles in the volume which that sensor is required to cover. The sensor antennas can be mounted on existing structures or new support structures, as required. It is important to also consider other factors on sensor siting; very important constraints being Multipath influence and sensor geometry. Even with clear line of sight, reflected signals might affect reception and then compromise position accuracy and probability of detection.

The sensor antennas must be sited such that at least three, and preferably four or more of the sensors have clear line of sight, simultaneously, to an aircraft or vehicle transponder antenna that is within the identified Coverage Volume.

The receiver synchronisation system has to be very precise and reliable as it is the basis of the quality of the positioning with the MLAT technique. If the synchronisation is based on an external reference transmitter, the sensor antennas must have clear line of sight to the reference signal. This must be considered when selecting the installation site(s).

The Central Processing System and the Control and Monitoring System (CMS) will normally be installed at a central location such as an equipment room at the Air Traffic Control Tower. The CMS provides the means to configure and control the system in addition to providing status of the system for maintenance purposes. The Central Processing System receives data from the sensors and generates Target Reports to be sent to the A-SMGCS Data Fusion system.

The Communications System is utilised to send data between the sensors and the Central Processing System. The system may be analogue or digital and make use of a variety of media such as copper wire, fibre or RF links. The system must have the bandwidth and quality to support the data rates sufficient to meet the system requirements.

1.7 TEST PROCEDURES (TEST METHODOLOGY)

Tests should be performed using a combination of modelling and simulation, direct performance measurement on site, and analysis and extrapolation of results. Normally, testing of individual items of equipment would be performed both at the factory or laboratory and on site, whereas the complete MLAT System test can only reasonably be conducted on site, using a combination of Targets of Opportunity and controlled aircraft and vehicles.

The recommended test procedures specified in this document are intended to be used as one means of demonstrating compliance with the performance requirements defined in Chapter 3.

The order of tests specified suggests that the equipment be subjected to a succession of tests as it moves from design, and design qualification, into operational use. For example, compliance with the requirements of Chapters 2, 3 and 4 shall have been demonstrated as a precondition to satisfactory completion of the installed system tests of Chapter 6.

1.7.1 Environmental Tests

Environmental test requirements are specified in Chapter 4. The procedures and their associated limits are intended to provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual operations.

1.7.2 Factory Tests

Factory test procedures are specified in Chapter 5. These tests provide a means of demonstrating compliance with those requirements of Chapter 3 that can be tested in the factory. Test results may be used by equipment manufacturers as design guidance, for monitoring manufacturing compliance and, in certain cases, for obtaining formal approval of equipment design.

1.7.3 Site Acceptance Tests

Tests for the installed equipment are performed to demonstrate compliance of the system under site dependent conditions.

The installed equipment test procedures for site acceptance and their associated limits are specified in Chapter 6.

CHAPTER 2

GENERAL DESIGN REQUIREMENTS

2.1 INTRODUCTION

This chapter establishes the design criteria and general operational requirements for MLAT Systems.

Other aspects of the MLAT System design are purely dependent on the manufacturer's philosophy as long as the minimum operational performance requirements specified in Chapter 3 are met.

There may also be additional requirements, local rules and regulations that are applicable for the design and the installation of MLAT Systems.

2.2 AIRWORTHINESS AND CERTIFICATION

The MLAT System is ground-based equipment and as such has no airworthiness requirements.

2.3 ELECTROMAGNETIC INTERFERENCE AND SUSCEPTIBILITY

The system will be required to meet European EMC standards as well as maintaining emissions within ITU regulations.

[REQ 1.] The system shall comply with European requirements regarding the CE mark.

[REQ 2.] The MLAT System shall have appropriate EMI/EMC characteristics for operation in an Aerodrome environment.

[REQ 3.] The MLAT System shall not interfere with other Aerodrome electrical, electronic, or communications equipment.

[REQ 4.] The performance of the MLAT System shall not be affected in any way by other equipment on or near the Aerodrome.

2.4 INTERFACES

The MLAT System communicates with components of the A-SMGCS and other external systems using standard communications protocols in order to assure inter-operability. An overview of the MLAT System external interfaces is provided in the diagram shown in FIGURE 2-1.

