EUROCONTROL



Enclosure 1

# EUROCONTROL Specification for ATM Surveillance System Performance

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**Abstract**

This document provides performance requirements for ATM surveillance system when supporting 3 and 5 NM horizontal separation applications. This specification has been developed by an international group of experts from air navigation service providers, system manufacturers and national supervisory authorities. This document can be used by air navigation service providers to define, as required by the SPI IR, the minimum performance that their surveillance system must meet. This specification also defines how the associated conformity assessment must be performed.



**Keywords**

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# EXECUTIVE SUMMARY

This document provides performance requirements for ATM surveillance system when supporting 3 and 5 NM horizontal separation applications. This specification has been developed by an international group of experts from air navigation service providers, system manufacturers and national supervisory authorities. This document can be used by air navigation service providers to define, as required by the SPI IR, the minimum performance that their surveillance system must meet. This specification also defines how the associated conformity assessment must be performed.

This specification was developed in parallel with the draft Surveillance Performance and Interoperability Implementing Rule (SPI IR). In July 2011 the draft SPI IR was accepted by the Single Sky Committee and is currently being prepared by the European Commission for publication within European Union Official Journal. This specification therefore complements and refines the requirements that will be reflected in Single European Sky (SES) legislation.

This specification is generic and technology independent. It must be supplemented by specific local requirements that may be due to safety constraints, to local technological choices, to the needs to support other services and functions and other local requirements. This specification is written to be compatible with recently published industry standards (EUROCAE) applicable to specific surveillance sensor technologies (ADS-B RAD and NRA and WAM).

The requirements defined in this specification are derived to the greatest extent possible from a top-down approach justifying high level requirements (e.g. Target Level of Safety TLS). Where necessary, the derivation of requirements has been supplemented by practical experience and state of the art system constraints.

Particular attention was paid to ensuring that each performance requirement was achievable and measurable and accompanied by an associated conformity assessment process. In this regard, measurements made on the basis of opportunity traffic are preferable as they fully reflect the system performance in its operational environment. Alternatively flight trials may also be undertaken. Proof offered through system design files or by system design assurance, the use of a test transponder or an injected test target is also acceptable when the other options are impracticable.

For the time being this specification is addressing the ATM surveillance system performance needed to support 3 and 5 NM horizontal separation. In the future this specification may be extended to address other air traffic services (e.g. other horizontal separation minima) and/or functions.

# 1 INTRODUCTION

## 1.1 Aim, scope and object of the document

This document has been developed to specify performance requirements applicable to surveillance system[1] and to define how the associated conformity assessments must be performed. Although the specified performance requirements are derived from operational requirements it is not a document to verify operational acceptability of surveillance system and it does not include a surveillance system generic safety assessment.

The aim of this document is to support ANSPs and NSAs in the implementation of the Surveillance Performance and Interoperability Implementing Rule (SPI IR). The latest draft of the future SPI IR is [RD 32].

This document introduces the concept of a surveillance application. A surveillance application is the support of a specific Air Traffic Service (ATS) or function using a specific category of surveillance system.

It also describes associated conformity assessment methods allowing ANSP to demonstrate compliance with this specification.

For each quality of service requirement this document provides statistical quality indicators to assess the actual performance based on output data. It does not provide data quality indicators that might be used to select/reject information.

The content of this document is the consolidated and agreed result of work and inputs from different members of the ATM surveillance community including ANSP's, NSA's and Industry based on their experience with their surveillance systems.

The performance requirements defined in the main body of this document are minimum requirements independent of the environment and applicable to all surveillance systems.

Meeting these requirements is not sufficient to demonstrate that the supported operation is safe. For example availability of the system is not covered as it is strongly depending on local environment. As required in the draft SPI IR ([RD 32]) this should be covered by a local safety assessment.

## 1.2 The supported Air Traffic Services and functions

The different air traffic services and main functions that are based on surveillance information are described in ICAO PANS-ATM Document 4444 ([RD 1]) and are summarised in Annex - E.

