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

TECHNICAL SPECIFICATION FOR WIDE AREA MULTILATERATION (WAM) SYSTEMS

ED-142

September 2010

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FOREWORD

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CHAPTER 1

GENERAL

1.1 PURPOSE AND SCOPE

This Technical Specification document specifies the minimum performance requirements for a Wide Area Multilateration (WAM) System that is part of a system providing airspace situational awareness to air traffic controllers and other users within the European Air Navigation Region.

In the frame of this document the WAM system is primarily intended for ATM in the ECAC area to provide, in both high and low density environments, the following air traffic surveillance services:

- 3 NM horizontal separation
- 5 NM horizontal separation

A WAM System compliant with this Technical Specification will be compatible with all relevant ICAO, EUROCONTROL and EUROCAE/RTCA specifications [**REF1** - **REF16**].

It is recognised that a WAM system may also provide an ADS-B data reception and handling capability, but consideration of such capability is outside the scope of this document. More information on ADS-B ground station capability can be found in [**REF16**].

A list of document references can be found in section *1.7*.

1.2 DOCUMENT STRUCTURE

Chapter 1 of this document provides information required to understand the need for the equipment characteristics and tests defined in the remaining chapters. It describes typical equipment applications and operational objectives. Definitions essential to proper understanding of this document are also provided in Chapter 1.

Chapter 2 contains general design requirements. These are requirements for which no specific tests have been defined within this document. Compliance can be verified through manufacturer provided documentation.

Chapter 3 contains the minimum performance specification for the equipment, defining performance under standard operating conditions.

Chapter 4 prescribes the environmental test conditions, which provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those which may be encountered in actual operations.

Chapter 5 describes recommended factory test procedures for demonstrating compliance with Chapter 3.

Chapter 6 describes recommended site test procedures for demonstrating compliance with Chapter 3.

1.3 APPLICATIONS OF THE DOCUMENT

Compliance with this technical specification by manufacturers, installers and users is recommended as a means of assuring that the equipment will satisfactorily perform its intended function(s).

1.3.1 Mandating and Recommendation Phrases

1.3.1.1 ‘Shall’

The use of the word ‘***Shall***’ indicates a mandated criterion; i.e. compliance with the particular procedure or specification is mandatory and no alternative may be applied.

1.3.1.2 ‘Should’

The use of the word ‘Should’ (and phrases such as ‘It is recommended that...’, etc.) indicate that though the procedure or criterion is regarded as the preferred option, alternative procedures, 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.

1.4 DESCRIPTION OF SYSTEM

1.4.1 General Introduction to Multilateration

This introduction to multilateration is intended for users of *Multilateration System* and those who procure the systems. It will help those parties to understand the system behaviour and the important factors in selecting a system. It is not intended as a designers guide for *Multilateration System*. Many details have been left out to keep the explanation fairly concise.

Air traffic surveillance systems use both cooperative and non-cooperative techniques to locate aircraft. While non-cooperative techniques rely on the reflection of energy directed at the aircraft, cooperative techniques require the carriage of a transponder on board the aircraft. The transponder receives an *Interrogation* signal from the cooperative surveillance system and replies with its own signal. Some transponders also make spontaneous transmissions (e.g. Mode S ‘*Squitter*‘) at defined intervals.

One method of locating an aircraft using the transponder signal is multilateration. In this technique, the transponder signal from the aircraft is received at multiple receivers at known locations. The signal arrives at the receivers at different times due to the different separation distances from the target. The *TDOA* can be calculated in a number of different ways, including cross-correlation of captured waveforms and differences between absolute *Time of Arrival* (*TOA*) measurements, and forms the basis of the multilateration technique. (Note that in *Multilateration System* which uses active *Interrogation*, this so-called ‘time-hyperbolic method’ can also be augmented by other techniques).

A *TDOA* measurement for a pair of receivers can be used to define a hyperboloid surface upon which the target lies; however a target at any point on this surface would exhibit the same *TDOA* and so further measurements are required to resolve this ambiguity. A third receiver gives rise to a second independent *TDOA* measurement, defining another hyperboloid which should, in the absence of excessive measurement errors, intersect with the first to reduce the ambiguity to a hyperbola curve.

Reduction of the target locus to a single point on this curve can then be achieved using a variety of methods: intersecting the curve with a horizontal plane of arbitrary height (usually zero); calculating the height of the target based on its Mode C replies and local meteorological data, and intersecting the curve with a horizontal plane at that height; or adding a fourth receiver to provide a third independent *TDOA* and its corresponding hyperboloid, the intersection of which with the curve reduces the ambiguity to a single point.

Further receivers can increase positional *Accuracy*, amongst other benefits.

1.4.2 WAM Minimum Operational Objectives

Wide Area Multilateration (WAM) systems provide independent cooperative surveillance.

Wide Area Multilateration uses the time difference of arrival (*TDOA*) multilateration principle to provide an accurate and reliable real-time location and identification of all aircraft, vehicles and other objects equipped with a Mode A/C/S transponder.

WAM is a modular system, adaptable to terminal and wide area surveillance requirements, as well as operation in difficult terrain. For each deployment, the most appropriate architecture configuration and related communication data link technology will be selected to meet the requirements of the customer, ensuring the optimal utilization of the available infrastructure.

In areas with sufficient Mode A/C/S *Interrogation* provided by local SSR or in areas with high transponder occupancy, WAM may utilize all available SSR replies to locate, identify and *Track* aircraft.

The WAM system may also serve as a means for surveillance provision duplication, as it is recommended that en-route airspace and major terminal areas require duplication of surveillance.

This document covers the WAM system requirements to provide at least the following surveillance applications:

- ‘En-route service’. Minimum performance ensuring safe application of separation minima of 5 NM.
- ‘TMA service’. Minimum performance ensuring safe application of separation minima of 3 NM.

Multilateration techniques have been successfully deployed for airport surveillance for many years now. More recently however, these same techniques are being utilized for wide area applications such as en-route or terminal control.

Terminal areas

A TMA (Terminal Manoeuvring Area) is the volume of airspace surrounding one or more principal aerodromes. The lateral extent will vary, depending on the disposition of aerodromes within or adjacent to the terminal area. The vertical dimensions will vary according to the way the airspace and the procedures for handling the air traffic flow are organized.

The coverage within major terminal areas extends from the lowest altitudes of the intermediate *Approach* segments for the principal aerodromes concerned. Coverage elsewhere will extend from the minimum levels at which surveillance services are required to be provided, to the upper limit of the terminal area.

Provisions should be made for the *Continuity* of coverage in the areas interfacing with en-route airspace.

En-route Airspace

En-route airspace is the volume of airspace outside terminal areas, where the climb, cruise and descent phases of flight take place and within which various types of air traffic services are provided.

The horizontal extent of the coverage should be to at least 30 NM beyond the area of responsibility of the relevant Area Control Centre (ACC), except where this is impossible to achieve due to geographical limitations.

1.4.3 Other Applications

Height monitoring equipment (HME)

Reduced Vertical Separation Minima (RVSM) is used to describe the standard vertical separation reduction from 2,000 ft to 1,000 ft for aircraft flying between FL 290 and FL410. With few exceptions, the vast majority of aircraft that operate in European airspace required certification to operate in RVSM airspace.

To validate the capability of the aircraft to maintain altitude to the RVSM requirement, height monitoring units are needed with an accurate height measuring capability. This is ideally achieved using a *Multilateration System*.

The barometric altitude information reported by an aircraft is compared to the geometric height measurement whenever that aircraft is within the vicinity of the HME. This allows the aircraft population to be subject to an ongoing monitoring process to help ensure that RVSM requirements are maintained.

Precision Runway Monitoring (PRM)

Independent parallel operations during Instrument Meteorological Conditions are typically limited by current radar surveillance to runways separated by 4,300 feet or more. PRM provides Air Traffic Control (ATC) with a display of arrivals along an extended centreline. In the event that an aircraft flies towards the adjacent runway's extended centreline, a PRM system automatically alerts ATC.

The potential for high accuracy and high update rate provided by a *Multilateration System* is ideally suited to PRM applications.

1.4.4 Update Interval and Output Period

The concepts of an "update interval" and "output period" are fundamental to the correct understanding this document and an important difference between a WAM system and a radar system.

WAM system receives target updates aperiodically as replies to interrogations from both the WAM system itself, as replies to interrogations of other systems (e.g. SSR and TCAS systems) and from squitter messages spontaneously transmitted by the target transponder/transmitter device. This is fundamentally different behaviour to radar which only processes and outputs replies determined to have been received when its main beam points in the direction of the target. It also means that the WAM system can output target data either aperiodically (immediately after the target signal is measured, i.e. "data-driven" output) or periodically. This approach is different from the radar that can only output data at a rate based on its antenna rotation time or scan period.

The term *Output Period* is used to define the selectable period that the WAM system uses to output target reports periodically.

The variable nature of the WAM *Output Period* means that the *Output Period* cannot be used for assessing WAM performance in the way the fixed scan period of radar can because for different values of the *Output Period*, the WAM system will provide target data with different probability, accuracy and other performance characteristic.

The term *Update Interval* is used to define the time interval over which the performance of the WAM system is measured. This allows the performance of the WAM system to be assessed independently of the *Output Period* configured in the system and it allows a mechanism for a meaningful comparison of the WAM performance against the radar one.

Maximum values of the *Update Interval* for 3 NM and 5 NM separations are specified in this document. These allow compliance with EUROCONTROL Surveillance Standard [**REF9**]. All the surveillance performance parameters that depend on a time interval are then specified in terms of the defined *Update Interval*.

1.5 COMPOSITION OF THE WAM

WAM systems typically consist of the following main ground components (see also Figure 1-1):

- Ground station
- Reference and Monitoring Transponder
- Central processor
- Network connections
- CMS and interfaces

1.5.1 Ground station

1.5.1.1 Receiving Unit (RXU)

The main tasks of the *Receiving Unit* are to receive signals from target SSR/Mode S transponders, digitize the signals, measure *TOA*, and transfer the digitized data over a suitable data link to the Central Processor (CP).

1.5.1.2 Transmitting Unit (TXU)

The main tasks of the *Transmitting Unit* are to interrogate target SSR/Mode S transponders, in accordance with requests received over a suitable data link from the CP.

1.5.2 Reference and Monitoring Transponders (RMTR)

If an RMTR is part of the system, it is used for *Integrity* checking, and is installed in and/or around the coverage area. It spontaneously transmits Mode S *Squitter* and/or responds to *Interrogation*. The transmitted *Squitters* can also be utilized for the *TOA* measurement synchronization.

1.5.3 Central Processor

A node within a WAM system where the information from multiple receiving stations is collated for the purposes of measuring target position through *TDOA* calculation, and assembling target reports for output from the WAM system. The Central Processor will also generally carry out other management functions.

1.5.4 Network connections

The communication links between the components of the WAM system. These may be dedicated links with fixed transmission delays, or may make use of general purpose communication infrastructure. The type of network connection used will generally be dictated by the timing method used by the particular WAM system.

1.5.5 CMS and interfaces

The required control and monitoring functions of the WAM system, together with the necessary interfaces to the other equipment.

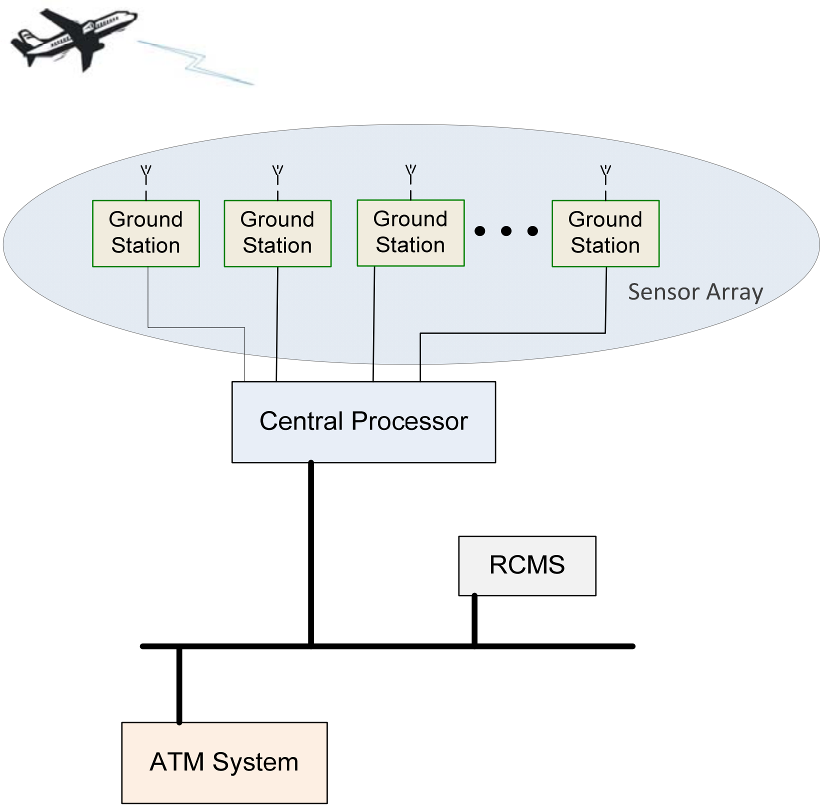

FIGURE 1-1: TYPICAL CONFIGURATION OF WAM

1.6 DEFINITIONS AND ABBREVIATIONS

1.6.1 Definitions

NOTE: *The use of italics within the definition indicates that the definition is described in terms of another definition.*

Accuracy

Accuracy is the quantitative bound of certainty in the calculated position for a target as related to the true position of that target.

NOTE: *Horizontal position Accuracy is expressed as a Root Mean Square (RMS) of an absolute distance error averaged over statistically significant set of measurements:*

$$RMS = \sqrt{(x - x')^2 + (y - y')^2}$$

Where (x, y) is the target's true horizontal position and (x', y') is a horizontal position measured by the WAM system.

Active Multilateration

A multilateration function carried out with signals obtained by *Interrogation* of target.

ADS-B

ADS-B: Automatic Dependent Surveillance – Broadcast (ADS-B) is 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

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.

Aircraft Identification (ACID)

The operational identification of the flight as used in the Item 7 of the 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).

E.g. as a result of *Squitter* or generated by external active interrogating systems.

Approach

Approach is the area from the runway threshold out to a distance of 20 nautical miles and within the runway glide path.

Availability

The probability that a system is able to perform its intended function at the initiation of the intended operation.

It is quantified as the proportion of time the system is actually available to the time the system is planned to be available. Periods of planned maintenance are discounted from *Availability* figures.

NOTE: *This definition is consistent with EUROCAE ED-126.*

Assurance Level (AL)

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

NOTE: *Assurance Level is defined in ED-109 and are numbered AL1 to AL6 with AL1 being the most stringent.*

Cartesian Coordinates

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

- X and Y – axes define a plane which is tangential to the WGS-84 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 Cat020 Standard document [REF7].*

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

Central processor

A node within a *WAM* system where the information from multiple *receiving stations* is collated for the purposes of measuring target position, assembling *target reports*, and carrying out other management functions of the *WAM* system.

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, assuming the system is available when the procedure is initiated.

NOTE: *This definition is consistent with EUROCAE ED-126.*

Data Age

The interval between the *Time of Applicability* of a piece of information and the time of output.

Data Driven Mode

The interval between successive *Target Reports* from the same target is governed by the rate at which successful *Position detection* are achieved by the WAM system.

Detection

A successful decode of a target transmission.

NOTES: *1. See also Position detection.*

2. Includes SSR interrogator replies and Squitter (1090MHz).

DOP (Dilution of Precision)

The influence of the geometrical configuration of the *Multilateration System* relative to the target on the *Accuracy* of the measured position of that target.

NOTE: *The locations of the receivers can be favourable or unfavourable for a given target location. An unfavourable location can greatly increase the error even if the TDOA Accuracy is maintained. A low DOP value represents a better positional Accuracy and relates to wider angular separation between the receivers used to calculate target position.*

Extrapolation [persistent data]

The continued use of parameters that remain constant or changes infrequently for inclusion in *Target Reports* when these parameters have not been explicitly refreshed or updated from the target source.

NOTE: *Such parameters should normally have a maximum acceptable Data Age beyond which Extrapolation should not be continued.*

Extrapolation [variable data]

The calculation of the value of a parameter at a specified point in time based upon a historical sequence of values for that parameter for inclusion in *Target Reports* when the parameter has not been explicitly refreshed or updated from the target source.

NOTE: *The calculations will require a tracking function to be performed on historical data in order to generate the extrapolated data.*

False Target Report

Either:

A *Target Report* at a position of greater distance from the true position than:

- 2100m for 5NM separation
- 1690m for 3NM separation.

Or

- A *Target Report* that is spurious i.e. does not relate to any target within the *Operational Coverage Volume*.

Ground station

A *Receiving Unit* or a *Transmitting Unit* or an arrangement of co-located *Receiving Unit* and *Transmitting Unit* with all supporting infrastructure.

NOTES: *1. This would include antennae; masts; communication links; power; environmental housing; etc as appropriate to the operating requirements.*

2. In Asterix specifications this is sometimes referred to as a Remote Sensor.

Identity

Operational identification consisting of either Aircraft Identity (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.

NOTE: *This is consistent with EUROCONTROL Surveillance Standard definition B-3.2.*

Interrogation

Generation of signals for the purpose of eliciting a transmission from target**.**

Illegal *Aircraft Address*

An address consisting of all zeros or all ones.

Multilateration System

A *Multilateration System* is any group of equipment configured to provide position and identification derived from target transmitted signals using Time Difference of Arrival (*TDOA*) techniques.

Multipath

The phenomenon whereby signals arrive at the antenna of a *Receiving Unit* 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.*

Multiple Targets

The condition whereby transmissions from a single target result in the simultaneous reporting of more than one target position.