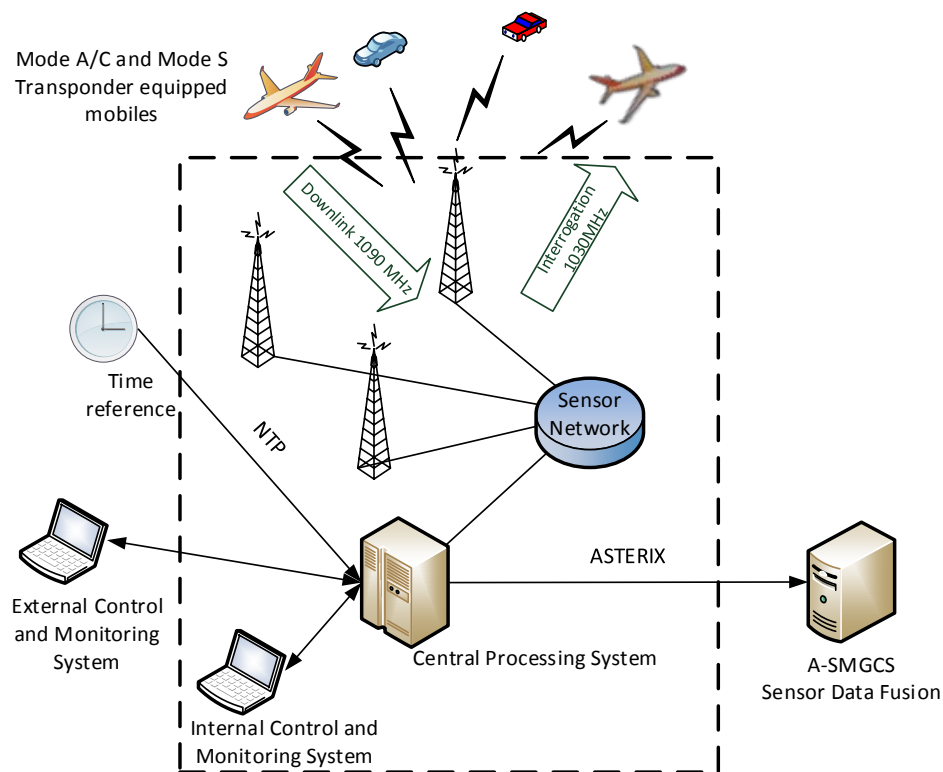


FIGURE 2-1: MLAT SYSTEM EXTERNAL INTERFACES

2.4.1 MLAT System Air Interface

- [REQ 5.] The MLAT System shall receive Mode S downlink messages and Mode A/C replies on the 1090 MHz frequency from equipped aircraft or vehicles.
- [ORQ 1.] If required, the MLAT System shall transmit Mode S uplink messages and Mode A/C interrogations on the 1030 MHz frequency.

2.4.2 MLAT System Outputs

- [REQ 6.] The output of the MLAT System shall consist of MLAT and ADS-B Target Reports and service messages.
- [REQ 7.] The output of the MLAT System shall be a digital data output utilising standard communication protocols as specified in section 3.1.6.

2.4.3 Time Reference Interface

- [REQ 8.] The MLAT System shall be capable of using the same time source as the A-SMGCS.

NOTE: *The purpose of this time source is to provide time synchronisation for the creation and use of Target Reports. This time source may be different to the time reference used for the position calculation.*

2.4.4 External Control and Monitoring Interface

- [REC 1.] The MLAT system should report via an external interface when a failure is detected by the CMS.
- [REC 2.] The MLAT System should be capable of interfacing with an external maintenance system for the purpose of reporting system status and accepting system commands.
- NOTE:** *The remote control and monitoring protocol can be implemented with SNMP, HTTP, or other protocols that enable monitoring.*

2.5 TECHNICAL CONTROL AND MONITORING

[REQ 9.] The MLAT System shall be equipped with a technical control and monitoring function covering all system elements and operational parameters to determine whether the MLAT System is operating within specified limits.

[REQ 10.] The Control and Monitoring Subsystem (CMS) shall provide:

- Monitoring of overall system status and integrity;
- Monitoring of the MLAT System components;
- Monitoring of key hardware and software performance parameters;
- Control of the MLAT System components;
- Reporting of status.

[REC 3.] It should be possible to access the system for maintenance and perform Control and Monitoring functions through an external interface (see 2.4.4).

2.5.1 Control

[REC 4.] The CMS should provide the capability of restarting connected system components.

[REC 5.] The CMS should have a security system that controls access to the command and parameter adjustment capabilities of the MLAT System.

[REC 6.] Only the highest level of access should enable all system controls.

2.5.2 Monitoring

[REQ 11.] The MLAT system status monitoring shall be performed automatically and made available for analysis.

[REQ 12.] The MLAT System shall provide information on failures of system components.

[REQ 13.] Technical monitoring of the MLAT key hardware and software performance parameters as further described in section 2.7 shall provide continuous information on the condition of the system.

2.5.3 Reporting

[REQ 14.] The CMS shall provide results of the Monitoring function.

2.5.4 Logging

[REQ 15.] The CMS shall log to a non-volatile storage when control actions are taken (either automatically or manually) and any change in status of the sensors or data processor is done.

[REC 7.] All messages on the CMS should be stored in an easily readable way in order to get a quick overview of the system status without using a decoder.

[REQ 16.] Provision shall be provided to retrieve and read current and archived data.

2.5.5 Data Recording

[REC 8.] The MLAT System should provide a capability to record all data inputs to the Central Processing System to allow subsequent analysis and playback.

[ORQ 2.] If included, the recording function shall provide the recording capabilities without impairing the MLAT system performance.

2.6 SYSTEM AVAILABILITY AND CONTINUITY OF SERVICE

System Availability and Continuity of Service encompass the Reliability and Maintainability of a system. For an MLAT System as part of an A-SMGCS, which will be used operationally in a continuous manner, rather than for a series of discrete operations, Availability and Continuity of Service are similar concepts (except that Availability would include scheduled outages of the system).

For an MLAT System as a distributed sensor, those Availability and Continuity of Service goals refer to the overall system rather than to single sensor sites.