The air traffic services that are currently addressed in this document are:

- 3 NM horizontal separation combined with 1000 ft vertical separation when providing approach control service,
- 5 NM horizontal separation combined with 1000/2000 ft vertical separation when providing approach control service or area control service.

[1] In the context of this document surveillance system is restricted to equipment only, not covering people and procedures.

In the future, this document may be extended to the support of other air traffic services and functions for which technical performance specification could be defined. It may address other types of air traffic services (aerodrome control service) and/or the same ATC services when providing other separation minima and/or air traffic functions (e.g. safety net) provided either on the ground or in the air.

## 1.3 Category of surveillance system

In this document a surveillance system is the set of equipment providing surveillance information under the form of digitized messages.

This document considers both cooperative and non-cooperative categories of surveillance systems:

- A cooperative surveillance system relies on and requires an equipment on board the aircraft and can provide all the surveillance data items pertaining to an aircraft including information coming from the aircraft itself (e.g. pressure altitude, aircraft identity).
- A non-cooperative surveillance system does not require equipment on board the aircraft but cannot provide information coming from the aircraft.

## 1.4 Structure of the document

This document is structured as follows:

- Section 1 (this section) presents the aim of the document and the addressed air traffic services and functions, explains its structure and describes the intended readers.
- Section 2 details the approach and the rationale that have been followed to develop this document. Additionally it describes the role of the document in the design process of a surveillance system.
- Section 3 provides the ATM surveillance system performance specifications.
- Section 4 provides some justifications of the selection of the qualities of service specified in section 3.
- Section 5 defines the conformity assessment criteria corresponding to each of the requirements defined in section 3.
- Annex - A describes the scope of the ATM surveillance system and its functions.
- Annex - B provides the list of the referenced documents and the definitions of the acronyms used.
- Annex - C provides traceability and justification links towards referenced documents.
- Annex - D provides the definitions of the data items, performance characteristics and environments referenced in this document.
- Annex - E summarises the different air traffic services and functions that are based on surveillance information.
- Annex - F analyses the ability of different surveillance system designs meeting the performance requirements specified in this document
- Annex - G provides further details on the OPA scenarios defined in section 3.
- Annex - H provides an approach based on collision risk model to justify a sub-set of the requirements.

## 1.5 Intended readers

The intended readers of this document include:

- The departments of the civil and military ANSP of ECAC countries who are responsible for procuring/designing, accepting, and maintaining ATM surveillance systems.
- The departments of the National Supervisory Authorities of ECAC countries who are responsible for verifying ATM surveillance systems.
- International standardisation bodies.
- The engineering industry department who are responsible for developing ATM surveillance systems and/or their components.

## 1.6 Relationship with ICAO approach

ICAO has recognised the benefit of defining the required performance of a surveillance system independent of the technologies that could be used. To this end a Required Surveillance Performance (RSP) concept is currently being developed by ICAO. This document can contribute to these ICAO activities.

# 2 DOCUMENT DEVELOPMENT APPROACH AND ROLE

## 2.1 Document development context

In order to develop this document several aspects have been taken into account:

- The lessons learnt from the application of the EUROCONTROL Standard Document for Radar Surveillance in En-route Airspace and Major Terminal Areas [RD 2].
- The Single European Sky legislation.
- The safety context.

These 3 aspects are further detailed in the following paragraphs.

### 2.1.1 Lessons learnt

This document takes into account the lessons learnt from the application of the EUROCONTROL Standard Document for Radar Surveillance in En-route Airspace and Major Terminal Areas [RD 2], which are:

- Difficulties in practically assessing some specified requirements.
- Only applicable to SSR and PSR whereas new surveillance technologies are now available (Mode S, WAM, ADS-B) and difficulties to transpose requirements to other technologies (e.g. MSPSR).
- Imposed high level implementation choices (2 SSR for en-route and one PSR + 2 SSR for major TMA) and difficulties to transpose requirements for other architectures.
- Lack of traceability between supported air traffic services or functions (i.e. users needs) and technical requirements.
- …

It also takes into account lessons learnt from past and ongoing EUROCONTROL surveillance deployment programmes and surveillance performance appraisal activity.