NOTE: *This effect may be caused by Multipath or by unresolved incorrect solutions. If the target is non-ambiguous through other Identity information then the condition will be readily identified and may be resolvable. If the target is ambiguous then it may not be possible to resolve that the Multiple targets are not valid.*

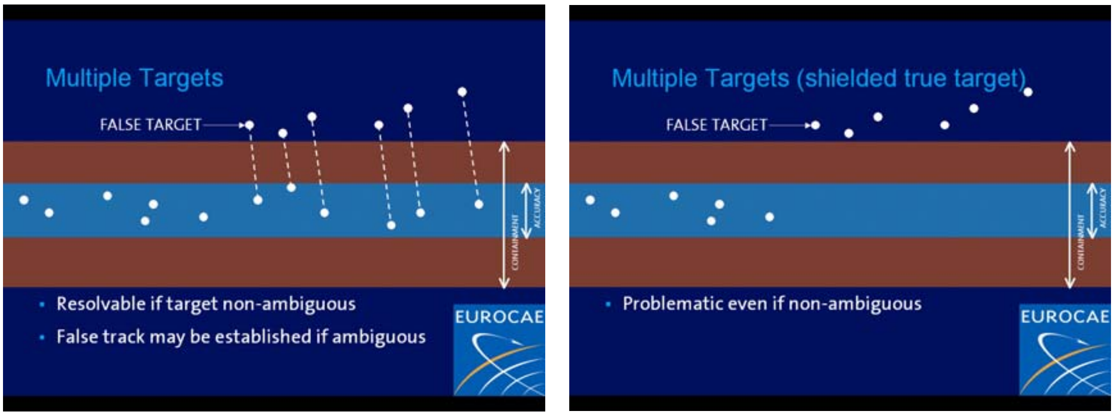

FIGURE 1-2: ILLUSTRATION OF MULTIPLE WHERE TRUE POSITION MAY OR MAY NOT BE PRESENT

Non-transponder device

Device capable of broadcasting 1090 extended *Squitter* (DF18) that is not part of a Mode S transponder.

Operational Coverage Volume

The geographic volume of interest within which the system provides surveillance with required performance.

Output Period

Time between successive *Target Reports* for the same target.

NOTE: *This term is applied to a WAM system operating in a Periodic Mode. (i.e. where a regular time interval between Target Reports is required). The Output Period should not exceed the Update Interval.*

Periodic Delayed Mode

The system operates a fixed time interval between successive *Target Reports* for the same target. The most recent measurement is delayed to the *Output Period* boundary. The *Time of Applicability* of the most recent measurement is preserved.

NOTE: *This mode will be used where a regular time interval between the outputs of Target Reports is required by the end user.*

Periodic Predicted Mode

The system operates a fixed time interval between successive *Target Reports* for the same target. The *Target Report* contains predicted information based upon previous data. *Time of Applicability* will be set to the time the *Target Report* is created.

NOTE: *This mode will be used where a regular time interval between the Time of Applicability of Target Reports is required by the end user.*

Position detection

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.

Predicted Position

A position obtained from an *Extrapolation* process when operating in Periodic Mode such that output data generated on each *Output Period* is applicable at the time of output.

NOTE: *If Predicted Position does not include a Position detection made within that Output Period then that target position will be considered to be extrapolated.*

Probability of position detection (PD)

The probability of generating a *Target Report* during the defined *Update Interval* where the *Target Report* has derived the target position from at least one *Valid Position Detection* occurring within the *Update Interval*.

Probability of false detection (PFD)

The ratio of the total number of *False Target Reports* to the number of all *Target Reports* output by the WAM system.

Probability of code detection (PCD)

The probability of outputting at least one correct and validated code (Mode A, Mode C) within an *Update Interval* in which a *Target Report* has been output.

For Mode S target, the ratio of *Target Reports* with correct *Aircraft Address* to the total number of Mode S *Target Reports.*

NOTE: *1. Separate probability figures will normally be applied to the PCD of Mode A, the PCD of Mode C, and the PCD of Aircraft Address.*

2. For a Mode S Target Report, the Mode A Code may be an Extrapolation [persistent data].

3. For a Mode S Target Report there will be a Pressure Altitude report instead of a Mode C code.

Probability of false code detection (PFCD)

The ratio of the number of *Target Reports* containing an incorrect but validated code to the total number of *Target Reports* which contain a code (Mode A, pressure altitude);

For Mode S target, the ratio of the number of *Target Reports* containing an incorrect *Aircraft Address* to the total number of Mode S *Target Reports*.

NOTE: *1. Separate probability figures will normally be applied to the PFCD of Mode A, the PFCD of Mode C, and the PFCD of Aircraft Address.*

2. For a Mode S Target Report, the Mode A Code may be an Extrapolation [persistent data].

3. For a Mode S Target Report there will be an altitude report instead of a Mode C code.

Probability of Position Long Gap (PLG)

The probability of two or more consecutive *Update Intervals* where no *Valid Position Detection* is obtained for a target.

NOTES: *1. The calculation of PLG excludes false target reports.*

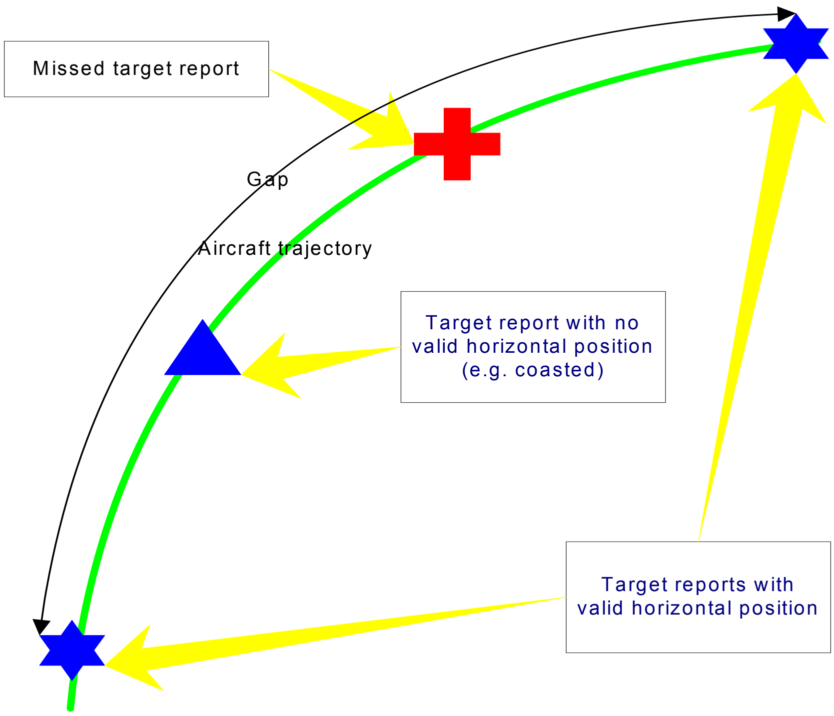

FIGURE 1-3: ILLUSTRATION OF A LONG POSITION GAP

Processing delay

The delay between the signal arriving at the *Receiving Unit* and the time at which a *Target Report* is output by the *Multilateration System*.

NOTE: *1. The time difference between receiving a signal at multiple Receiving Unit is assumed negligible (generally shorter than one millisecond) as a component of Processing delay.*

2. Processing delay is a measure of WAM performance. Processing delay requirements should have an associated probability.

3. This definition applies to Data Driven Mode only.

Positional Resolution

The distance between two targets below which the surveillance system can no longer achieve specified performance.

Receiving Unit

A device capable of *Detection* of signals-in-space and processing these into a form suitable for onward transmission.

Reference Point

The origin of the co-ordinate system of a multilateration system from which all positional information is measured.

Smoothing

Smoothing is the process of averaging/filtering by the WAM system of multiple measurements for a single target to produce consolidated output data.

NOTE: *Smoothing may be used to reduce the measurement noise in Position detection. It may also be used in circumstances of high position detection rates to limit Target Report rates to an acceptable level.*

Squitter

A spontaneous transmission generated at a pseudo random rate by a Mode S transponder.

System Capacity

System capacity is defined as the minimum number of target that the system must process within a specified time interval.

Target

Any vehicle or aircraft equipped with an SSR transponder or equivalent, which has been turned on and is functioning in compliance with its Minimum Operating Performance Standards.

Target Report

An output of a *Multilateration System* providing position, *Identity* and potentially additional information for a target obtained by multilateration calculation on one or more target transmission received at a number of sensors (see also *Position detection*).

NOTE: *A Target Report may be generated from a single Position detection. Alternatively it may be derived from a number of target transmissions through a Smoothing or Extrapolation process.*

Target Trajectory

A reconstruction of a single target's movement within the coverage of a surveillance system by means of associating a sequence of *Target Reports*.

NOTE: *An analysis function capable of generating target trajectories from recordings of surveillance data may be used in the analysis of system Accuracy, and also in the measurement of probabilities of Position detection/false detection.*

Time of Applicability

The time at which a measurement or *Extrapolation* of any varying parameter can be considered as true within the bounds of expected error.

NOTE: *Error in estimating Time of Applicability is a contribution to overall error and should therefore be minimised by design. Processing delay beyond the point where Time of Applicability has been applied does not contribute to error, but contributes to Data Age.*

Time Difference of Arrival (TDOA)

The *TDOA* is the difference in relative time that a transmission from the same target is received at different *Receiving Unit*

NOTE: *TDOA relates directly to path length difference between a targets and a number of sensors and is the principle upon which multilateration is performed.*

Time of Arrival (TOA)

The *Time of Arrival* is the time a transmission from a target is received at a *Receiving Unit*.

Track

A progressive series of *Target Reports* that have been associated with a single target.

Transmitting Unit

A device capable of generating signals for the purpose of target *Interrogation* in accordance with ICAO Annex 10 Volume IV for Secondary Surveillance Radar.

Transponder

A device compliant with ICAO Annex 10 Volume IV for reception of, and response to *Interrogation* from a Secondary Surveillance Radar**.**

NOTE: *Of particular relevance to WAM systems is a device that does not receive or respond to Interrogation but emulates some or all transponder transmission types (e.g. Mode S Extended Squitter).*

Update

A renewal of *Target Reports* relating to all targets under surveillance.

Update Interval

The maximum permissible time interval between successive *Target Reports* for the same target.

NOTE: *Use of Update Interval and an associated probability is a measure of WAM performance that is equivalent to radar performance measured in terms of the probability of detection of a target in a single rotation period.*

Valid Position Detection

A *Position Detection* that indicates the true position of a target within the expected bounds of *Accuracy*.

NOTE: *A Position Detection which is not a Valid Position Detection may give rise to a False Target Report.*

Validation

The determination that the requirements for a product are sufficiently correct and complete.

Verification

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

1.6.2 Abbreviations

ACAS	Airborne Collision Avoidance System
ACC	Area Control Centre
ACID	Aircraft Identification
ADS-B	Automatic Dependent Surveillance - Broadcast
AL	Assurance Level
ANS	Air Navigation System
ASTERIX	All purpose STructured EuRocontrol surveillance Information eXchange
ATC	Air Traffic Control
ATM	Air Traffic Management
BDS	comm-B Data Selector
BITE	Built In Test Equipment
CA	Communication Capability
CE	Conformité Européenne (European CE mark)
CMS	Control and Monitoring System
CNS	Communication, Navigation and Surveillance
CP	Central Processor
DF	Downlink Format

DOP	Dilution of Precision
DPR	Data Phase Reversals
EEC	European Economic Community
EHS	Enhanced Surveillance
ELS	Elementary Surveillance
EMC	Electromagnetic compatibility
ETSI EN	European Telecommunications Standards Institute European Norm
EU	European Union
FAA	Federal European Authority
FAT	Factory Acceptance Test
FL	Flight level
FS	Flight Status
GBS	Ground Bit Status
HME	Height monitoring
ICAO	International Civil Aviation Organisation
IFR	Instrumental Flight Rules
ILS	Instrument Landing System
LRU	Line Replaceable Unit
LVD	Low Voltage Directive
MB	Mode S comm-B data
MLAT	Multilateration
MOPS	Minimum Operational Performance Specification
MSL	Mean Sea Level
MTBCF	Mean Time Between Critical Failures
MTTR	Mean Time To Repair
NM	Nautical Miles
OVL	Overload Indicator
PCD	Probability of Code Detection
PD	Probability of Position Detection
PFCD	Probability of False Code Detection
PFD	Probability of False Detection
PLG	Probability of Long position Gap
PRM	Parallel Runway Monitoring
RA	Resolution Advisory
RF	Radio Frequency
RMS	Root Mean Square
RMTR	Reference and Monitoring Transponder
RTCA	Radio Technical Commission for Aeronautics
RVSM	Reduced Vertical Separation Minima
RXU	Receiving Unit

SAC	The System Area Code
SAE	the Society of Automotive Engineers
SAT	Site Acceptance Test
SDP	Standard Deviation of Position
SIC	System Identification Code
SPI	Special Position Identification
SPR	Synch Phase Reversal
SSR	Secondary Surveillance Radar
SWAL	Software Assurance Level
TDOA	Time difference of arrival
TMA	Terminal Manoeuvring Area
TOA	Time of Arrival
TP	Test Procedure
TPL	Test Plan
TR	Test Result
TT	Type Test
TXU	Transmitting Unit
UF	Uplink Format
UTC	Coordinated Universal Time
WAM	Wide Area Multilateration
WEEE	Waste electrical and electronic equipment
WGS	World Geodetic System

1.7 REFERENCES

1.7.1 ICAO

REF1 Annex 10 — *Aeronautical Telecommunications* Volume IV — *Surveillance and Collision Avoidance Systems*

REF2 Annex 11 — *Air Traffic Services*

REF3 *Procedures for Air Navigation Services — Air Traffic Management* (PANS-ATM, Doc 4444)

REF4 Technical Provisions for Mode S Services and Extended Squitter (Doc 9871)

1.7.2 Eurocontrol

REF5 EUROCONTROL Standard Document for Surveillance Data Exchange, Part 1, All Purpose Structured Eurocontrol Surveillance Information Exchange (ASTERIX), SUR.ET1.ST05.2000-STD-01-01

REF6 EUROCONTROL Standard Document for Surveillance Data Exchange, Part 18: Category 019, Edition 1.2, Multilateration *System* Status Messages, SUR.ET1.ST05.2000-STD-18-02

REF7 EUROCONTROL Standard Document for Surveillance Data Exchange, Part 14: Category 020, Edition 1.5, Multilateration Target Reports, SUR.ET1.ST05.2000-STD-14-02

REF8 EUROCONTROL Standard Document for Surveillance Data Exchange, Part 14: Category 020, Appendix A, Coding Rules for "Reserved Expansion Field", Edition 1.2, SUR.ET1.ST05.2000-STD-14-02

REF9 EUROCONTROL Standard Document for Radar Surveillance in En-Route Airspace and Major Terminal Areas, Edition 1.0 March 1997, SUR.ET1.ST01.1000-STD-01-01

REF10 European Mode S Station Coverage Map Interface Control Document SUR/MODES/EMS/ICD-03 edition 1.16

1.7.3 EUROCAE/RTCA

REF11 EUROCAE, Guidelines for Communication, Navigation, Surveillance and Air Traffic Control (CNS/ATM) Systems Software Integrity Assurance ED-109

REF12 EUROCAE, Guidelines for ANS Software Safety Assurance ED-153

REF13 Minimum Aviation System Performance Standards for ADS-B, RTCA/DO-242, February 19, 1998

REF14 Minimum Operational Performance Standards for 1090 MHz Extended Squitter ADS-B and TIS-B, ED-102A/DO-260B, 2010

REF15 Minimum Operational Performance Standards for Secondary Surveillance Radar Mode S Transponders ED-73C; Minimum Operational Performance Standards for Air Traffic Control Radar Beacon System/Mode Select (ATCRBS/Mode S) Airborne Equipment, DO-181D

REF16 Technical Specification for a 1090 Mhz Extended Squitter ADS-B Ground station ED-129

CHAPTER 2

GENERAL DESIGN REQUIREMENTS

2.1 INTRODUCTION

This chapter establishes the design considerations for a WAM system. It contains requirements for which no specific tests have been defined within this document. Compliance can be verified through manufacturer provided documentation.

2.2 FUNCTIONAL REQUIREMENTS

The WAM system ***shall*** contain the necessary functions to measure the horizontal position and provide altitude and *Identity* of all targets transmitting on 1090MHz in its intended coverage volume.