### 2.1.2 Single European Sky (SES) regulation

The SES regulation is based on the 4 following EC regulations

- EC Regulation 549/2004 (the framework Regulation) amended by Regulation (EC) 1070/2009 (SES II)
  - ➢ Objective to establish a harmonized regulatory framework for the creation of the single European sky
- EC Regulation 550/2004 (the service provision Regulation) amended by Regulation (EC) 1070/2009 (SES II)
  - ➢ Objective to establish common requirements for the safe and efficient provision of air navigation services in the Community
- EC Regulation 551/2004 (the airspace Regulation) amended by Regulation (EC) 1070/2009 (SES II)
  - ➢ Objective to support the concept of progressively more integrated operating airspace and to establish common procedures for airspace design, planning and management
- EC Regulation 552/2004 (the interoperability Regulation) amended by Regulation (EC) 1070/2009 (SES II)
  - ➢ Objective and scope
    - ▪ Ensure interoperability between systems, constituents and associated procedures of the EATMN
    - ▪ Ensure the coordinated and rapid introduction on new agreed and validated concepts of operations or technology

Figure 1 further explains the “Interoperability Regulation” in which this document is aimed to fall.

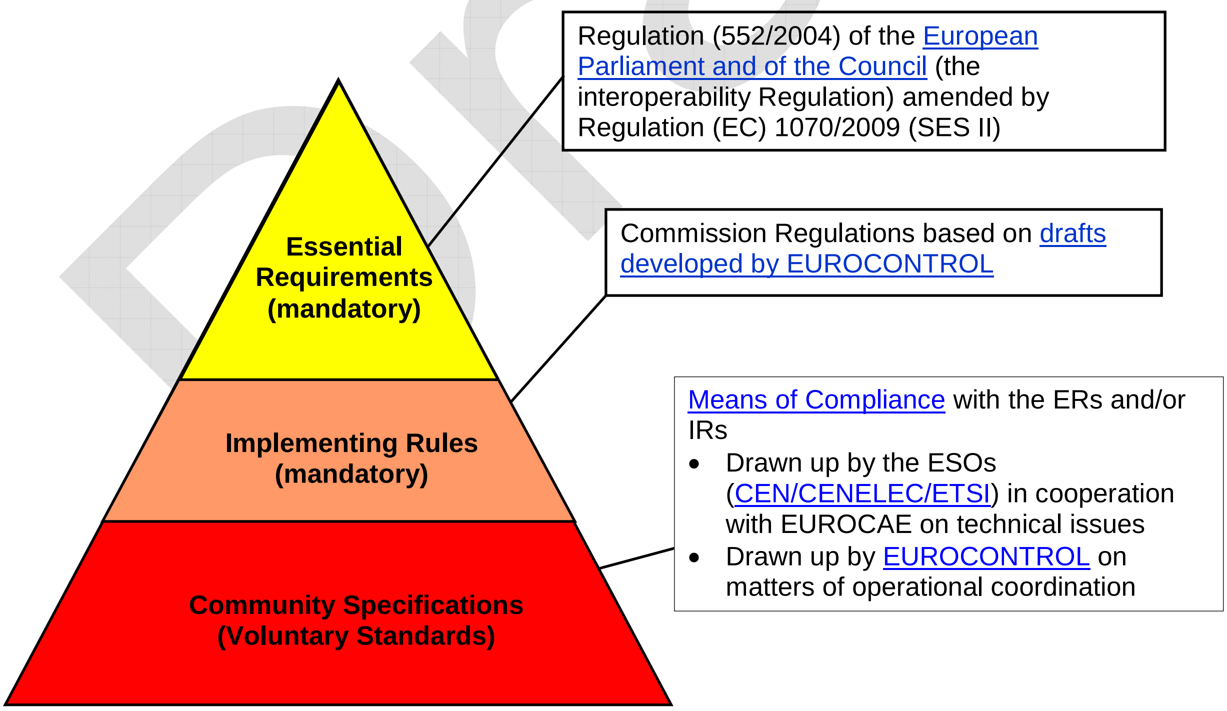


**Figure 1: Single European Sky interoperability regulation framework**

As such the provisions detailed herein support the following Essential Requirements:

- Ensure seamless operation of aircraft with surveillance systems over all of Europe.
- Ensure a defined minimum level of interoperability, for data and performance requirements, between European surveillance systems.
- Facilitate the introduction of new surveillance technologies.

The provisions detailed herein could also be used as an input to a surveillance system safety assessment, the production of which may be a requirement of the SPI IR.

## 2.2 Document development approach

Taking into account the context of the document development, it has been agreed that this document will identify a set of requirements that are:

- Service or function specific
- Independent of environment in order to be applicable everywhere in Europe
- Easily verifiable/measurable on a regular basis
- Representing a minimum baseline to be supplemented by additional requirements dictated by the local environment and by a local safety assessment.
- Allowing maximum flexibility in the surveillance system design process and associated technology choices.

The sub-sections below further justify these 5 objectives that have been assigned to the development of this document.

In order to prepare the evolution of this document to support these objectives and in addition to the current mandatory requirements, a set of recommended requirements have been defined. These requirements are provided as a reasonable target for surveillance systems that are being procured in the near future.

### 2.2.1 Service/function specific

The objective is to define these requirements for each supported air traffic services or functions.

Being service/function specific will permit ANSP's to tailor the surveillance system requirements in accordance with its intended use (e.g. the services and functions it supports).

### 2.2.2 Environment independent

The objective of that specification is to define requirements that are as much as possible independent of environment – applicable everywhere in Europe. Whereas the number of supported services and functions is reasonable and they are well defined, the range of environments that can be met in Europe is currently wide and it is difficult to classify objectively these different environments. Thus a generic approach has been adopted.

### 2.2.3 Measurable

To be of use it is recognised that the requirements specified in this document should be easily measurable and can be regularly monitored.

Performance requirements should be verified using a sufficiently large data set to mitigate the effect of statistical anomalies.

Whilst this approach is appropriate for many of the requirements detailed in this document it is also recognised that integrity requirements may, by their infrequent nature, necessitate an alternative approach. Therefore whenever such a type of requirement is specified its specific conformity assessment method will also be detailed with a view to addressing the limited number of cases to consider.

### 2.2.4 Interoperability and seamless operation

This specification defines a level of performance (quality of service) that a surveillance system shall provide to ensure both a defined minimum level of interoperability with neighbouring systems and for the seamless operation of flights over all of Europe.

It is to be noted that this document does not address interoperability from a data format point of view.

### 2.2.5 Design flexibility

The objective is to define these requirements at a level allowing as much design flexibility as possible. For this reason the surveillance system performance requirements are defined end-to-end (see Annex A - 2). The idea is to leave the maximum freedom to system designers in their choices.

## 2.3 Role of this document within the surveillance system design process

The performance requirements detailed in this document are an initial input in the complex process of designing a surveillance system.

The document contains requirements to cover generic scenarios for identified air traffic services. These requirements should be supplemented by local criteria addressing particular features of the local surveillance system environment and/or local business objectives. Such criteria may include, for example:

- system capacity (business objectives)
- additional data items (e.g. Downlink Aircraft Parameters -DAP)

Surveillance systems have been developed and are used to improve ATM safety. However, infrequent failures of its functions may contribute to ATM risk. The role of surveillance system safety assessment is to analyse such failures, to verify that the potential contribution of surveillance system failures to ATM risk remains within agreed limits and to define, if necessary, mitigations.

As an integral part of the design process, any surveillance system either being put in operation or being modified will be subject to a complete safety assessment process as required in the SPI IR

The surveillance system performance requirements defined in this document can be used as an input to local surveillance system safety assessment. For example, when using the EUROCONTROL SAME (Safety Assessment Made Easier) framework ([RD 34] and [RD 35]) these requirements can be used as an input to the “Success approach”.

The forthcoming SPI IR may also introduce mandatory requirements for a safety assessment to be conducted for existing surveillance system.