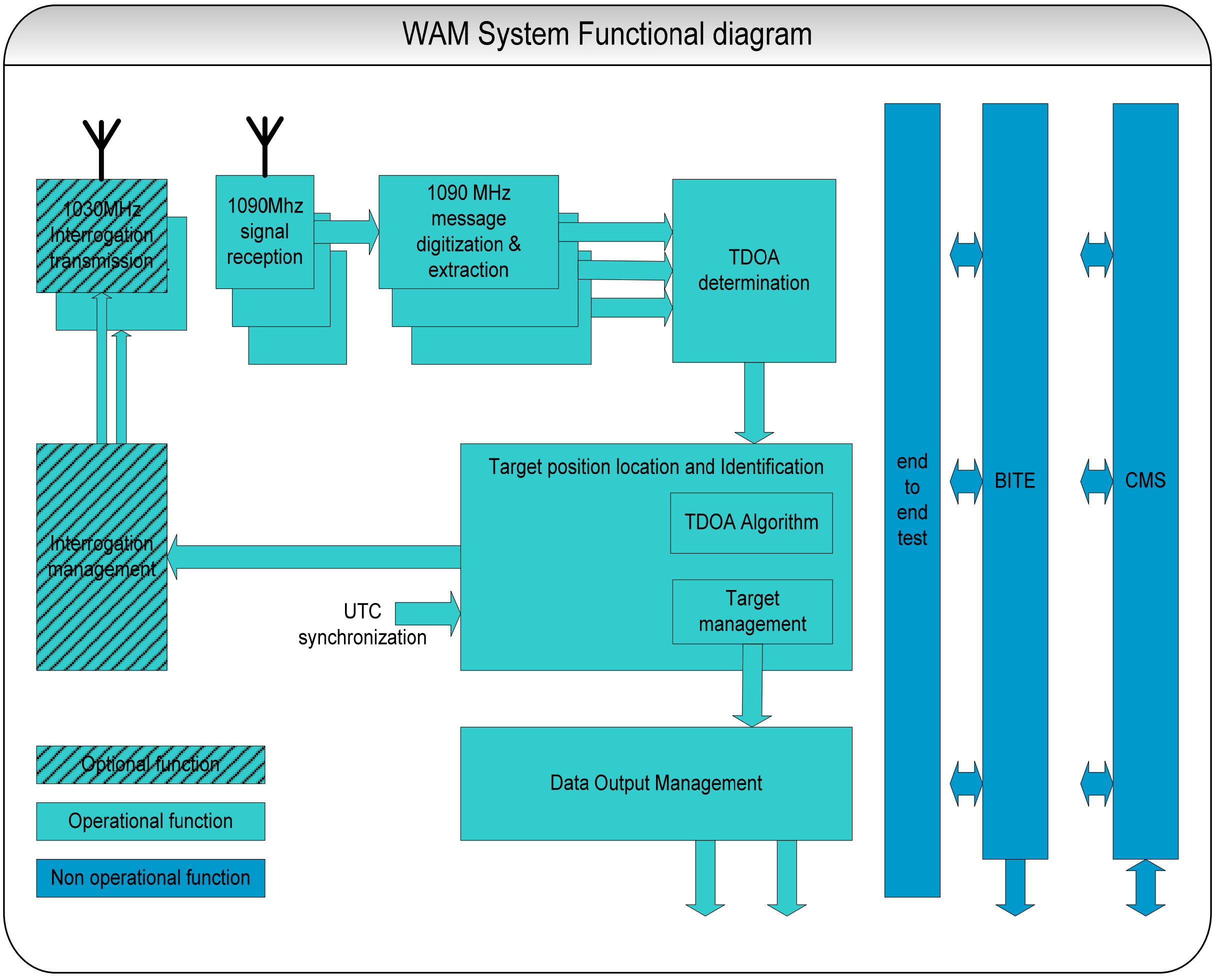

FIGURE 2-1: FUNCTIONAL DESCRIPTION OF WAM SYSTEM

The WAM System ***shall*** be capable of providing at least the following functions as described in Figure 2-1:

a). **1090 MHz Signal Reception**: a function to receive 1090 MHz RF signals. This function will be replicated at different locations/sites to support multilateration.

b). **1090 MHz Digitization & Message Extraction**: a function to digitize the signal and to extract Mode A/C replies, Mode S replies, Mode S Acquisition and Extended *Squitter* transmitted by Airborne and/or Vehicle transponder.

c). ***TDOA*** **determination**: a function to determine the difference in *Time of Arrival* of the same signal across receiving sites.

d). **Target Position Location and Identification**: a function that calculates the position at which a signal has been transmitted (***TDOA*** **Algorithm**) and manages the different *Detection* and data obtained for each target (**Target Management**).

e). **Data Output Management**: a function which provides users with target data and system status.

f). ***Interrogation*** **Management**: A function which manages the *Interrogation* that must be sent to actively interrogate targets.

g). **1030 MHz** ***Interrogation*** **transmission**: A function which transmits *interrogations* on 1030 MHz.

h). **Built In Test Equipment (BITE):** A function which monitors the health of the system and which allows isolation of failures.

i). **Control and Monitoring System (CMS):** A function which allows the configuration and control of the WAM system and reports its current service status.

j). **End-to-end test**: A function which checks the complete RF signal and data processing path of the system.

NOTE: *The use of 1030 MHz signal transmission, and consequently Interrogation management may not be required in certain applications.*

The multilateration position ***shall*** be derived independently of latitude and longitude obtained from ADS-B message content. If Mode S Enhanced Surveillance (EHS) is to be used, guidance is provided in Appendix A.

2.2.1 1090 MHz Signal Reception

The WAM system receives signals transmitted over the 1090MHz RF band.

The WAM system detects and identifies target equipped with ICAO Annex 10 compliant transponder (Mode A/C only, Mode S, Extended *Squitter*) and *Non-transponder device*.

2.2.2 1030 MHz *Interrogation* Transmission

The WAM system is capable of interrogating in Mode A, Mode C and Mode S.

The *interrogation* power and repetition rate ***shall*** be kept to a minimum, consistent with the operational requirements, in order to minimise the effect of active WAM operation on the 1030/1090 MHz radio frequency environment in compliance with ICAO Annex 10 requirements.

2.2.2.1 Mode S Interrogation

The WAM system ***shall*** not set 'Mode S Interrogator Identifier (II) or Surveillance Identifier (SI) code lockout' on any target.

The WAM system ***shall*** not use Mode S all-call *Interrogation* (UF11).

2.2.2.2 Mode A/C Interrogation

The WAM system ***shall*** not use the Mode S inter-mode 'Mode A/C/S all-call *interrogation*'(also known as Mode A/C/S long P4).

2.2.3 Data Output Management

The WAM system outputs target and status reports on multiple outputs, which are individually configurable.

The WAM system ***shall*** provide at least two separate physical output connections.

2.2.4 Built In Test Equipment

The WAM system ***shall*** include a Built In Test Equipment (BITE) such that there is a continuous monitoring of the operating status of the equipment.

It ***shall*** be possible to operate BITE in both Operational and Maintenance modes (see *2.3.1*)

The BITE coverage rate ***shall*** be at least 90% (i.e. failures capable of degrading performance below minimum requirements ***shall*** be detected in 90% of cases)

The BITE fault finding rate ***shall*** be at least 95% (i.e. 95% of all detected failures ***shall*** be isolated to within a three LRU group).

The WAM system BITE ***shall*** be able to register a fault condition without the presence of an external control and monitoring system.

NOTE: *The ability to register a fault means that BITE information is stored within the WAM system such that an external control and monitoring system may identify that a fault has occurred even if the occurrence was prior to the control and monitoring system being connected.*

2.2.5 Control and Monitoring System (CMS)

The CMS allows configuration control of the WAM system. Its implementation is considered to be manufacturer and/or user specific and hence it is not further defined in this document.

For systems requiring an external CMS interface, as a minimum this ***shall*** conform to SNMP standard, v2.

2.3 CONTROLS

2.3.1 WAM system Modes and States

The WAM system ***shall*** provide as a minimum two modes, namely:

- 'Operational': the system is available for operation.
- 'Maintenance': the system is under maintenance and is not available for operation.

The WAM System ***shall*** have as a minimum two states namely:

- GO - Minimum system performance is achieved across the *Operational Coverage Volume*.
- NOGO - Minimum system performance is not achieved across the *Operational Coverage Volume*. - or - the system is unable to ascertain that minimum system performance is achieved across the Operational Coverage Volume.

NOTE: *Modes are generally set by an operator, while state is a property of the WAM system generally determined by itself.*

The WAM system ***shall*** report its state of operation (GO/ NOGO).

The WAM system ***shall*** be able to be manually commanded from one mode to another mode by a maintenance operator.

After power-on the WAM system ***shall*** enter the mode it was previously in before power-off.

2.3.2 System Security

The WAM system ***shall*** control the access to the system by users.

NOTE: *Normally achieved by password controlled login.*

2.4 SOFTWARE DESIGN

Software design ***shall*** follow the guidelines for the assurance of software contained in ED-109 [**REF11**].

The Assurance Level should be AL4 as defined in ED-109 or, as an alternative, for systems or system elements developed before the issue of this standard, a safety argument for the software based on in-service evidence should be used for assurance.

NOTE: *ED-109 provides a clear set of software development guidelines for equipment suppliers and hence is used for this document's requirements. ED-153, Guidelines For ANS Software Safety Assurance* ***[REF12]*** *is aimed at ANSPs and is therefore not used for a formal requirement in this document. To assist understanding of the equivalence of these standards, ED-109 AL4 corresponds to SWAL3 in ED-153.*

NOTE: *For less stringent applications than those specified in 1.1 or where WAM is not sole means of surveillance, lower assurance levels may be acceptable.*

2.5 HARDWARE DESIGN

The system ***shall*** comply with all relevant EU regulatory standards.

NOTE: *For example the following standards may apply:*

Directive 2006/95/EC	Electrical Equipment - Low Voltage Directive (LVD)
Directive 2004/108/EC	Electromagnetic compatibility (EMC)
Directive 92/58/EC	Health and safety signs and markings

NOTE: *Directive 2006/95/EC lays down the requirements covering all health and safety risks of electrical equipment operating within certain voltage ranges. It replaces previous Directive 73/23/EEC.*

NOTE: *Directive 2004/108/EC lays down requirements in order to preventing electrical and electronic equipment from generating or being affected by electromagnetic disturbances. It replaces Directive 89/336/EEC*

The system ***shall*** be CE marked to demonstrate compliance with EU directives for product safety.

2.6 WAM SYSTEM EXPANDABILITY

The WAM system should provide the ability to increase or alter the *Operational Coverage Volume* or the System Performance through the addition or redeployment of *Receiving Unit* and/or *Transmitting Unit.*

2.7 DATA RECORDING

2.7.1 Access points

The WAM system ***shall*** provide capability to make available test points/interfaces where key data could be accessed and recorded.

NOTE: *this could be done as a hardware interface or a software interface (data available in a specific file)*

The protocols and formats available on these recording points ***shall*** be documented.

The WAM system ***shall*** provide recording access to *Target Reports* and service messages output without impacting the operational use of the system.

The WAM system ***shall*** provide recording access to equipment and system status and performance data without impacting the operational use of the system.

The WAM system ***shall*** provide recording access in order to investigate the effects of the loss of one or several *Receiving Unit.*

NOTE: *This allows the Verification of multiple N-m scenarios on one flight test.*

Where active interrogation is used, the WAM system ***shall*** provide recording access to interrogator commands in order to investigate the loss of essential or expected target information at the system output.

2.7.2 Recording capability

2.7.2.1 System status and Performance

The WAM system ***shall*** maintain a time stamped record of the operating status, states and modes of the equipment.

NOTE: *This may typically be achieved through a Control and Monitoring System.*

2.7.2.2 User interaction

The WAM system ***shall*** be able to log any user interaction on WAM configuration including:

- Access attempts
- Control actions
- Configuration changes

2.8 AVAILABILITY, RELIABILITY AND MAINTAINABILITY

2.8.1 Availability

The *Availability*, excluding agreed maintenance periods, ***shall*** not be less than 99.99%.

[*Availability* = MTBCF/(MTBCF + MTTR)]

NOTE: *Due to the distributed nature of a WAM system there are multiple ways of achieving availability. One way is equipment redundancy, another one is site redundancy. This is done by adding more sites than the minimum to create an N-m scenario where N is the number of sites and m is the number that can fail without loss in quality of service. (Where m=1 this means any one site can fail and the system continues to provide the required performance). When specifying a solution it is preferable to specify only the required availability rather than a method by which it should be achieved as this allows the best solution for the actual site geometry.*

2.8.2 Mean Time Between Critical Failures (MTBCF) & Mean Time to Repair (MTTR)

The availability figure defined will typically be met with MTBCF and MTTR figures of 10,000 hours and 1 hour respectively.

NOTE: *A critical failure is deemed to have occurred if the WAM system enters a NOGO state during normal operation.*

CHAPTER 3

MINIMUM PERFORMANCE SPECIFICATION UNDER STANDARD CONDITIONS

3.1 INTRODUCTION

The requirements specified in this chapter are the minimum surveillance performance specifications for a Wide Area Multilateration (WAM) system to support 3 NM and 5 NM separation surveillance applications. They ***shall*** be met in standard operational conditions.

The WAM system defined in this chapter provides:

- The same surveillance data as SSR
- Equivalent or better level of independent cooperative surveillance service as that provided by SSR
- Equivalent or better *Integrity*, *Continuity* and *Availability* to that provided by SSR

The requirements listed in the rest of this chapter define:

- required surveillance data
- required functionality to be an independent source of surveillance data
- required data performance and *Integrity*

They ***shall*** be met in standard operational conditions.

NOTE1: *WAM has the capability to support other applications. Some of these applications could be more demanding, e.g. Final Approach monitoring, parallel Runway Monitoring (PRM), Height Monitoring.*

NOTE2: *In practice the same WAM system components will serve all application classes. Proper design of system geometry and number of units will allow the system to meet appropriate Detection probability, Update rate, Accuracy figures and other performances as required for a particular application. Example: a WAM system can support 5 NM in a part of its coverage and 3nm radar separation in another part of its coverage.*

3.2 SYSTEM REQUIREMENTS

3.2.1 Target processing

The WAM system ***shall*** be capable of detecting and processing Mode A/C and Mode S targets.

The WAM system ***shall*** be capable of detecting and handling correctly 2 aircraft with identical *Aircraft Address* separated by more than 10NM within the defined coverage volume.

3.2.2 Interrogation

When used, the Mode A, Mode C, Mode S *interrogations* transmitted by the WAM system ***shall*** meet all the relevant ICAO Annex 10 requirements [**REF1**].

The system transmitting power ***shall*** be configurable to allow it to be minimised whilst still meeting the standard operational requirements.

3.2.2.1 Elementary Mode S Interrogation

Where Mode S *interrogations* are required, the WAM system ***shall*** interrogate Mode S aircraft using selective Mode S roll-call interrogations.

The WAM system ***shall*** be able to interrogate for the following target data:

- Pressure Altitude
- Mode A code
- *Aircraft Identification (ACID – BDS 2,0)*
- Datalink Capability Report (BDS 1,0)

3.2.2.2 Mode A/C Interrogation

Where Mode A/C *interrogations* are required, the WAM system ***shall*** interrogate Mode A/C aircraft using Mode A/C *Interrogation* or Mode A/C only all call (i.e. Inter-mode with short P4 pulse).

3.3 PERFORMANCE

The performance requirements specified in this section are applicable to the targets located within the defined *Operational Coverage Volume* of the system.

3.3.1 Update Interval

The WAM system ***shall*** meet the performance requirements specified in Chapter 3 at the defined *Update Interval*.

The defined *Update Interval* ***shall*** not exceed the following:

- 8 seconds for the En-route application
- 5 seconds for the TMA application

3.3.2 Update of changed aircraft information

The WAM system ***shall*** output changes in the following aircraft information within 3 times the maximum *Update Interval* (24 seconds for the En-route application and 15 seconds for the TMA application) with a probability of 95%:

- ACID
- Mode A code (where required by the user)

The WAM system ***shall*** output changes in the following aircraft information within the maximum *Update Interval* (8 seconds for the En-route application and 5 seconds for the TMA application) with a probability of 95%:

- Emergency Codes
- SPI (where required by the user)

3.3.3 Probability of position detection (PD)

The *Probability of position detection* within the defined *Update Interval* ***shall*** be greater than or equal to **97%** for any target.

3.3.4 Probability of long position gaps (PLG)

The probability of long position gap for more than 3 times the maximum *Update Interval* +10% (26.4 seconds for En-route application and 16.5 seconds for TMA application) ***shall*** be less than or equal to 0.1%.

NOTE: *This requirement excludes anomalies due to transponder issues.*

3.3.5 Probability of false detection (PFD)

The *Probability of false detection* ***shall*** be less than or equal to **0.1%**.

NOTE: *The Probability of false detection includes the Probability of a Multiple Target Report.*

3.3.6 Probability of code detection (PCD)

The WAM system ***shall*** provide a correct *Aircraft Address* within the defined *Update Interval* with a probability greater than or equal to **99%.**

The WAM system ***shall*** provide a correct and validated Mode A code within the defined *Update Interval* with a probability greater than or equal to **98%.**

The WAM system ***shall*** provide a correct and validated Mode C code within the defined *Update Interval* with a probability greater than or equal to **96%.**

3.3.7 Probability of False Code Detection (PFCD)

The Probability of False *Aircraft Address* detection ***shall*** be less than or equal to **0.1%**.

The Probability of False Mode A code detection ***shall*** be less than or equal to **0.1%**.

The Probability of False pressure altitude ***shall*** be less than or equal to **0.1%**.

The Probability of False *ACID* detection ***shall*** be less than or equal to **0.1%.**

3.3.8 Horizontal Position Accuracy

The Horizontal position errors ***shall*** not exceed:

- 350 m RMS for the En-route application
- 150 m RMS for the TMA application

NOTE1: *The horizontal position error is calculated for the time of applicability provided by the target report.*

NOTE2: *This document does not specify how the accuracy performance is achieved. WAM systems may use interrogations to achieve required accuracy. If the accuracy performance is to be achieved without interrogation this will need to be specified as an additional user requirement.*

3.3.9 Target Report Time Stamp

The WAM system ***shall*** provide time-stamping of target position synchronized with UTC.

The timing error between the time stamp (UTC Time of Day) associated with a *Target Report* and the *Time of Applicability* of the *Target Report* ***shall*** be less than or equal to 100 ms.

3.3.10 Positional Resolution (Mode A/C)

Positional Resolution is specified for two close targets equipped with the Mode A/C transponders with different Mode A codes within two horizontal separations, according the following table:

Horizontal separation	Airspace type	
	En-route service	TMA service
Separation 1	3 500 m (2 NM)	1 200 m (0,6 NM)
Separation 2	7 000 m (4 NM)	3 500 m (2 NM)

NOTE: *Figures in the table were derived from European Surveillance Standard.*

3.3.10.1 Positional Resolution - Position Detection

The *Probability of position detection* of two different Mode A/C transponder equipped targets within defined *Update Interval* ***shall*** be greater than or equal to:

- **60%** at Separation 1
- **98%** at Separation 2

NOTE: *Probability value for Separation 2 is greater than the Probability of Position Detection value (Section 0) as it is defined for the specific case of pairs of aircraft of known separation.*

3.3.10.2 Positional Resolution - Mode A/C Code Detection

The probability of correct Mode A and C code detection of two different Mode A/C transponders equipped targets, within defined *Update Interval* ***shall*** be greater than or equal to:

- **30%** at Separation 1
- **90%** at Separation 2

3.3.11 Processing delay

In *Data Driven Mode*, the processing delay ***shall*** be less than or equal to 1 second measured from the time of reception of the target signal at a *Receiving Unit* to the WAM system outputting a *Target Report*.

NOTE: *It is assumed, that the delay of the communication infrastructure used within the WAM system will not exceed 500 ms.*

In *Periodic Delayed Mode*, when the last received measured position within the *Output Period* is transmitted, the maximum *Processing delay* ***shall*** be less than or equal to the duration of the *Output Period* plus 1s.

In *Periodic Predicted Mode*, when the *Predicted Position* at time of output is transmitted, the maximum *Processing delay* ***shall*** be 0.5 second.

3.3.12 Track Initiation

Track initiation time is defined as the time from when a target enters the WAM system *Operational Coverage Volume* with an active transponder to the output of the first position *Target Report* from the WAM system.

The *Track* initiation time ***shall*** be less than or equal to 5 times the defined *Update Interval* with the probability of 99%.