## 2.4 Choice of the category of surveillance system to deploy

A cooperative surveillance system, provided that all the aircraft to which the service is provided are equipped in accordance with the local regulation, can support the full range of air traffic environment in Europe, therefore wherever possible such category of system should be deployed. A safety assessment demonstrating that the system (equipment, procedure and people) can support the intended services and functions in its environment is nevertheless required.

A non-cooperative surveillance system may also be used, provided that the local traffic density is compatible with the ATCO workload needed to “manually” establish and maintain the correlation of aircraft horizontal position with the aircraft pressure altitude, the aircraft identity and the other surveillance data items. The required safety assessment demonstrating that the system (equipment, procedure and people) can support the intended services and functions in its environment shall take into account this specific workload.

An association of cooperative and non-cooperative surveillance systems may also be used to cope with a mixed environment (equipped and non-equipped aircraft) provided that the non-cooperative traffic density is compatible with the additional ATCO workload described above. The required safety assessment demonstrating that the system (equipment, procedure and people) can support the intended services and functions in its environment shall take into account this specific workload.

In that case, the two systems may be, plus or minus, integrated into a single system or may even be operated as two independent systems providing two parallel data streams to the ATCO.

The following chapters define separate performance requirements for cooperative and non-cooperative surveillance systems. The conformity assessment procedures describe how to separate the assessment of cooperative and non-cooperative performance requirement in case of association of the two categories of surveillance system.

As a summary, the choice of the category of surveillance system(s) to be deployed, cooperative, non-cooperative or association of both, is the decision of the ANSP depending on local environment and constraints such as the percentage of transponder equipped aircraft, traffic density, airspace structure and design, business objectives, etc. Therefore there are no generic criteria to define which category of system needs to be deployed.

## 2.5 Performance metrics/indicators

In order to define the performance metrics/indicators, this document uses the International Organization for Standardization (ISO) Quality of Service framework (see document [RD 5]). This could allow a transition to a more structured required surveillance performance approach.

The ISO 13236 framework ([RD 5]) defines 8 generic quality of service characteristics, which are then refined so as to properly reflect the salient features of ATM surveillance system:

- **Time**: time-related characteristics fall into two main groups: absolute timing and time intervals between events, which can be further specialised in terms of transfer delays etc.
- **Coherence**: coherence-related characteristics correspond to the notion of having a certain piece of information available over a certain area, which can be defined geographically or as a logical abstraction (e.g. as the inter networked set of computers over which a certain function is distributed). An important variant denoted as "temporal consistency" introduced by ISO 13236 is to attach a maximum duration to the transient state that exists when a piece of information is being updated over a certain area.
- **Capacity**: capacity-related characteristics represent the capability to provide a certain number of units of service to the users.
- **Integrity**: integrity-related characteristics appreciate the influence of errors and inaccuracies on the Quality of Service. In a narrow sense, "integrity" is traditionally associated to error rate issues while "accuracy" is introduced to convey a notion of precision. An important specialisation of integrity in this wider sense of "accuracy" is the notion of "relevance", understood as the subjective degree of adequacy of the service to its intended use.
- **Safety**: safety-related characteristics deal with the overall impact of the service on user operations in terms of the potential risk entailed by its failures (whatever their nature: human error, hardware breakdown, software bug, security breach/leak).
- **Security**: security-related characteristics address the issue of protecting the users of the service against voluntary of involuntary interference by third parties.
- **Reliability**: reliability-related characteristics are used to assess the frequency and duration of service failures. Important generic specialisations are "availability" and "maintainability". In a narrow sense "reliability" denote the failure rate/probability.
- **Priority**: priority-related characteristics address issues of precedence hierarchies among users competing for the service.

From the previous list the following quality of service characteristics have been selected and further refined:

- **Time** is translated in processing delay for the data items that are forwarded from the aircraft to the surveillance system user on the ground.
- **Coherence** is translated in the time consistency of the provided aircraft positions.
- Capacity is not retained because it depends on surveillance system environment and cannot be defined generically.
- **Integrity** is further refined in three different performance characteristics: core errors, correlated errors, spurious and large errors of data items.
- Safety and security are deliberately not addressed in this document, but must be separately.
- **Reliability** is further refined in availability and continuity of the data items and of the complete surveillance system.
- Priority has not been retained because it was not found applicable to the current applications addressed in this document.

For each data item and for the complete system, performance metrics will be chosen within the 7 columns corresponding to the different quality of service that have been considered in this document. For each of the addressed application, a table (see example Table 1) will map for the provided data items and for the system (rows) the specified performance requirements/metrics onto the retained quality of service (columns).

| | **Availability** | **Continuity** | **Integrity** | | | **Time** | **Coherence** |
|---|---|---|---|---|---|---|---|
| | | | Core error | Correlated error | Spurious error | | |
| Data item 1 | X | X | X | X | X | - | X |
| Data item 2 | X | X | - | - | - | X | - |
| … | | | | | | | |
| System | X | X | - | - | - | - | - |

**Table 1: Example of mapping of performance metrics on quality of service characteristics**

# 3 PERFORMANCE REQUIREMENT SPECIFICATION FOR SURVEILLANCE APPLICATIONS

## 3.1 3/5 NM horizontal separation operational services

This document considers two families of elementary services:

- horizontal distance-based separation with a minimum of 5 NM, it is called “5 NM horizontal separation”.
- horizontal distance-based separation with a minimum of 3 NM, it is called “3 NM horizontal separation”.

As aircraft separation has to be provided horizontally or vertically, these two families of elementary service have to be considered in conjunction with vertical separation minima (VSM), i.e. 1000 ft or 2000 ft .

5 NM and 3 NM are the more generally applied horizontal separation minima as specified in ICAO Document 4444 [RD 1] § 8.7.3.

It is assumed that the surveillance system performance defined to support these elementary services will also be sufficient to support, in the context of Air Traffic Control Services, vectoring of aircraft (see [RD 1] § 8.6.5), general flight path monitoring and navigation assistance (see [RD 1] § 8.6.6).

On the other hand, this surveillance system performance is not deemed sufficient to support the following services as defined in ICAO Document 4444 [RD 1]: distance-based separation with a minimum of less than 3 NM, time-based separation, separation of aircraft holding in flight, flight path monitoring on parallel ILS approaches, surveillance radar approaches, precision radar approaches, flight path monitoring on final approach, vectoring of aircraft to final approach.

Air traffic functions that use surveillance information like ground safety nets (e.g. Short Term Conflict Alert – STCA see [RD 1] § 15.7.2; Minimum Safe Altitude Warning – MSAW see [RD 1] § 15.7.4; Area Proximity Warning – APW and Approach Path Monitor – APM) may also be considered in next issues of this document.

## 3.2 3/5 NM horizontal separation application definitions

This version of the document covers 4 applications, corresponding to the combination of the two selected elementary ATC services with the two categories of surveillance systems. They have been chosen as the first to be addressed as they are deemed to correspond to the most commonly applied applications using surveillance information in Europe.

| | | Provided ATC service | |
|---|---|---|---|
| | | 5 NM horizontal separation | 3 NM horizontal separation |
| Category of surveillance system | Cooperative | 5N_C | 3N_C |
| | Non-cooperative | 5N_N | 3N_N |

**Table 2: Addressed application**

## 3.3 3/5 NM horizontal separation operational performance assessment (OPA) scenarios

In order to be independent of traffic density (see § 2.2.2) the performance requirements are based on a set of elementary OPA scenarios that are derived from ICAO Document 4444 [RD 1].

These scenarios are expected to cover all the cases of operational separation between two aircraft.

The performance requirements figures specified in this document are based on these basic OPA scenarios. In practice an air traffic controller will have to face a number of these scenarios, either combined and/or duplicated, at the same time and/or within a short time frame, therefore increased surveillance system performance may be needed to cope with the cumulated number of scenario cases (e.g. due to traffic density).

For the scenarios in the horizontal plane, the previous aircraft positions are displayed in shaded color whereas the actual aircraft positions are displayed in normal color.

For the scenarios in the vertical plane, the successive aircraft positions are numbered.

The following paragraphs provide a high level description of the different scenarios. More detailed scenario descriptions for 3 NM and 5 NM horizontal separation are provided in Annex - G.