If the system is designed to detect aircraft during a take-off the *Track* Initiation should be less than or equal to 3 times the defined *Update Interval* with the probability of 99%.

3.3.13 Target Capacity

The Target Capacity is defined as the maximum number of targets for which the system is able to meet all the specified surveillance performance requirements. The required capacity depends on particular airspace volume and upon environment characteristics.

As a minimum, the WAM system ***shall*** be able to simultaneously acquire and maintain tracking on 250 targets within its stated *Operational Coverage Volume*.

NOTE1: *This minimum value reflects the inherent scalability of a WAM system, recognising that much higher capacities can be achieved where required.*

NOTE2: *Required Target capacity and Update Interval will have direct impact on data-link capacity used for the system.*

<u>Overload mechanism</u>:

An overload mechanism ***shall*** be provided to detect when the number of targets exceeds a configurable capacity threshold. When the threshold is exceeded the WAM system ***shall*** set overflow indicator, ASTERIX OVL bit in item I019/550, in the system status report.

Where an overload is detected the system ***shall*** enter a NOGO state.

3.4 DATA OUTPUT MANAGEMENT

This section specifies the data output interface in order to assure inter-operability with ATC processing systems receiving the WAM system *Target Reports* and status messages.

3.4.1 Data Output Modes

The WAM system ***shall*** be able to output data operating in one or more of the following output modes:

- *Data Driven Mode*: Data Driven Mode is appropriate for surveillance processing systems capable of handling high data rates and non-periodic update
- *Periodic Delayed Mode*: Periodic Delayed Mode is for surveillance processing systems were the data rate needs to be minimised or periodic update is required. This mode is inappropriate for direct input to display systems.
- *Periodic Predicted Mode*: Periodic Predicted Mode is suitable for direct input to display systems, and for surveillance processing systems.

3.4.2 Data output format

The WAM system ***shall*** be capable of providing data output in the Eurocontrol ASTERIX Cat020 [**REF7**] (incl. Appendix A [**REF8**]) or later editions, and Cat019 format [**REF6**] or later edition.

The following two types of data ***shall*** be output:

- *Target Report* (plot/*Track*) data - ASTERIX CAT 020 reports
- Service messages (overall system status, subsystem status, WAM reference position) - ASTERIX CAT 019 reports.

3.4.3 Target Reports

The WAM system ***shall*** be capable of outputting the following data items within *Target Report*s:

- Data Source Identifier
- *Target Report* Descriptor
- Time of Day (Time Stamp)
- Horizontal Position (WGS84)
- Mode 3/A Code
- *Aircraft Identification* (ACID)
- Pressure Altitude: FL derived from Mode S Altitude (25ft increments) or Mode C value (100ft increments)
- Horizontal Position *Accuracy* (Standard Deviation of position [error])
- SPI
- *Aircraft Address* (*Target Address*)
- Flight Status

- Transponder Communications/ACAS Capability
- Indication of Duplicated or *Illegal Aircraft Address*
- *Data Age* of the *Pressure Altitude*

The following *Target Reports* data items are OPTIONAL:

- Horizontal Position (*Cartesian Coordinates*)
- *Track* Number
- *Track* Status
- Calculated Track Velocity
- Calculated Acceleration
- Contributing Receivers (to the MLAT target position)
- Calculated Height (Measured/Geometric height)
- Standard Deviation of the Calculated Height
- Mode S MB data
- ACAS Resolution Advisory Report
- Mode-1 Code
- Mode-2 Code
- *Data Ages*

3.4.4 Mandatory Target Report Items

This section specifies the target data which the WAM system ***shall*** be capable of providing as a minimum. Corresponding data item in the Cat020 *Target Report* is provided in brackets.

3.4.4.1 Data source identifier (I020/010)

The System Identification Code (SIC) and the System Area Code (SAC), as defined in the ASTERIX standard, ***shall*** be configurable.

3.4.4.2 Target Report Descriptor (I020/020)

This Descriptor ***shall*** contain the following information as a minimum:

- TYP: Signal sources contributing to MLAT measurement
- RAB: Field monitor indicator
- SPI: Presence of SPI
- GBS: Ground bit status

3.4.4.3 Time of Day (I020/140)

The Time of Day ***shall*** represent the *Time of Applicability* of the *Target Report* expressed as UTC time of day.

If the horizontal position is present in the *Target Report*, the Time of Day ***shall*** represent the *Time of Applicability* of the horizontal position data.

3.4.4.4 Horizontal Position in WGS-84 Coordinates (I020/041)

The WAM system ***shall*** output the horizontal position of a target transponder antenna in WGS-84 Coordinates.

3.4.4.5 Position Accuracy (horizontal) (I020/REF, PA/SDW)

The WAM system ***shall*** be capable of providing the horizontal position *Accuracy* in terms of Standard Deviations and Covariance.

<u>Position *Accuracy* data in WGS-84 coordinates</u>

Position *Accuracy* of the horizontal position in WGS-84 coordinates ***shall*** comprise the following characteristics:

σ_{Lat}	- Standard Deviation of WGS-84 Latitude
σ_{Lon}	- Standard Deviation of WGS-84 Longitude
COV-WGS	- Lat/Long Covariance component

Lat/Long Covariance component is a 'signed square root of Covariance', defined as follows:

COV-WGS = sign (Cov(Lat,Long)) * sqrt (abs (Cov(Lat,Long)))

where: Cov(Lat,Long) is the Covariance between Latitude and Longitude

3.4.4.6 Identity (Mode 3/A Code or Aircraft Identification) (I020/070 and I020/245)

The WAM system ***shall*** be capable of outputting the operational target *Identity* in terms of Mode 3/A code and *Aircraft Identification*.

Mode-3/A code ***shall*** be reported with the following indicators:

- *Validation*
- *Garbling*
- *Extrapolation* - this indicates whether or not the Mode 3/A code has been extracted from a transponder reply. The *Extrapolation* bit is set when the code is not extracted.

The Mode 3/A code ***shall*** be extracted from a Mode S message or a Mode A reply.

3.4.4.7 Pressure Altitude (I020/090)

The WAM system ***shall*** be capable of outputting the Pressure Altitude received from the aircraft in terms of the Flight Level in Binary Representation. The Pressure Altitude derived from a Mode S message ***shall*** take precedence over Mode C when available and valid.

The Pressure Altitude ***shall*** be reported with the following indicators:

- *Validation*
- *Garbling*

The Pressure Altitude ***shall*** not be smoothed or predicted.

The age of the Pressure Altitude ***shall*** be reported in any ASTERIX *Target Report* in which the Pressure Altitude is provided.

3.4.4.8 Aircraft Address (I020/220)

The WAM system ***shall*** be capable of providing the *Aircraft Address* for Mode S target.

3.4.4.9 Flight Status, Transponder Communications/ACAS Capability (I020/230)

The WAM system ***shall*** be capable of providing the Flight Status, Communications capability of the transponder and capability of the onboard ACAS equipment for Mode S target.

3.4.4.10 Special Position Identification (SPI)

The SPI ***shall*** be output when available from one of the following sources:

- Mode A reply
- Mode S reply
- Mode S Extended *Squitter*

NOTE: *The SPI is reported in ASTERIX CAT 020 through the Target Report Descriptor (I020/020) and in case of Mode S target, also through the Flight Status (I020/230).*

3.4.4.11 Duplicated or Illegal Aircraft Address indicator (I020/030)

The WAM system ***shall*** be able to indicate a duplicated or *Illegal Aircraft Address* through the appropriate Data Item in ASTERIX CAT020.

3.4.4.12 Time of Asterix Report Transmission (I020/REF, TRT)

The Time of Asterix Report Transmission ***shall*** be output in any ASTERIX *Target Report* in which any Data Age item (I020/REF, DA field) is provided.

NOTE: *TRT is the time used as a reference for different Data-ages provided in I020/REF, DA field.*

3.4.5 Optional Target Report Items

This section specifies *Target Report* items recommended as optional WAM output capabilities. If implemented, the respective provisions ***shall*** be followed to exclude any potential ambiguity and ensure basic consistency with ASTERIX standards.

3.4.5.1 Track Number (I020/161)

The WAM system ***shall*** be capable of providing a unique *Track* number associated with each *Target Report*.

3.4.5.2 Track Status (I020/170)

When the target is tracked, the WAM system ***shall*** indicate whether a *Track* is confirmed, extrapolated and if the position is measured or smoothed. In data item I020/170 this ***shall*** be indicated within the following subfields:

- CNF: *Track* in initiation phase or *Track* confirmed
- CST: extrapolated *Track*
- STH: measured or smoothed position

3.4.5.3 Horizontal Position in Cartesian Coordinates (I020/042)

The WAM system ***shall*** be capable of outputting the horizontal position of a target transponder antenna in *Cartesian Coordinates* relative to a user defined *Reference Point*. The WGS-84 coordinates of the *Reference Point* should be sent in the relevant ASTERIX CAT 019 message.

NOTE: *This capability is allowed for backward compatibility with existing downstream systems that require Cartesian Coordinates. Where possible the Horizontal Position in WGS-84 Coordinates (I020/041) should be used instead of this item as it provides data that is independent of the system location.*

3.4.5.4 Position Accuracy data in Cartesian Coordinates

Position *Accuracy* of the horizontal position in *Cartesian Coordinates* ***shall*** comprise the following characteristics:

σ_x	- Standard Deviation of X component
σ_y	- Standard Deviation of Y component
$\boldsymbol{\rho}$(x,y)	- Correlation coefficient or
COV-XY	- XY Covariance component

Covariance component is a 'signed square root of Covariance', defined as follows:

COV-XY = sign (Cov(x, y)) * sqrt (abs (Cov(x, y)))

where: Cov(x, y) is the Covariance between X and Y coordinates

Standard Deviation in *Cartesian Coordinates* ***shall*** be expressed in the *Cartesian Coordinates* system defined in Cat020 Standard document [**REF7**].

NOTE: *This capability is allowed for backward compatibility with existing downstream systems that require Cartesian Coordinates. Where possible the Position Accuracy (horizontal) in WGS-84 coordinates (I020/REF, PA/SDW) should be used instead of this item as it provides data that is independent of the system location.*

3.4.5.5 Calculated Track Velocity (I020/REF, GVV or I020/202)

The Calculated *Track* Velocity ***shall*** be output when the WAM system provides *Track Target Reports*.

The *Track* velocity ***shall*** be expressed in WGS84 Coordinates as the Ground Velocity Vector (I020/REF, GVV) or in *Cartesian Coordinates* (I020/202).

NOTE: *Where possible the Ground Velocity Vector (I020/REF, GVV) should be used as it provides data that is independent of the system location.*

3.4.5.6 Calculated Acceleration (I020/210)

The Calculated Acceleration ***shall*** be output when the WAM system provides *Track Target Reports*.

The Calculated Acceleration ***shall*** be expressed in *Cartesian Coordinates*.

3.4.5.7 Calculated Height (I020/105, I020/110)

The WAM ***shall*** be capable of providing the Calculated Height in terms of Geometric Height (I020/105) or Measured Height (I020/110). The Calculated Height ***shall*** only be output when a 3D multilateration position solution is available.

The <u>Geometric Height (WGS-84)</u> is defined as the vertical distance between the targets and the projection of the earth's ellipsoid.

The <u>Measured Height</u> is defined in local *Cartesian Coordinates* relative to a user defined *Reference Point*. The WGS-84 coordinates of the *Reference Point* should be sent in the relevant ASTERIX CAT 019 message.

NOTE: *Where possible the Geometric Height in WGS-84 (I020/105) should be used as it provides data that is independent of the system location.*

3.4.5.8 Standard Deviation of the Geometric Height (I020/REF, PA/SDH)

The Standard Deviation of the Geometric Height ***shall*** be output together with the Geometric Height.

3.4.5.9 Contributing Receivers (I020/400)

The WAM system ***shall*** be capable of reporting the receivers that are contributing to the target position.

3.4.6 Status and Service Message

3.4.6.1 Mandatory status data

The WAM system ***shall*** be capable of outputting the following status data and service messages using the ASTERIX CAT019:

- Message Type (Periodic, Event Driven)
- Data Source Identifier (see par. *3.4.4.1*)
- Time Of Day
- System Status (states: GO, NOGO)
- System overload indicator

Service messages ***shall*** be sent periodically and in the case of change of the status.

3.4.6.2 Optional status data

The following status data items are optional:

- Tracking Processor Detailed Status
- Remote Sensor Detailed Status
- Reference Transponder Detailed Status
- Time validity indicator

NOTE: *The Time Validity Indicator indicates the system is synchronized with the UTC. If the system is not synchronised to UTC the system will be set in a NOGO state.*

- When the relative *Cartesian* Coordinates position is used for *Target Report*, then the following data on the WAM *Reference Point* ***shall*** be sent:
- Position of the MLAT System *Reference Point* in WGS-84
- Height of the MLAT System *Reference Point* in WGS-84
- WGS-84 Undulation

3.4.7 Mapping of WAM target reports to ASTERIX Cat020 data items

The Eurocontrol ASTERIX Cat020 is specifically intended for MLAT systems. The following table provides an overview of Cat020 data items and mapping to the relevant required WAM target reports.

TABLE 1: ASTERIX CAT 020 TARGET REPORTS

Data Item No.	Description	ED-142 Req.	Para graph	Note
I020/010	Data Source Identifier	**M**	**3.4.4.1**	Each Cat020 target report
I020/020	Target Report Descriptor	**M**	**3.4.4.2**	Each Cat020 target report
I020/030	Warning/Error Conditions	**O**	**3.4.4.11**	Illegal or Duplicated *Aircraft Address*
I020/041	Position in WGS-84 Coordinates	**M**	**3.4.4.4**	if a valid position available
I020/042	Position in *Cartesian Coordinates*	**O**	**3.4.5.3**	Mainly for Airport MLAT
I020/050	Mode-2 Code in Octal Representation	**O**	**n/a**	MIL interoperability – WAM
I020/055	Mode-1 Code in Octal Representation	**O**	**n/a**	MIL interoperability – WAM
I020/070	Mode-3/A Code in Octal Representation	**M**	**3.4.4.6**	from Mode S or Mode A
I020/090	Flight Level in Binary Representation	**M**	**3.4.4.7**	from Mode S or Mode C
I020/100	Mode-C Code	**O**	**n/a**	Additional info to I020/090
I020/105	Geometric Height (WGS-84)	**O**	**3.4.5.7**	HME, auxiliary for WAM
I020/110	Measured Height (Local Coordinates)	**O**	**3.4.5.7**	auxiliary (Airport MLAT)
I020/140	Time of Day	**M**	**3.4.4.3**	Each Cat020 target report
I020/161	*Track* Number	**O**	**3.4.5.1**	If MLAT outputs *Track* report
I020/170	*Track* Status	**O**	**3.4.5.2**	If MLAT outputs *Track* report
I020/202	Calculated *Track* Velocity in *Cartesian Coordinates*	**O**	**3.4.5.5**	Calculated from MLAT *Track*
I020/210	Calculated Acceleration	**O**	**3.4.5.6**	Calculated from MLAT *Track*
I020/220	Target Address	**M**	**3.4.4.8**	*Aircraft Address*
I020/230	Comms/ACAS Capability and Flight Status	**M**	**3.4.4.9**	if Flight Status available
I020/245	Target Identification	**M**	**3.4.4.6**	*Aircraft Identification*
I020/250	Mode S MB Data	**O**	**3.5.2**	Enhanced Mode S
I020/260	ACAS Resolution Advisory Report	**O**	**3.5.2**	BDS 3,0
I020/300	Vehicle Fleet Identification	**O**	**n/a**	Airport MLAT only
I020/310	Pre-programmed Message	**O**	**n/a**	Airport MLAT only
I020/400	Contributing Receivers	**O**	**3.4.5.9**	If MLAT outputs plot report
I020/REF, PA field	Position *Accuracy* (horizontal)	**M** **O**	**3.4.4.5** **3.4.5.4**	SDW subfield – WGS-84 SDC subfield – Cartesian
I020/REF, PA field	Position *Accuracy* (vertical)	**O**	**3.4.5.8**	SDH subfield – SD of Geometric Height in WGS-84
I020/REF, GVV field	Ground Velocity Vector	**O**	**3.4.5.5**	Ground Speed and Track Angle
I020/REF, TRT field	Time of Asterix Report Transmission	**M**	**3.4.4.12**	Time reference for Data ages
I020/REF, DA field	Data-Ages, FL subfield	**M**	**3.4.4.7**	FL subfield – Age of Pressure Altitude

LEGEND:

ED-142 Req. – Required WAM output capability:

M – Mandatory item (The WAM system ***shall*** be able to provide the respective data)

O – Optional item (The WAM system ***should*** be able to provide the respective data)

Paragraph – Corresponding paragraph of the Section 3.4.

3.4.8 Mapping of WAM status and service messages to ASTERIX Cat019

The Eurocontrol ASTERIX Cat019 is specifically intended for MLAT systems. The following table provides for a full overview of Cat019 data items and mapping to the required WAM status and service reports.

TABLE 2: ASTERIX CAT 019 STATUS AND SERVICE REPORTS

Data Item	Value	ED-142 Req.
I019/000 Message Type	**002** (Periodic Status Message) **003** (Event Status Message)	**M** **M**
I019/010 Data Source Identifier	SAC and SIC	**M**
I019/140 Time of Day	UTC time stamp corresponding to the time of transmission of the report	**M**
I019/550 System Status	Messages type **002** and **003** (Status of the WAM system and of the Test Target, Overload indicator and Time source validity)	**M**
I019/551 Tracking Processor Detailed Status	Configuration & Status of the Target Processors	**O**
I019/552 Remote Sensor Detailed Status	Configuration & Status of the Remote Sensors	**O**
I019/553 Reference Transponder Detailed Status	Configuration & Status of the Reference Transponder	**O**
I019/600 Position of the MLT System	Only required for messages of type **002** Horizontal position in WGS-84 coordinates	**O**
I019/610 Height of the MLT System *Reference Point*	Only required for messages of type **002** Height (WGS-84) above MSL	**O**
I019/600 WGS-84 Undulation	Only required for messages of type **002** Undulation of the WAM System *Reference Point*	**O**

LEGEND:

ED-142 Req. – Required WAM output capability:

M – Mandatory item (The WAM system ***shall*** be able to provide the respective data)

O – Optional item (The WAM system ***should*** be able to provide the respective data)

3.5 OPTIONAL REQUIREMENTS

3.5.1 Optional Reference and Monitoring Transponder (RMTR)

Reference and Monitoring Transponders (RMTR) may be used for the end-to-end test of the WAM system.