### 3.3.1 Crossing tracks scenario

This scenario corresponds to two tracks crossing with an angle between 45° and 135°. A particular case with an angle of 90° is represented on Figure 2.

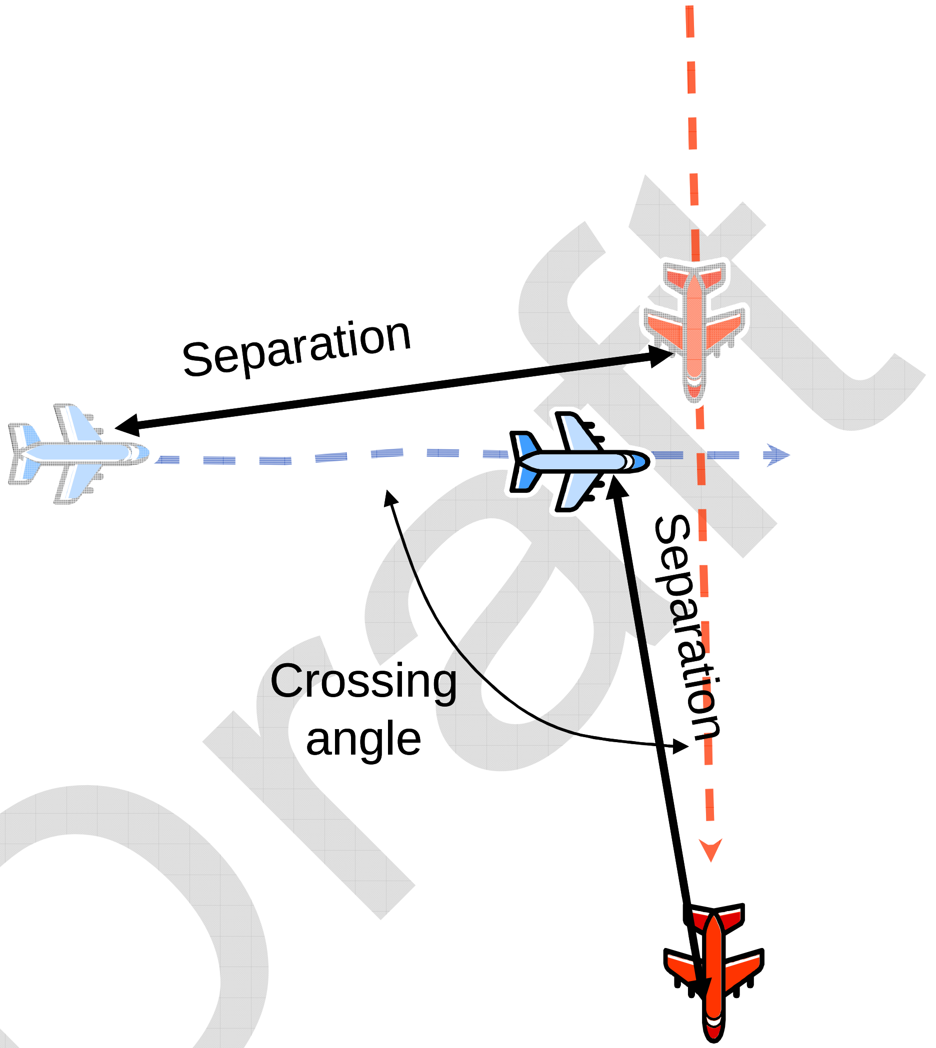


**Figure 2: Crossing tracks scenario**

### 3.3.2 Crossing same track scenario

This scenario corresponds to two tracks crossing with an angle between -45° and 45°. A particular case with an angle of 0° (no lateral offset) is represented on Figure 3.