When used, the RMTR ***shall*** be compliant with ICAO Annex 10.

User specified data for the RMTR ***shall*** include:

- *Aircraft Address*;
- Altitude information;
- Mode A code;
- Aircraft Identification

The on-the-ground status ***shall*** be set to 'on the ground'.

The RMTR ***shall*** be configurable by a trained user.

For a dual channel all parameters ***shall*** be separately configurable for each channel.

Each parameter ***shall*** remain unchanged during periods of power interruption.

The WAM processing ***shall*** flag *Target Report* output from the test transponder as field monitor reports in *Target Reports*.

The WAM processing ***shall*** provide the capability to suppress RMTR reports from delivery to ATC.

3.5.2 Optional Resolution Advisory Report Extraction

The WAM system ***shall*** extract the register BDS 3,0 for the duration that an ACAS RA is detected.

The WAM system ***shall*** provide the RA report in ASTERIX I020/260.

3.5.3 Optional Enhanced Surveillance capability

The WAM system shall provide Enhanced Surveillance Airborne Parameters from equipped targets.

NOTE. *Appendix A provides guidelines on protocols and functions which may be used to support Enhanced Surveillance.*

CHAPTER 4

MINIMUM PERFORMANCE SPECIFICATION UNDER ENVIRONMENTAL TEST CONDITIONS

4.1 INTRODUCTION

The WAM system shares similar system elements with telecommunications equipment and as such the ETSI EN 300 019 series of environmental testing specifications were chosen as appropriate standards to define the required environmental testing.

The WAM system ***shall*** meet all of the performance requirements specified within Chapter 3, under the test conditions defined within this chapter.

4.2 STORAGE

WAM system equipment, including packaging, ***shall*** be capable of storage at weather-protected, partially temperature controlled locations, under the conditions defined within ETSI EN 300 019 1-1 Class 1.1.

4.3 TRANSPORT

WAM system equipment, including packaging, ***shall*** be capable of careful transportation, under the conditions defined within ETSI EN 300 019 1-2 Class 2.2.

Where the WAM system is to be transported using commercial distributors, it is recommended that the system should be capable of transportation under the conditions defined within ETSI EN 300 019 1-2 Class 2.3.

4.4 INDOOR USE

WAM system *Ground station* equipment installed at indoor locations ***shall*** be capable of use at partly temperature controlled locations, under the conditions defined within ETSI EN 300 019 1-3 Class 3.2.

4.5 EQUIPMENT ROOM USE

WAM system Central Processor and CMS equipment installed in the equipment room ***shall*** be capable of use at temperature controlled locations, under the conditions defined within ETSI EN 300 019 1-3 Class 3.1.

4.6 OUTDOOR USE

WAM system equipment installed at outdoor locations ***shall*** be capable of use at non-weather protected environments, under the conditions defined within ETSI EN 300 019 1-4 Class 4.1.

If the WAM system equipment is to be used in locations subject to extremes of heat or cold then it is recommended that the most stringent of the following classes is applied:

- Class 4.1E: Non-weather protected – extended (extreme Europe)
- Class 4.2L: Non-weather protected – extremely cold (worldwide)
- Class 4.2H: Non-weather protected – extremely warm (worldwide).

CHAPTER 5

TEST PROCEDURES

5.1 INTRODUCTION

This chapter specifies the conditions for testing and the test procedures for verifying the performance of the WAM system in the factory. Two classes of tests are defined in this chapter - Type Tests and Factory Acceptance Tests.

Type Tests are intended to support generic type testing of a WAM system. WAM manufacturers would run these tests once and document the test results for future reference. Customers may accept compliance to the requirements by inspection of the test documentation, or may require that some or all factory test procedures be run.

Factory Acceptance Test (FAT) is performed on each system before delivery.

The purpose of the FAT is to demonstrate that all items of a WAM system are correctly manufactured and meet their individual requirements. It is therefore acceptable to perform sub system tests to verify system performance provided sufficient evidence is presented that the tested functionality is not compromised through integration.

It should be noted that some performance parameters might be affected by processing load, dependent on the number of targets being handled. When undertaking the prescribed tests, consideration should be given to providing representative scenarios.

The distributed nature of a WAM system means that bespoke test equipment will be required for *Verification* testing in a factory environment.

5.2 GENERAL CONDITIONS FOR TESTING

5.2.1 Test Plan and Procedures

Before the tests start, it is necessary to produce a Test Plan, a Test Procedure and a Test Results template.

The Test Plan (TPL) describes the organisation of the tests and the testing schedule. The TPL includes a description of the tested system, its final configuration and the interfaces to systems that are not subject to the *Verification,* but are conditional for the final efficiency of the WAM system (data links, energy management, etc.). The TPL has to describe potential risks to individuals that take part in the *Verification* process and/or control (attend) the WAM system and other test tools and apparatuses.

The Test Procedure (TP) specifies the purpose of the test to be performed, what parameter is to be tested and the performance metrics, as well as describing the test procedure. Some operational parameters are specified with acceptable tolerances and the TP should state the limiting values which still allow the user to accept the WAM system for operational use.

The Test Results (TR) provide a record of the measured test results and may include notes describing the conditions under which such results were achieved (see details in *5.2.4* below).

The Build State Record should record forms part of the TR and the version and issue number and configuration of all equipments tested, complete to LRU level and test equipment used, including copies/references to test equipment calibration certificates.

The aforesaid TPL, TP and TR template documents are usually submitted to the WAM system customer for approval before the launch of the factory acceptance testing process.

5.2.2 Test Report

The respective sheet of TR is filled in after completing each test, specifying the following information:

- Test date and time
- Names and roles of test participants
- Part numbers of hardware and WAM system configuration
- Version of the installed software
- Description and identification of test tools and apparatuses, if any
- Test results – measured values or operational performances
- Description of and reasons for deviations from the prescribed scenario, if any
- In the event of a failure – description of the identified anomaly
- Description of other findings that were not part of the result prescribed in TP

5.2.3 Safety precautions

The organisation of the tests and the description of the test procedure have to assure safe conditions for all WAM system *Verification* participants. Test participants which are not familiar with the function and control of the tested WAM system should be made demonstrably familiar with potential safety risks prior to the start of the *Verification*/FAT process. Accordingly, each *Verification* participant has to be made familiar with the WAM system control to a degree ensuring that the system cannot be damaged and the tests distorted on the grounds of wrong system control or configuration used arising from insufficient knowledge.

5.2.4 Associated equipment and systems

All other equipment items and systems, particularly communication data links which are directly linked with the WAM system or are conditional for the operation of the WAM system, have to be accessible and operational for the purpose of performing the tests. Before the WAM system is validated, such related equipment will be checked to confirm that its technical properties and operating performances meet the requirements stated in the technical requirements for the WAM system.

5.2.5 On-site conditions

Continuous checks have to be performed during the tests to ensure that the on-site conditions (temperature, humidity, wind speed, etc.) are within the tolerances stated in Chapter 4 hereof. A record of the on-site test conditions in which the FAT tests were performed should be included within the Test Results Book.

5.3 BASIC CONFORMITY TEST

The WAM system shall be inspected to determine conformity with acceptable workmanship and engineering practices that the equipment is complete in accordance with the specifications, and that proper mechanical and electrical connections have been made.

5.4 FACTORY TESTS

Each test is defined in the following format:

- Test purpose – description of the system feature or requirement to be tested
- Test Equipment - description of any test equipment needed to perform the test
- Test Procedure - description of test method, including analysis of test data

The requirements to be tested are those defined in Chapter 3 of this document which are testable in a factory environment. Table 5-1 below lists the factory test procedures and the corresponding requirements section from Section 3 which are tested by each test procedure.

TABLE 5-1: FACTORY TESTS

Section	Test	Tested Requirement(s)	Recommended Test Class
5.4.1	Interrogations	3.2.2 Interrogation 3.2.2.1 Mode S Interrogation 3.2.2.2 Mode A/C interrogation	TT
5.4.2	Target Processing	3.2.1 Target Processing	TT
5.4.3	Target Report Time Stamp	3.3.9 Target Report Time Stamp	TT
5.4.4	Processing Delay	3.3.11 Processing Delay	FAT
5.4.5	Target Capacity	3.3.13 Target Capacity	FAT
5.4.6	Data Output Modes	3.4.1 Data Output Modes Data Driven Mode Periodic Mode	TT
5.4.7	Target Output	3.4.2 Data Output Format 3.4.3 Target Reports 3.4.4 Mandatory Items	TT
5.4.8	Status Output	3.4.2 Data Output Format 3.4.6 Status and Service Message 3.4.6.1 Mandatory Status Data	TT
5.4.9	Duplicate Mode S Address	3.2.1 Target Data Processing	TT

NOTE: *TT – Type Test*

FAT – Factory Acceptance Test

5.4.1 Interrogation

5.4.1.1 Test Purpose

Demonstrate that the WAM system is capable of transmitting selective Mode S Roll-call *Interrogation* (UF4 and UF5).

Demonstrate that the WAM system is capable of transmitting Mode A, Mode C or Mode A/C only all-call (Intermodes A/C with P4 short) *Interrogation*.

Demonstrate that the *Interrogation* meet relevant ICAO Annex 10 requirements.

Demonstrate that the interrogation power is configurable.

5.4.1.2 Test Equipment

- Test equipment for collecting and analyzing the 1030 MHz RF output of the WAM transmitting stations. Examples of such equipment include spectrum analyzers, oscilloscopes and RF peak power meters.
- A means of triggering Mode S and Mode A/C interrogation from the WAM system.

NOTE: *The test configuration and test equipment defined for this test is intentionally generic to allow the manufacturer to select the most appropriate configuration suitable for their system design. One option is to perform a standalone test of the WAM transmitting station, using special test tools to trigger interrogations. An alternative Approach is to use the normal interrogation capabilities of the WAM system, using Mode A/C and Mode S transponders to trigger interrogations.*

An example test setup is shown in the following diagram:

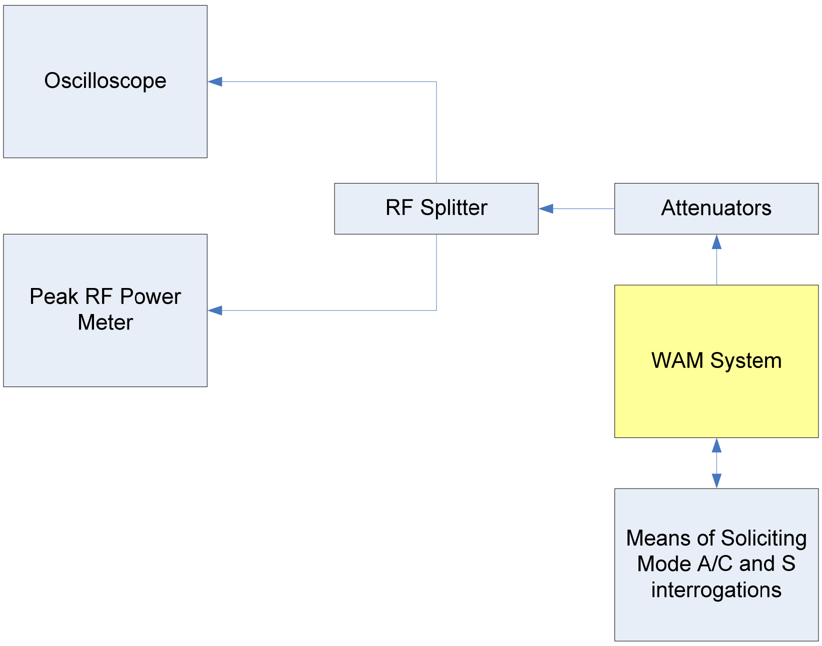

FIGURE 5-1: TEST SETUP

5.4.1.3 Test Procedure

5.4.1.3.1 Mode A/C Interrogations Test

1) Setup the WAM system to transmit Mode A/C *Interrogation* with a configurable interrogation power
2) Verify that the *Interrogation* pulses are present and that pulse width and pulse spacing is in accordance with ICAO Annex 10, using an RF power meter or similar equipment:
3) Verify that the interrogation pulses consist at a minimum of the P1 and P3 pulses, and of optional 'short' P4 pulses, structured as shown in Figure 5-2. The P4 pulse is present if Mode A/C only all-call interrogations are used.

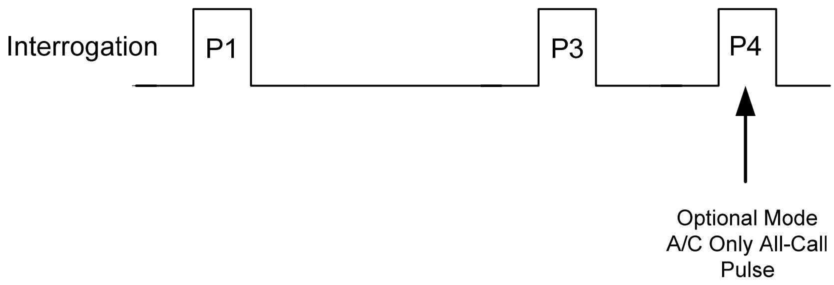

FIGURE 5-2: MODE A/C INTERROGATION PULSE PATTERN

4) Verify that the spacing between pulses is in accordance with Table 5-2.

Interval (leading edge to leading edge)	Spacing	Spacing Tolerance
P1-P3 (Mode A)	8 µs	±0.2 µs
P1-P3 (Mode C)	21 µs	±0.2 µs
P3-P4	2 µs	±0.05 µs

TABLE 5-2: MODE A/C INTERROGATION PULSE SPACING

NOTE: *some WAM manufacturers may be using the TCAS whisper-shout technique for Mode A/C Interrogation, in which case an S1 pulse is transmitted 2 µs (±0.10 µs) before the P1 pulse.*

5) Verify that the pulse characteristics are in accordance with Table 5-3 for all pulses.

Duration	Tolerance	Rise Time Min/Max	Decay Time Min/Max
0.8 µs	±0.1 µs	0.05/0.1 µs	0.05/0.2 µs

TABLE 5-3: MODE A/C INTERROGATION PULSE CHARACTERISTICS

NOTE: *a 0.8 µs P4 pulse duration indicates that the WAM system uses Mode A/C Only All-Call interrogations, not Mode A/C/S All-Call.*

6) Using a spectrum analyser (or similar equipment), verify that the centre frequency is 1030 MHz ±0.01MHz and that interrogation spectrum does not exceed the limits specified in Figure 5-3.

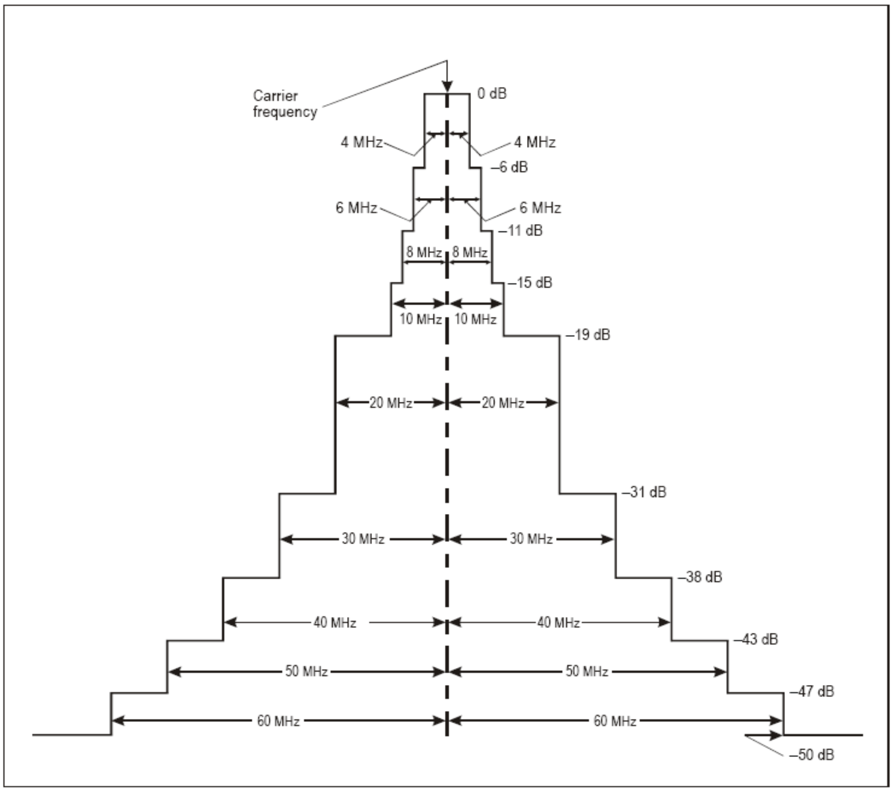

FIGURE 5-3: INTERROGATION SPECTRUM

7) Verify Interrogation pulses amplitude:

P1 amplitude = commanded interrogation power ±1dB

P3 amplitude = P1 amplitude ±1dB

P4 amplitude = P3 amplitude ±1dB

8) Set the interrogation power to a new value. Verify interrogation pulses amplitude as in the previous steps.

5.4.1.3.2 Mode S Interrogations Test

NOTE: *It is assumed that Mode S UF4 and UF5 Interrogation can be independently enabled in the WAM system, and that the Interrogation rates are configurable.*

1) Make sure that Mode A/C *Interrogations* are turned off in the WAM system.

2) Configure the WAM system to generate UF4 *Interrogation* with a known *Aircraft Address* requesting a DF4 reply. This may be achieved by placing the WAM system into a test mode or by using a Mode S transponder, or through other means. Configure the interrogation power to a known value.

NOTE: *the Aircraft Address should be selected to maximize the presence of binary 1's in the Mode S interrogation message.*

3) Verify that the *Interrogation* commence with pulses consist of P1, P2, P6 pulses, as shown in Figure 5-4, and that the spacing between pulses is in accordance with Table 5-4:

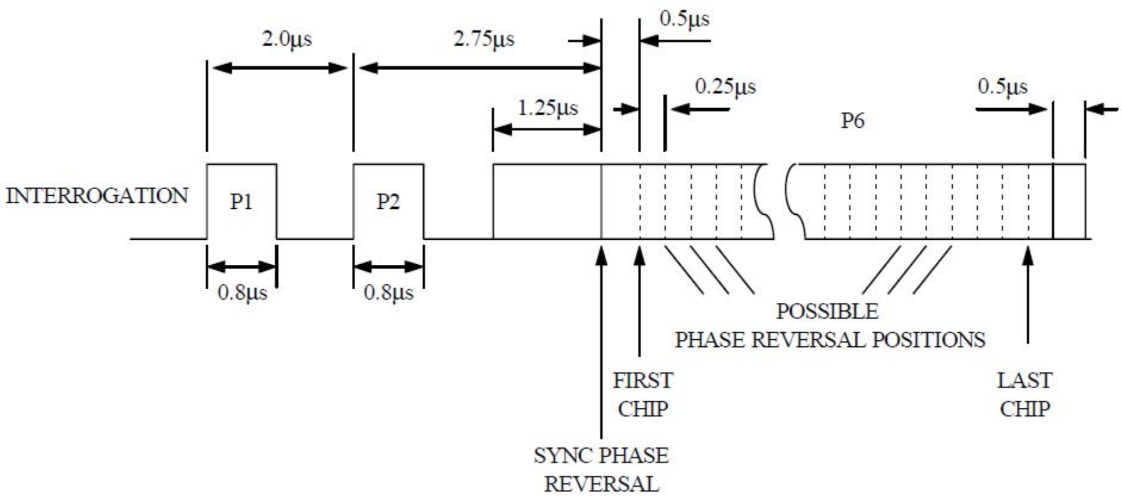

FIGURE 5-4: MODE S INTERROGATION PULSE PATTERN

Interval	Spacing	Tolerance
P1 – P2	2 µs	±0.05 µs
P2 to P6 Sync Phase Reversal	2.75 µs	±0.05 µs
P6 leading edge to P6 Synch Phase Reversal	1.25 µs	±0.05 µs

TABLE 5-4: MODE S INTERROGATION PULSE SPACING

4) Verify pulse characteristics (pulse duration, rise time, decay time) are as specified in Table 5-5.

Pulse	Duration	Tolerance	Rise Time Min/Max	Decay Time Min/Max
P1, P2	0.8 µs	±0.1 µs	0.05/0.1 µs	0.05/0.2 µs
P6	16.25 µs	±0.25 µs	0.05/0.1 µs	0.05/0.2 µs

TABLE 5-5: MODE S INTERROGATION PULSE CHARACTERISTICS

5) Phase Modulation: verify that the P6 pulse has internal binary differential phase modulation consisting of 180-degree phase reversals of the carrier at a 4 MHz rate, as specified in Table 5-6.

Parameter	Expected Result
Synch Phase Reversal (SPR)	SPR is first phase reversal. SPR occurs 2.75 µs from P2 leading edge SPR duration < 0.08 µs
Data Phase Reversals (DPR)	A DPR is present for each binary 1 of the 56-bit interrogation message When the DPR is present, it occurs at specific time intervals: every 0.25 µs ± 0.02 µs, i.e. every ‘chip’, starting 0.5 µs after the SPR DPR duration < 0.08 µs

TABLE 5-6: MODE S INTERROGATION PHASE MODULATION

6) Verify interrogation pulses amplitude are as specified in Table 5-7.

Pulse	Amplitude
P1	= commanded interrogation power ± 1 dB
P2	> P1 – 0.25 dB
P6 (first µs)	> P1 – 0.25 dB
P6	< 1 dB amplitude variation
P6	< 0.25 dB amplitude variation between successive chips

TABLE 5-7: MODE S INTERROGATION PULSE AMPLITUDE

7) Verify the following fields in the 56-bit interrogation message:
   - UF field (bits 1-5) = 4 , indicating a UF4 Mode C interrogation
   - PC field (bits 6-8) ≠ 1, indicating that all-call lockout is not used
   - RR field (bits 9-13) < 16, indicating request for a reply with surveillance format
   - Discrete interrogations are used: the AP field (last 24 bits of the interrogation message) contains the Mode S transponder’s address overlaid over the message parity.

8) Verify that the centre frequency is 1030 MHz ±0.01MHz and that *Interrogation* spectrum does not exceed the limits specified in Figue 5-3, using a spectrum analyzer (or similar equipment).

9) Repeat the above steps, enabling UF5/DF5 Interrogation.

10) Verify the following fields in the 56-bit *Interrogation message*:

   - UF field (bits 1-5) = 5 , indicating a UF5 Mode A *Interrogation*
   - PC field (bits 6-8) ≠ 1, indicating that all-call lockout is not used
   - RR field (bits 9-13) < 16, indicating request for a reply with surveillance format

11) Repeat steps 1 to 8 with UF4 interrogation requesting DF20 reply. RR field shall be set appropriately for BDS 1,0 extraction.

12) Repeat steps 1 to 8 with UF5 interrogation requesting DF21 reply. RR field shall be set appropriately for BDS 2,0 extraction.

13) Set the interrogation power to a new value. Verify interrogation pulses amplitude as in previous steps.

5.4.2 Target Processing

5.4.2.1 Test Purpose

Demonstrate that the WAM system is able to detect and process Mode S and Mode A/C targets.

5.4.2.2 Test Equipment

- A means of generating Mode A/C and Mode S replies (DF4, DF5, DF11). This may require WAM system *Interrogation* to elicit replies.
- A means of connecting the reply generator to the WAM system.
- A means of recording the replies detected by the WAM system.

NOTE: *The test equipment defined for this test is intentionally generic to leave the test design open for the manufacturer to select the most appropriate configuration suitable for their system design. One option is to use a test transponder and series of delay lines connected to the WAM receivers. The WAM system can then multilaterate on the replies generating a plot output which may be observed on the ASTERIX CAT 20 interface. An alternative Approach is to monitor the decoded replies on a suitable internal interface.*

5.4.2.3 Test Procedures

5.4.2.3.1 Mode A/C Detection

1) Configure the signal generator to generate Mode A replies with a known Mode A code.
2) Configure the WAM system to detect and decode the generated replies.
3) Monitor the replies detected by the WAM system at an appropriate interface and validate the Mode A code has been correctly detected and decoded.
4) Configure the signal generator to generate Mode A replies with a known Mode A code and SPI bit set.
5) Monitor the replies detected by the WAM system at an appropriate interface and validate both the Mode A code and the SPI bit have been correctly detected and decoded.
6) Configure the signal generator to generate Mode C replies with a known pressure altitude
7) Configure the WAM system to detect and decode the generated reply.
8) Monitor the replies detected by the WAM system at an appropriate interface and validate the pressure altitude been correctly detected and decoded.

NOTE: The above steps can be combined to allow testing of Mode A and Mode C reply processing at the same time, provided the test equipment can generate both types of replies (when using a test transponder for example).

5.4.2.3.2 Mode S Detection

1) Configure the signal generator to generate Mode S DF11 replies with a known *Aircraft Address* and communications capability (CA field).
2) Configure the WAM system to detect and decode the generated reply.
3) Monitor the replies detected by the WAM system at an appropriate interface and validate the *Aircraft Address* and communications capability (CA field) have been correctly detected and decoded.
4) Configure the SSR signal generator to generate Mode S DF4 replies with a known *Aircraft Address*, pressure altitude, flight status (FS field).
5) Configure the WAM system to detect and decode the generated reply.
6) Monitor the replies detected by the WAM system at an appropriate interface and validate the pressure altitude code and flight status.
7) Configure the SSR signal generator to generate Mode S DF5 replies with a known Mode A code, flight status (FS field).
8) Configure the WAM system to detect and decode the generated reply.
9) Monitor the replies detected by the WAM system at an appropriate interface and validate the Mode A code and flight status have been correctly detected and decoded.

NOTE: An acceptable alternative to the above steps would be to perform an end to end test using the WAM system in its normal operating mode with a Mode S transponder. In this case, correct reply processing would be verified at the ASTERIX CAT20 output of the system.

5.4.3 Target Report Time Stamp

5.4.3.1 Test Purpose

Demonstrate that the time stamp associated with a target report is synchronized with UTC and is within 100 ms of the target´s *Time of Applicability* for the supported target reporting modes (data driven and/or periodic delayed).

5.4.3.2 Test Equipment

- A means of injecting a target signal at a known UTC time.
- An ASTERIX data recorder or similar equipment to record the WAM system output.
- A tool to analyse the recorded ASTERIX data.

5.4.3.3 Test Procedures

1) Verify that the WAM system is synchronized to a UTC source.
2) Configure the WAM system in ‘data driven’ output mode.
3) Inject a known target signal at a known UTC time (at a known offset from the UTC second epoch, as an example).
4) Record the output of the WAM system to extract the time of day (time stamp) of the ASTERIX output message associated with the known injected target.
5) Verify that the difference between the target´s time of day (I020/140) and the time of target injection is less than 100 ms.
6) Configure the WAM system in periodic delayed output mode,.

7) Record the output of the WAM system.

8) Verify that the difference between the target´s time of day (I020/140) and the last time of target injection is less than 100 ms.

NOTE: *the only difference between the Data Driven Mode and the periodic mode with calculated positions output is that the target is reported once per Output Period in periodic mode as opposed to each time it is detected. In both cases, the target's timestamp should be set to the time of target detection.*

9) Configure the WAM system in periodic predicted output mode.

10) Record the output of the WAM system.

11) Verify that the target is reported at the specified output rate, and that the target's time of day is within 100 ms of the UTC time at which the target is reported.

5.4.4 Processing delay

5.4.4.1 Test Purpose

Demonstrate the following *Processing delay*:

- In *Data Driven Mode*, the maximum *Target Report* delay is less than 1 second.
- In periodic delayed mode, when the last measured position is transmitted, the maximum *Target Report* delay is less than the duration of the *Output Period* plus 1 second.
- In periodic predicted mode, when the *Predicted Position* at time of output is transmitted, the maximum *Target Report* delay is less than 0.5 second.

5.4.4.2 Test Equipment

- A means of simulating the maximum WAM *System Capacity* of 250 targets at an appropriate stage of the system to ensure all significant delay elements are included. This may be achieved using a multi stage *Approach*. For example the maximum *Processing delay* may be measured through each sub system component using appropriate data records at each stage and then accumulated to provide an overall figure for the system *Processing delay*.
- Data recorder(s) or similar equipment to record the WAM system or sub-system outputs, with the ability to timestamp each recorded message.
- A tool to analyse the recorded data.

5.4.4.3 Test Procedure

NOTE: *The precise test procedure will vary depending on whether the end to end delay is measured in one step or divided into multiple sub sections; however the basic test procedure is outlined below.*

An acceptable method of measuring the Processing delay is to record the ASTERIX output of the WAM system and compare the message timestamp (Time of Day field) to the recorded message time.

5.4.4.3.1 Data Driven Mode

1) Verify that the system under test, the data recorder and the data source (if necessary) are synchronized to the same UTC source

2) Simulate inputs to the system which enable the system under test to be operating at its maximum capacity.

3) If necessary configure the system under test for 'data driven' mode.

4) Record the output of the system under test.

5) Determine the worst case time delay through the system under test.

6) If required accumulate the worst case delays to calculate the end to end worst case system delay.

7) Verify that the worst case *Processing delay* does not exceed 1 second.

5.4.4.3.2 Periodic Delayed Mode (measured positions)

1) Verify that the system under test, the data recorder and the data source (if necessary) are synchronized to the same UTC source

2) Simulate inputs to the system which enable the system under test to be operating at its maximum capacity.

3) If necessary configure the system under test for ‘periodic delayed mode’ with ‘measured positions’.

4) Record the output of the system under test.

5) Determine the worst case time delay through the system under test.

6) If required accumulate the worst case delays to calculate the end to end worst case system delay.

7) Verify that the worst case *Processing delay* does not exceed *Output Period* + 1 second.

5.4.4.3.3 Periodic Predicted Mode (Predicted Position)

NOTE: *The periodic predicted mode using Predicted Position only requires the observation of the systems ASTERIX Cat 20 outputs.*

1) Simulate inputs to the system which enable the system under test to be operating at its maximum capacity.

2) Configure the system under test for ‘periodic predicted mode’ with ‘*Predicted Position*‘.

3) Record the ASTERIX output of the WAM system.

4) Compare the time of message report to the time of day included within the ASTERIX message (I020/140) for each reported target. Verify that the worst case time difference does not exceed 0.5 second.

5.4.5 Target Capacity

5.4.5.1 Test Purpose

Demonstrate the system is capable of processing at least 250 targets within the coverage volume.

Demonstrate that a target overload condition is reported when the number of targets exceeds a configurable capacity threshold.

5.4.5.2 Test Equipment

- A means of simulating in excess of 250 targets at an appropriate stage of the system to ensure all significant processing elements are included. This may be achieved by testing each system element in isolation e.g. verifying the receiver station does not overload when receiving replies from 250 aircraft (100 per aircraft per second). Then verifying that the Central processor does not overload when receiving data from receivers reporting 250 aircraft. When testing each sub element it is acceptable to simulate the input data.
- An ASTERIX data recorder or similar equipment to record the WAM system output.
- A tool to analyse the recorded ASTERIX data.

5.4.5.3 Test Procedure

1) Simulate 250 different targets into the system and record the ASTERIX *Target Reports* (Category 20) and status reports (Category 19).
2) Analyse the recorded target data and verify that all simulated target are reported.
3) Analyse the recorded status data and verify that no errors or overload conditions are reported: Operational Status (NOGO) indicates Operational, Overload Indicator (OVL) indicates No Overload.
4) Set the maximum number of target threshold in the WAM system and simulate a number of targets that exceeds this threshold. Record the output of the WAM system
5) Analyse the recorded status data and verify that an overload conditions is reported: Operational Status (NOGO) indicates Degraded or NOGO, Overload Indicator (OVL) indicates Overload.

NOTE: *If this test is conducted by segmenting the system and testing each individual sub element it is the responsibility of the manufacture to provide a sufficiently detailed description of the efficacy of the Approach taken and the results obtained at each test boundary point.*

5.4.6 Data Output Modes

5.4.6.1 Test Purpose

Demonstrate that the WAM system is capable of reporting targets in *Data Driven Mode* and in periodic mode; using both the last calculated position and the *Predicted Position* at the time of output.

5.4.6.2 Test Equipment

- A means of injecting/simulating targets at a variable rate. This may be achieved by simulating at RF or using a using a receiver simulator to generate simulated receiver data to play into the Central processor.
- An ASTERIX data recorder or similar equipment to record the WAM system output.
- A tool to analyse the recorded ASTERIX data.

5.4.6.3 Test Procedure

5.4.6.3.1 Data Driven Mode

1) Configure the WAM system to output targets in *Data Driven Mode*.
2) Inject a target signal at a known rate.
3) Record the ASTERIX output of the WAM system.
4) Verify that the time between *Target Reports* matches the target injection rate.
5) Repeat the above steps for 2 additional injection rates and verify that the time between *Target Reports* matches the target injection rate.

5.4.6.3.2 Periodic Delayed Mode (measured positions)

1) Configure the WAM system to output targets in periodic delayed mode, set the *Output Period* and set the output type to be the last measured position.
2) Inject a target signal at a rate that is greater than 1 / *Output Period*.
3) Verify that there is only one *Target Report* per *Output Period* and that the time between *Target Reports* is equal to the *Output Period.*

4) Repeat the above steps, setting the target injection rate to less than 1 / *Output Period*.

5) Verify that there is at most one *Target Report* per *Output Period* and that some *Output Periods* have no *Target Report*.

5.4.6.3.3 Periodic Predicted Mode (Predicted Position)

1) Configure the WAM system to output targets in periodic predicted mode, set the *Output Period* and set the output type to the position predicted to the time of output.

2) Inject a target signal at a rate that is greater than 1 / *Output Period*.

3) Verify that there is only one *Target Report* per *Output Period* and that the time between *Target Reports* is equal to the *Output Period*.

4) Stop the target injection. Verify that the target continues to be reported at each *Output Period* until the target is dropped.

5.4.7 Target Output

5.4.7.1 Test Purpose

Demonstrate that the WAM system outputs *Target Reports* in the ASTERIX Category 20 data format with correct content.

5.4.7.2 Test Equipment

- A means of simulating target data with known Mode A code, pressure altitude, and Aircraft ID.

NOTE: *Target simulation may be achieved by simulating targets at RF or injecting simulated receiver data into the Central processor.*

- A means of simulating moving targets.
- An ASTERIX data recorder or similar equipment to record the WAM system output.
- A tool to analyse the recorded ASTERIX data.

5.4.7.3 Test Procedure

5.4.7.3.1 Mode S Target Output

1) Generate simulated target data for a Mode S equipped aircraft with a known *Aircraft Address*, Mode A code, pressure altitude and Aircraft ID.

2) Configure the WAM system with known SIC and SAC codes for the WAM output.

3) Record the ASTERIX CAT20 output of the WAM system.

4) Verify correctness of the ASTERIX CAT20 *Target Report*s associated with the Mode S target:

   - Data Source Identifier (I020/010) is set to the configured SIC and SAC codes.
   - MS bit is set to 1 in the *Target Report* Descriptor (I020/020), indicating Mode S multilateration. All other bits in I020/020 are set to 0.

- Mode A Code (I020/070) set to the simulated target's Mode A code.
  - "V" bit indicates code is valid (set to 0).
  - "G" bit indicates code is not garbled (set to 0).
  - "L" bit indicates the WAM system extrapolation of the Mode A code. The "L" bit should be set to 1 when the Mode A code has not been extracted from a transponder reply but the last reported value has been repeated.
- Flight Level (I020/090) set to the simulated target's pressure altitude.
  - "V" bit indicates code is valid (set to 0).
  - "G" bit indicates code is not garbled (set to 0).
- Pressure Altitude age is reported in the Data Ages item of the Reserve Expansion Field (REF).
- Target Address (I020/220) set to the simulated target's *Aircraft Address*.
- Target Identification (I020/245) set to the simulated target´s aircraft ID.

5) Modify the simulated target´s Mode A code. Verify that the new Mode A code is reported within 24 seconds of the code change for the En-route application and 15 seconds for the TMA application.

6) Modify the simulated target´s Aircraft ID. Verify that the new Mode ACID is reported within 24 seconds of the ACID change for the En-route application and 15 seconds for the TMA application.

7) Trigger a SPI condition in the simulated target (by pressing the IDENT switch if using a test transponder, as an example*).* Verify that a SPI bit is reported within 8 seconds for the En-route application and 5 seconds for the TMA application. The SPI should be verified in I020/20 and in the Flight Status field (I020/230).

8) Simulate an "on the ground" condition and verify that "on the ground" is indicated in the Flight Status field (I020/230).

9) Simulate an alert condition and verify that an alert is reported within 8 seconds for the En-route application and 5 seconds for the TMA application. The alert is indicated in the Flight Status field (I020/230).

5.4.7.3.2 Mode A/C Target Output

1) Generate simulated target data for a Mode A/C only equipped aircraft with a known Mode A code and pressure altitude.

2) Record the ASTERIX CAT20 output of the WAM system.

3) Verify correctness of the ASTERIX CAT20 *Target Reports* associated with the Mode A/C target:

- Data Source Identifier (I020/010) set to the configured SIC and SAC codes.
- SSR bit is set to 1 in *Target Report* Descriptor (I020/020), indicating Non Mode S multilateration. All other bits in I020/020 are set to 0.
- Mode A Code (I020/070) set to the simulated target's Mode A code.
  - "V" bit indicates code is valid (set to 0).
  - "G" bit indicates code is not garbled (set to 0).

- Flight Level (I020/090) set to the simulated target’s pressure altitude.
  - “V” bit indicates code is valid (set to 0).
  - “G” bit indicates code is not garbled (set to 0).
- Pressure Altitude age is reported in the Data Ages item of the Reserve Expansion Field (REF).

4) Modify the simulated target´s Mode A code. Verify that the new Mode A code is reported in the CAT20 *Target Report* within 24 seconds for the En-route and within 15 seconds for the TMA application.

5) Simulate a SPI condition. Verify that a SPI bit is reported within 8 seconds for the En-route and within 5 seconds for the TMA application. SPI should be verified in I020/20.

5.4.7.3.3 Target Position Calculation

1) Simulate targets at multiple locations.

2) Record the ASTERIX CAT20 output of the WAM system.

3) Compare the recorded target data to the simulated positions: verify that the position in WGS84 coordinates (I020/41) and flight level (I020/090) match the simulated scenario.

4) Verify that the reported position *Accuracy* is consistent with the target locations. The accuracy should be reported in the Standard Deviation of Position (WGS84) data item included in the Reserve Expansion Field (REF) of the CAT20 target report.

5) Simulate a target with a step change of the altitude. Verify that the reported pressure altitude is identical to the injected altitude, indicating that the reported altitude is not smoothed.

6) Simulate a moving target with an ascending or descending altitude. Stop injection of Mode C altitude data in the middle of the ascent (or descent). Verify that the last reported altitude is identical to the last injected altitude, indicating that the reported altitude is not predicted

5.4.8 Status Output

5.4.8.1 Test Purpose

Demonstrate that the WAM system outputs a System Status message in the ASTERIX Category 19 format with correct content.

5.4.8.2 Test Equipment

- An ASTERIX data recorder or similar equipment to record the WAM system output.
- A tool to analyse the recorded ASTERIX data.

5.4.8.3 Test Procedure

1) Run the WAM system in a normal configuration and ensure that no fault conditions are reported.

2) Configure the WAM system with known SIC and SAC codes for the WAM output.

3) Record the ASTERIX output of the WAM system.

4) Verify that ASTERIX CAT19 status messages are output as follows:

   - Message Type (I019/000) = 2, indicating a periodic message.
   - Data Source Identifier (I019/010) contains the configured SIC and SAC codes.
   - Time of Day (I019/140) shows that messages are reported at least once per minute.
   - System Status (I019/550): NOGO field set to 0, indicating an Operational status.

5) Create a fault condition in the WAM system.

6) Examine the ASTERIX CAT19 output and verify that:

   - A CAT19 status message is reported upon fault occurrence, with a Message Type (I019/000) set to 3 to indicate an event driven message.
   - System Status (I019/550): NOGO field set to 2, indicating a NOGO status.

5.4.9 Duplicate Mode S Address

5.4.9.1 Test Purpose

Demonstrate that the WAM system is capable of detecting and handling correctly two aircraft with identical *Aircraft Address* separated by more than 10 NM.

5.4.9.2 Test Equipment

- A means of simulating Mode S targets at known positions and with known Mode S addresses.

NOTE: *Target simulation may be achieved by simulating targets at RF or injecting simulated receiver data into the Central processor.*

- An ASTERIX data recorder or similar equipment to record the WAM system output.
- A tool to analyse the recorded ASTERIX data.

5.4.9.3 Test Procedure

1) Generate simulated target data for a few Mode S equipped aircrafts: the aircrafts are at known positions; two of the aircraft have identical *Aircraft Address* and are separated by more than 10 NM.

2) Record the ASTERIX CAT20 output of the WAM system.

3) Verify correctness of the ASTERIX CAT20 *Target Report*s generated by the WAM system:

   - All injected Mode S targets are reported with the correct Mode S address and at the correct position.
   - Two of the targets are reported with the same address and with a duplicated Mode S address condition indicated in the Warning/Error Data item (W/E value = 16 in I020/30).

CHAPTER 6

INSTALLED EQUIPMENT PERFORMANCE

6.1 INTRODUCTION

This Chapter specifies the conditions for site acceptance testing (SAT) and the testing procedures necessary for the *Verification* of the WAM system after installation and optimisation of the system in the location of operational use.

The post-installation WAM system *Verification* is split into two parts; *Verification* of technical parameters and *Verification* of operational performance.

The post-installation WAM system *Verification* usually involves system handover between the supplier and the user.

6.2 GENERAL CONDITIONS FOR TESTING

6.2.1 Test plan and procedures

Before the tests start, it is necessary to produce a Test Plan, Test Procedure and Test Result template.

The Test Plan (TPL) describes the organisation of the tests and the testing schedule. The TPL includes a description of the system under test, its final configuration and the interfaces to systems that are not subject to *Verification* but are conditional for the effective operation of the WAM system (data links, energy management, etc.). It also describes the potential risks to individuals that take part in the *Verification* process and/or control (attend) the WAM system and other test tools and apparatus.

The Test Procedure (TP) is a set of scenarios for the respective *Verification* actions. Each scenario has to specify the purpose of the test to be performed, what parameter is to be tested and the specified level of performance metric, as well as describe the test procedure. Some operational parameters are specified with acceptable tolerances and the TP should state the limiting values which still allow the user to accept the WAM system for operational use.

The Test Results (TR) provide a record of the measured test results and may include notes describing the conditions under which such results were achieved (see details in 6.2.4 below).

The Build State Record forms part of the TR and should record the version and issue number and configuration of all equipment tested, complete to LRU level and test equipment used, including copies/references to test equipment calibration certificates.

The aforesaid TPL, TP and TR template documents are usually submitted to the WAM system customer for approval before the launch of the system *Verification*/site acceptance testing process.

6.2.2 Test Report

A TR sheet is filled in after completing each test, specifying the following information:

- Test date and time
- Names and roles of test participants
- Part numbers of hardware and WAM system configuration
- Version of the installed software
- External conditions (weather conditions, air traffic density, etc.)
- Description and identification of test tools and apparatuses, if any
- Test results – measured values or operational performances

- Description of and reasons for deviations from the prescribed scenario, if any
- In the event of a failure – description of the identified anomaly
- Type of aircraft and aircraft equipment used for the operational test scenarios concerned
- Description of other findings that were not part of the result prescribed in TP

6.2.3 Safety precautions

The organisation of the tests and the description of the test procedure have to assure safe conditions for all WAM system *Verification* participants. Test participants who are not familiar with the function and control of the tested WAM system should be made demonstrably familiar with potential safety risks prior to the start of the *Verification*/SAT process. Accordingly, each *Verification* participant has to be made familiar with the WAM system control to such a degree that ensures that the system cannot be damaged and the tests distorted on the grounds of incorrect system control or configuration arising from insufficient knowledge.

6.2.4 Associated equipment and systems

All other equipment items and systems, particularly communication data links which are directly linked with the WAM system or are conditional for the operation of the WAM system, have to be accessible and operational for the purpose of performing the tests. Before the WAM system is validated, such related equipment should be checked to confirm that its technical properties and operating performances meet the requirements stated in the technical requirements for the WAM system.

6.2.5 On-site conditions

Continuous checks have to be performed during the tests to make sure that the on-site conditions (temperature, humidity, wind speed, etc.) are within the tolerances stated in Chapter 4 hereof. A record of the on-site test conditions in which the SAT tests were performed should be included within the Test Results.

6.2.6 Test Equipment

Test equipment shall be shown to be fit for purpose.

6.2.6.1 Flight Test aircraft

Besides opportunity flights, dedicated flight test aircraft can be used for the site acceptance tests. Aircraft used for such specific flights should be equipped with a Mode A/C and/or Level 2 Mode S Transponder compliant to ED-73.

Before the tests start, the Transponder should be tested to ensure that its output power and sensitivity are set to the minimum ICAO Annex 10 specified limits.

Other items of onboard or additional equipment in aircraft used for WAM system specific test flights (NAV and COM equipment) have to meet the requirements for the scenarios described in the TP.

6.3 BASIC CONFORMITY TEST

6.3.1 Conformity Test

The installed WAM system shall be inspected to determine conformity with acceptable workmanship and engineering practices, that the equipment is complete in accordance with the specifications, that proper mechanical and electrical connections have been made, and that the equipment is installed in accordance with the manufacturer's recommendations and local regulations. The manufacturer shall demonstrate correct operation as appropriate.

6.3.2 Maintainability

The installed WAM system has to be repairable and controllable. The *Verification* process includes a check as to whether the respective WAM system elements are accessible and replaceable and whether it is possible to clearly identify the type and part numbers or other forms of identification. The same applies to both hardware and software (software versions have to be identified clearly).

The checks of physical accessibility of the WAM system for the sake of repairs, maintenance and checks go hand in hand with checks of completeness and correctness of technical documentation, particularly the operation and maintenance manual.

6.4 PERFORMANCE TESTS

Each performance test is presented under a separate heading and structured in the format given below:

- Requirement - definition of the parameter to be tested
- Test Equipment - description of all test equipment items needed to perform the test
- Test Procedure - description of the test method to be applied, including analysis of the test data

The parameters to be tested are those defined in Chapter 3 of this document.

Test	Chapter 3 Reference	Chapter 6.4 Reference
Probability of Position Detection (PD)	3.3.3	6.4.1
Probability of False Detection (PFD)	3.3.5	6.4.2
Probability of Code Detection (PCD)	3.3.6	6.4.3
Probability of False Code Detection (PFCD)	3.3.7	6.4.4
Horizontal Position *Accuracy*	3.3.8	6.4.5
Position Resolution	3.3.10	6.4.6
Track Initiation Time	3.3.12	6.4.7
Probability of Long Position Gaps (PLG)	3.3.4	6.4.8

6.4.1 Probability of Position Detection (PD)

6.4.1.1 Test Purpose

Demonstrate that the WAM system meets the required Probability of Position Detection within required coverage volume for Mode A/C and Mode S targets.

The *Probability of position detection* (PD) is the probability of generating a *Target Report* during the defined *Update Interval* where the *Target Report* has derived the target position from at least one *Valid Position Detection* occurring within the *Update Interval*.

6.4.1.2 Test Equipment

- Opportunity flights and/or dedicated flight test aircraft
- ASTERIX data recorder
- Data analysis tool

6.4.1.3 Test Procedure – Targets of opportunity

- The test should be undertaken in sufficient portions of the coverage volume to avoid distortion of the data by anomalies specific to one area
- Record the output of the WAM system for a statistically meaningful number of plots
- Process the recorded data to form target trajectories from the individual *Target Reports*.
- For each *Target Trajectory* estimate the time at which the target entered the coverage region, estimate the time the target exited the coverage region and determine the time of the first and last *Target Report* received within the coverage region. Then determine t_s and t_e for each *Track*.
    - Where t_s is the time of the first *Target Report* received on entering the coverage area, or the predicted time the target entered the coverage area plus the maximum *Track* initiation time, whichever is earlier.
    - Where t_e is the time of the last *Target Report* received before leaving the coverage area, or the predicted time the target exited the coverage area less the *Update* period, which ever is later.
- Use the following equation to calculate the system's probability of detection:

$$PPD = \left(\frac{\sum_{i=1}^{i=N} D_i}{\sum_{i=1}^{i=N} E_i} \right) \times 100$$

Where:

D_i = number of *Update Intervals* with at least 1 *Target Report* containing a *Valid Position Detection* for trajectory *i*

E_i = number of expected *Update Intervals* for trajectory *i*

N = total number of trajectories

$$E_i = \frac{(t_e - t_s)}{UI} + 1$$

Where:

UI = the *Update Interval*

6.4.1.4 Test Procedure – Flight Test (Optional)

- The test should be undertaken in sufficient portions of the coverage volume to avoid distortions of the data by anomalies specific to one area
- Perform a flight test with Mode S Transponder and record ASTERIX output data
- Use the recorded data from both flight tests to calculate the probability of detection for the flight trial aircraft as defined below:

$$PPD = \left(\frac{D}{E}\right) \times 100$$

Where:

D = number of *Update Intervals* with at least 1 *Target Report* containing a *Valid Position Detection* with a *Time of Applicability* that corresponds to the period during which the aircraft was within the defined coverage region.

E = number of expected *Update Intervals*

$$E = \frac{(t_c)}{UI}$$

Where:

t_c = the total test time the aircraft was within the coverage region

UI = the *Update Interval*

- Repeat the flight test with Mode A/C only transponder and record ASTERIX output data using the same procedure to calculate probability of detection for Mode A/C only equipped aircraft.

6.4.2 Probability of false detection (PFD)

6.4.2.1 Test Purpose

Demonstrate that the WAM system meets the required *Probability of false detection*.

The *Probability of false detection* (PFD) is the ratio of the total number of *False Target Reports* to the number of all *Target Reports* output by the WAM system.

NOTE: *The Probability of false detection includes the Probability of a Multiple Target Report.*

6.4.2.2 Test Equipment

- Opportunity flights (if necessary these could be enhanced by the use of a dedicated flight test aircraft)
- ASTERIX data recorder

6.4.2.3 Test Procedure

- The test should be undertaken in sufficient portions of the coverage volume to avoid distortions of the data by anomalies specific to one area
- Record the output of the WAM system
- Process the recorded data to form *Target Trajectory* from the individual *Target Reports*
- Identify any trajectories which are not real. Any *Target Report* associated with these trajectories shall be classified as a *False Target Report*.
- Identify the number of *Target Reports* that cannot be associated with real *Target Trajectory*. These shall be classified as *False Target Reports.*
- Use the recorded data to calculate the *Probability of false detection* using the following formula:

$$PFD = \left(\frac{F}{T}\right) \times 100$$

Where:

F = number of *False Target Reports*

T = total number of *Target Reports*

6.4.3 Probability of code detection (PCD)

6.4.3.1 Test Purpose

Demonstrate that the WAM system meets the required *Probability of code detection*.

The *Probability of code detection* (PCD) is the probability of outputting at least one correct and validated code (Mode A, Mode C) within an *Update Interval* in which a *Target Report* has been output.

For Mode S target, the ratio of *Target Reports* with correct *Aircraft Address* to the total number of Mode S *Target Reports*.

6.4.3.2 Test Equipment

- Opportunity flights (if necessary these could be enhanced by the use of a dedicated flight test aircraft)
- ASTERIX data recorder

6.4.3.3 Test Procedure

- The test should be undertaken in sufficient portions of the coverage volume to avoid distortions of the data by anomalies specific to one area
- Record ASTERIX data for a sufficient period
- Analyse the recorded data and determine the number of correct *Aircraft Address*es and correct and validated Mode A/C codes. This may be achieved by establishing target trajectories from the *Target Reports* to determine the expected Mode A and C codes and *Aircraft Address*es. Alternative methods may also be used.
- Calculate the *Probability of code detection* for Mode S using formula:

$$PCD\_S = \left(\frac{\sum_{i=1}^{i=N} N\_MS\_CORRECT_i}{\sum_{i=1}^{i=N} N\_UI_i} \right) \times 100$$

Where:

N_MS_CORRECT = the number of *Update Intervals* with at least one correct *Aircraft Address* for Target Trajectory i

N_UI_i = the number of *Update Intervals* with at least one Mode S *Target Report* for *Target Trajectory i*

- Calculate the Probability of Mode A Code Detection using formula:

$$PCD\_A = \left(\frac{\sum_{i=1}^{i=N} N\_MA\_CORRECT_i}{\sum_{i=1}^{i=N} N\_UI_i} \right) \times 100$$

Where:

$N\_MA\_CORRECT_i$ = the number of *Update Intervals* with at least one correct and validated Mode A code for *Target Trajectory i*

N_UI_i = the number of *Update Intervals* with at least one *Target Report* for *Target Trajectory i*

- Calculate the Probability of Mode C Code Detection using formula (use segments of trajectories with constant flight level only):

$$PCD\_C = \left(\frac{\sum_{i=1}^{i=N} N\_MC\_CORRECT_i}{\sum_{i=1}^{i=N} N\_UI_i} \right) \times 100$$

Where:

$N\_MC\_CORRECT_i$ = the number of *Update Intervals* with at least one correct and validated Mode C code for *Track* segment *i*

N_UI_i = the number of *Update Intervals* with at least one *Target Report* for *Track* segment *i*

***N* =** Total number of trajectory segments

NOTE: *Correct Mode C is defined as a value within a range centred on the reconstructed value.*

6.4.4 Probability of False Code Detection (PFCD)

6.4.4.1 Test Purpose

Demonstrate that the WAM system meets the required *Probability of False Code Detection*.

The *Probability of False Code Detection* (PFCD) is the ratio of the number of *Target Reports* containing an incorrect but validated code to the total number of *Target Reports* which contain a validated code (Mode A, pressure altitude).

For Mode S targets, the ratio of the number of *Target Reports* containing an incorrect *Aircraft Address* to the total number of Mode S *Target Reports* and the ratio of the number of *Target Reports* containing an incorrect *Aircraft Identification (ACID)* to the total number of Mode S *Target Reports* containing *Aircraft Identification.*

6.4.4.2 Test Equipment

- Opportunity flights (if necessary these could be enhanced by the use of a dedicated flight test aircraft)
- ASTERIX data recorder

6.4.4.3 Test Procedure

- The test should be undertaken in sufficient portions of the coverage volume to avoid distortions of the data by anomalies specific to one area.
- Record the output of the WAM system.
- Analyse the recorded data and determine the number of Mode S Target Reports containing incorrect *Aircraft Address*es, and incorrect *Aircraft Identifications*
- Analyse the recorded data and determine the number of Target Reports containing incorrect and validated Mode A/C codes.

- Determine the ratio of Mode S Target Reports containing incorrect *Aircraft Addresses* to the number of Mode S *Target Reports*.
- Determine the ratio of Mode S Target Reports containing incorrect *Aircraft Identifications* to the total number of Mode S *Target Reports* containing an *Aircraft Identification.*
- Determine the ratio of Target Reports containing incorrect and validated Mode A codes to the number of *Target Reports* containing a validated Mode A code.
- Determine the ratio of Target Reports containing incorrect and validated pressure altitude to the number of *Target Reports* containing a validated pressure altitude.

6.4.5 Horizontal Position Accuracy

6.4.5.1 Test Purpose

Demonstrate that the WAM system meets the required Horizontal Position *Accuracy*.

Horizontal Position *Accuracy* is the quantitative bound of certainty in the calculated position for a target as related to the true position of that target and is expressed as a Root Mean Square (RMS) of an absolute distance error.

6.4.5.2 Test Equipment

- Dedicated flight test aircraft
- Reference source for true aircraft position of known quality
- ASTERIX data recorder

6.4.5.3 Test Procedure

- The test should be undertaken in sufficient portions of the coverage volume to avoid distortions of the data by anomalies specific to one area
- Perform flight test with the Mode S transponder and record ASTERIX output data
- Perform flight test with the Mode A/C only transponder and record ASTERIX output data
- Use the recorded data to calculate the Horizontal Position *Accuracy* as follows
- Calculate the RMS value of horizontal error at the *Time of Applicability* of each *Target Report* for all *Target Reports* using the formula:

$$RMS = \sqrt{\frac{\sum_{i=1}^{N} dr_i^{\,2}}{N}}$$

Where:

dr_i = absolute error in horizontal plane

N = the number of plots

6.4.6 Position Resolution (Mode A/C Transponder)

6.4.6.1 Test Purpose

Demonstrate that the WAM system meets the required Position Resolution.

Position Resolution is the minimum distance between targets whereby the surveillance system may successfully resolve distinct targets.

6.4.6.2 Test Equipment

- Targets of opportunity or two dedicated test mode A/C only transponders (installed in two dedicated test flight aircrafts or one dedicated test flight aircraft and a fixed location).
- ASTERIX data recorder

6.4.6.3 Test Procedure

- The test should be performed once in a representative position of the coverage volume.
- *Target Reports* are recorded for Mode A/C only transponders (either selected from the targets of opportunity or from the controlled test transponders) during periods when the separations between two transponders is as defined in section 3.3.10.
- Process the recorded data to form target trajectories.
- Select pairs of target trajectories that show target within the required minimum separation distance of each other. Some boundary region will have to be specified, with the defined minimum separation setting the upper bound, to realistically collect statistically significant data.
- For each pair of selected target trajectories estimate the time the target entered the boundary region, estimate the time the target exited the boundary region and determine the time the first and last *Target Reports* were received within the boundary region. Then determine t_s and t_e for each *Track*.
    - Where t_s is the time of the first *Target Report* received on entering the boundary region, or the predicted time the target entered the boundary region plus the *Update Interval*, which ever earlier.
    - Where t_e is the time of the last *Target Report* received before leaving the boundary region, or the predicted time the target exited the boundary region less the update period, which ever is later.
- Use the following equation to calculate the system's position resolution probability of detection:

$$PPD = \left(\frac{\sum_{i=1}^{i=N} D_i}{\sum_{i=1}^{i=N} E_i} \right) \times 100$$

Where:

D_i = number of *Update Intervals* with at least 1 *Target Report* containing a *Valid Position Detection* for *Track i* within the boundary region

E_i = number of expected *Update Intervals* for *Track i* within the boundary region

N = total number of *Tracks*

$$E_i = \frac{(t_e - t_s)}{UI} + 1$$

Where:

UI = the *Update Interval*

- Use the recorded data to calculate the *Probability of code detection* as in section 6.4.3 restricting the data set to *Track* pairs that lie within the boundary region.

6.4.7 Track Initiation Time

6.4.7.1 Test Purpose

Demonstrate that WAM system establishes a target *Track* within the maximum *Track* Initiation Time with the probability of 99%.

Track Initiation Time is defined as the time from when a target enters the WAM system *Operational Coverage Volume* with an active transponder to the output of the first position *Target Report* from the WAM system.

6.4.7.2 Test Equipment

- Dedicated Mode A/C/S transponder. The transponder should have a known initiation delay from switch on to transmission
- ASTERIX data recorder
- Means of time reference

6.4.7.3 Test Procedure

- The test should be performed once in a representative position within the coverage volume
- Switch the transponder from standby to active and record time of switching
- Determine the time of the first *Target Report*
- Repeat the previous standby/active procedure several times
- Calculate *Track* Initiation time using formula:

$$TI = \frac{\sum_{i=1}^{N} T\_init_i - T\_transp\_ON_i}{N}$$

Where:

$\boldsymbol{T\_transp\_ON_i}$ = the time of switching the transponder from standby to active

$\boldsymbol{T\_init_i}$ = the time of the first *Target Report* using the same time reference as $\boldsymbol{T\_transp\ ON_i}$

N = the number of standby/active repetitions

Add the transponder initialisation delay to $\boldsymbol{T\_transp\_ON_i}$ if necessary

- Calculate the probability that the *Track* initiation time is shorter than or equal to 5 times the defined *Update Interval*: (PTI)

$$PTI = \frac{D}{E} * 100$$

Where:

D = the number of *Track* Initiation times (TI) shorter than or equal to 5 times the defined *Update Interval*.

E = the total number of measured *Track* Initiation times

6.4.8 Probability of Long Position Gaps (PLG)

6.4.8.1 Test Purpose

Demonstrate that the WAM system meets the required Probability of Long Position Gaps (PLG).

A long position gap is a gap lasting more than 3 maximum *Update Intervals* plus 10% (26.4s for En-route and 16.5s for TMA).

6.4.8.2 Test Equipment

- Opportunity flights / test flight
- ASTERIX data recorder
- Data analysis tool

6.4.8.3 Test Procedure – Targets of opportunity

- The test should be undertaken in sufficient portions of the coverage volume to avoid distortion of the data by anomalies specific to one area
- Record the output of the WAM system for a statistically meaningful number of plots
- Process the recorded data to form target trajectories from the individual *Target Reports*.
- Count the number of expected *Update Interval*s for all trajectories within the Operational Coverage Volume (E_{total}).

$$E_{total} = \sum_{i=1}^{N} Ei$$

Where

N = Total number of trajectories

E_i = number of expected *Update Interval*s for trajectory i (E_i is measured as specified in 6.4.1.3)

Determine the gaps without a position update (*Valid Position Detection*) with a size larger than 26.4s for En-route and 16.5s for TMA (i.e. long gap). If the gap is partially located outside the *Operational Coverage Volume*, it shall not be taken into account

- Count the number (N_G) of reconstructed/expected *Update intervals* located in the *Operational Coverage Volume* and included in these gaps.

For each gap determine t_{gs} the time at which the gap starts (i.e. the time of the last report with a *Valid Position Detection* before the gap) and t_{ge} the time at which the gap ends (i.e., the first report after the gap with a *Valid Position Detection*).

Use the following equation to determine N_G:

$$N_G = \sum_{i=1}^{N} N\_UI_i$$

Where

N = total number of long gaps

N_UI_i = the number of *Update Intervals* without *Target Report* containing *Valid Position Detection* in long gap *i*

$$N\_UI_i = \left\lfloor \frac{(t_{ge} - t_{gs})}{UI} \right\rfloor$$

Where

UI = the maximum *Update Interval*
$\lfloor \ \rfloor$ is the floor function or the integer part

- Calculate the probability of update interval without horizontal position in long gap ratio using the following equation:

$$PLG = \frac{N_G}{E_{total}}$$

6.4.8.4 Test Procedure – Flight Test (Optional)

- Calculate the long gap ratio as specified in 6.4.8.3 but only using the trajectory of the flight test.

APPENDIX A:

GUIDELINES FOR THE IMPLEMENTATION OF MODE S ENHANCED SURVEILLANCE CAPABILITY IN A WAM SYSTEM

A.1 INTRODUCTION

Mode S Enhanced Surveillance (EHS) consists of the provision of specified Mode S Air Derived Dataset (ADD) for use in ground air traffic management (ATM) systems.

The provision of DAP such as magnetic heading, air speed, selected altitude and vertical rate, enables controllers to better assess the separation situations, thus enhancing safety and capacity. It also helps reduce the increasing number of cases where aircraft overshoot their assigned altitudes (referred to as level busts) and improve the performance of other safety net tools.

Mode S EHS is used in designated airspace in Europe where most instrument flight rules (IFR) flights are mandated to provide certain aircraft parameters.

The following paragraphs provide technical guidance on the provision of Mode S ADD Enhanced Surveillance.

A.2 AIRCRAFT REGISTERS

Aircraft parameters are stored in different Mode S transponder data registers. Each of these registers contains 56 bits of data and can contain several airborne parameters. Each register is referenced by a Comm-B Data Selector or BDS number expressed in hexadecimal with a maximum value of F,F (255 in decimal). In the rest of this appendix a specific register is referenced either by using its BDS code (e.g. register accessed by BDS code 1,0) or by a register number expressed in hexadecimal (e.g. register 10_{16}) as used in ICAO Doc9871 [**REF4**].

The availability of these registers and other Mode S specific protocols are considered as Mode S unique data-link capabilities and hence are referred to as Mode S Specific Services in Doc 9871.

The following registers support the EHS function:

Register accessed by BDS code	Content
1,0	Data-link capability report (Version number, Mode S specific services capability (register 17_{16} and $1D_{16}$), Aircraft Identification capability, …
1,7	Common Usage GICB capability report indicating which other registers are available in the aircraft installation
2,0	Aircraft Identification
3,0	ACAS active resolution Advisory report
4,0	Selected Vertical Intention (Selected altitude, Barometric Pressure setting, …)
5,0	Track and turn report (Roll Angle, True track Angle, Ground speed, Track Angle rate, True Airspeed)
6,0	Heading and speed report (Magnetic Heading, Indicated Airspeed, Mach, Barometric Altitude Rate, Inertial Vertical Velocity)

NOTE: *Bit 25 of register 1016 indicates that a Mode S specific service is supported. The GICB services supported are indicated in register 1716 and the MSP (Mode S Specific Protocol) services supported are indicated in register $1D_{16}$. One of these MSP services is the dataflash application which has been developed to reduce the number of Airborne Parameter extractions. Data-flash has not been implemented in Mode S transponders and therefore this appendix does not recommend the extraction of register $1D_{16}$.*

Registers accessed by BDS 4,0 / 5,0 and 6,0 will be periodically extracted all along the life of the trajectories of aircraft supporting EHS. Other registers are defined and are implemented on some platforms. They could also be used to support EHS.

Note that the following registers are used to support Elementary Surveillance.

Register accessed by BDS code	*Content*
1,0	*Data-link capability report (Version number, Mode S specific services capability (register 17_{16} and $1D_{16}$), Aircraft Identification capability,…*
2,0	*Aircraft Identification*
3,0	*ACAS active resolution Advisory report*

The tables defining the different registers are available in ICAO DOC 9871 (Technical Provisions for Mode S Services and Extended Squitter) and in ED73 (Mode S transponder MOPS).

The format of the different registers has evolved over time. The Mode S subnetwork version number allows differentiating which version of the format is used. The different version numbers are defined in ICAO Doc 9871 Table A-2-16 note12. For example version number 3 corresponds to Annex 10 applicable in 2002, i.e., Amendment 77.

NOTE: *This version number has not been correctly implemented and a great majority of transponders compatible with ICAO Annex 10 Amendment 77 are still reporting 0.*

A.3 MODE S PROTOCOLS USED TO SUPPORT EHS

A.3.1 GICB protocol

The Ground Initiated Comm-B protocol allows the interrogator to extract Comm-B replies containing data from one of the 255 transponder data registers and to provide its contents in the MB field of a Mode S reply.

The BDS number of the register to be downlinked is specified in the Mode S interrogation uplink format (*UF*) using the *RR* field and the *RRS* subfield to respectively define the BDS MSB bits (BDS1 = first hexadecimal digit of the BDS number) and, optionally if different from 0, the BDS LSB bits (BDS2 = second hexadecimal digit of the BDS number).

In response to such interrogation the aircraft register is downlinked in the *MB* field of a *DF20* or *DF21* Mode S reply format.

The register number is present in the first byte of the MB field for register accessed by *BDS* 1,0 / 2,0 / 3,0 however the BDS number is not available in the content of the other registers, therefore a system receiving a *DF*20/21 is not able to determine with 100% certitude which register is contained in the received reply if it has not initiated itself the corresponding interrogation.

A.3.2 Comm B broadcast protocol

The registers accessed by BDS 1,0 / 2,0 provide information which changes very rarely during the course of a particular flight. In order to avoid periodic extraction of these registers, a change in their content will initiate a Comm-B broadcast. Such broadcast is announced by raising a flag in all Mode S replies. This flag consists in using specific values (alternatively 4 and 5 to differentiate successive broadcasts) in the *DR* field (Downlink Request) of the replies.

A Comm-B Broadcast remains announced/active for 18s to allow sufficient time for the receivers to detect the broadcast announcement and perform the extraction of a specific register (equivalent to register 0) by using an interrogation with RR=16 and RRS=0 (if presents in the format).

The MB data of the reply will contain the 56 bits of the register, with the first 8 bits indicating which register has been broadcast, therefore the reason for having the first 8 bits of register accessed by BDS 1,0 / 2,0 containing the BDS number.

The register accessed by BDS 1,7 also changes very rarely. The announcement of a change is performed by toggling bit 36 in the register accessed by BDS 1,0. Because this bit has changed in the register accessed by BSD 1,0 this register is broadcast as described above.

Note that a change to register accessed by BDS 3,0 is also announced using the DR field (values 2,3,6 and 7) which triggers an extraction of the register accessed by BDS 3,0 (RR=3, RRS=0 if used)

A.3.3 ADS-B 1090 Extended Squitter

ADS-B 1090 Extended Squitter messages spontaneously transmitted by the transponder contain ADS-B Airborne Derived Data (ADD).

The ground velocity provided in the Extended Squitter airborne velocity message can be used to calculate the ground speed and the True Tack Angle provided in register 50_{16}.

The vertical rate provided in the Extended Squitter airborne velocity message can be used in place of the Inertial Vertical Velocity provided in register 60_{16}. However specific attention is necessary as in certain case the content will be the “Barometric Altitude Rate”.

The ADS-B 1090 Extended Squitter version 2 messages (ED-102A [**REF14**]) will contain the Selected Altitude and the Barometric Pressure Setting which may be used in place of the same data contained in register 40_{16}.

A.4 FUNCTIONAL GUIDANCE FOR A SYSTEM SUPPORTING MODE S EHS

The list of DAP to be provided may be configurable in order to adapt the system to the local requirements and only extract when necessary the data required for the local applications. This will also be useful to adapt the list of DAP to the aircraft fleet capability or to new ground surveillance applications all along the life of the WAM system.

The list of DAPS may include the following information:

- Set 1:
  - MCP/FCU Selected Altitude
  - FMS selected Altitude
  - Barometric pressure setting,
  - MCP/FCU Mode bits
  - Target Altitude

- Set2:
  - Roll Angle,
  - True Track Angle
  - Ground Speed
  - Track Angle Rate
  - True Airspeed
- Set 3
  - Magnetic Heading
  - Indicated Airspeed
  - Mach
  - Barometric Altitude Rate
  - Inertial Vertical Velocity.

NOTE: *In 2010, valid FMS selected altitude is only available on a limited number of platforms and valid Target Altitude is rarely available.*

The system may provide the capability to configure a minimum periodicity at which the DAP will be provided.

WAM system may use a maximum age for the DAPs in order to not to provide too old DAPs.

When DAP are not available from opportunity messages the WAM system may extract the corresponding register to retrieve the information.

It is recommended that WAM system combines the DAP extractions with other interrogations to minimize the number of interrogations used.

It is recommended that the WAM system assess the Aircraft installation capability before extracting register containing DAPs.

NOTE: *To assess the aircraft installation capability is a protection to avoid extracting false information or losing the detection on old versions of Mode S transponder which do not respond at all to extraction of registers which are not supported.*

The WAM system may be configured to accept DAP for transponders reporting a minimum Mode S subnetwork version number.

NOTE: *At the end of 2009 only 25% of the aircraft reported correct Mode S subnetwork version (3 or above). To maximize the benefit of EHS it is possible to accept data from transponders indicating Mode S subnetwork version number 0. However in the case of old transponders delivering old data format it may be required to set the version value to 3.*

When assessing the Aircraft installation capability the WAM system may provide the additional possibility to force the register capability without taking into account Register 10_{16} bit 25 and capability reported in register 17_{16}.

NOTE: *The capability to override bit25 of register 1016 can be useful if there are too many transponders not correctly managing the bit25 in register 1016. The capability to not take into account the installation capability declared in register 1716 can be useful to force the extraction of airborne register on transponder not correctly managing register 1716 or to prove that the WAM system can extract registers on more aircraft than those currently supporting EHS.*

In order to reduce the RF pollution WAM system may limit the extraction of EHS parameters to a limited area of their coverage. The definition of this area may be done by using a Mode S Datalink Responsibility coverage map in the EMS MAP ICD format [**REF10**].

NOTE: *The EHS data transmission capability of transponders defined in Annex 10 is limited. Issues resulting from EHS interrogation collisions have been detected in the European core area. In the future it is possible that the area in which EHS extraction is performed may be limited.. The use of the same map format than the one used by Mode S radar will ease a possible future central management of the data-link responsibility.*

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