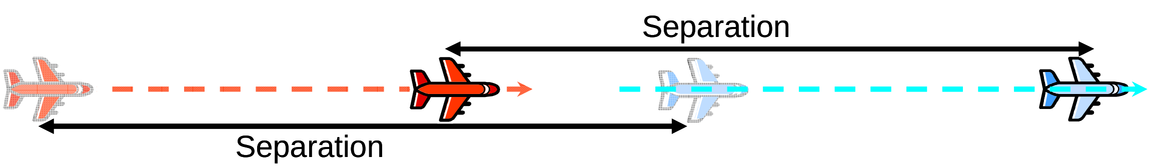


**Figure 3: Same track scenario**

Another particular case with an angle of 0° and a lateral offset is represented on Figure 4.

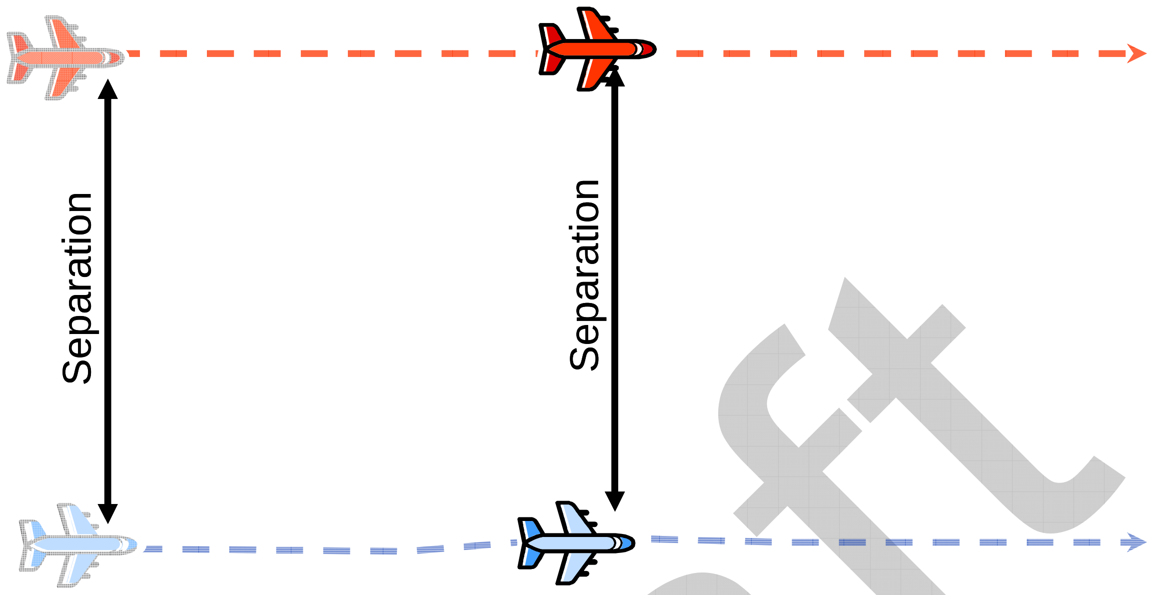


**Figure 4: Parallel tracks scenario**

### 3.3.3 Crossing reciprocal track scenario

This scenario corresponds to two tracks crossing with an angle between 135° and 225°. A particular case with an angle of 180° is represented on Figure 5.

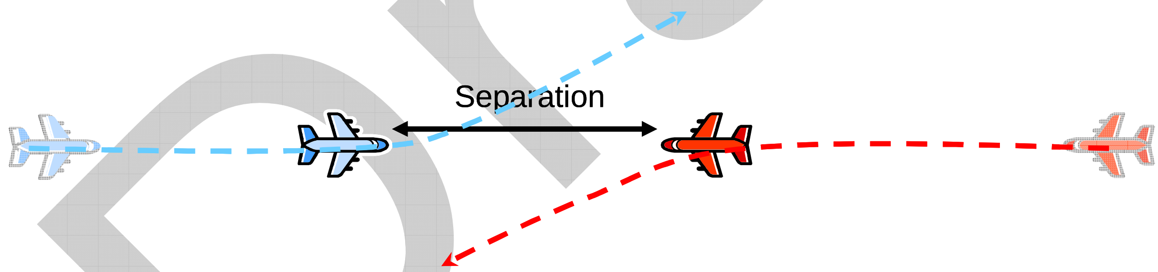


**Figure 5: Reciprocal tracks scenario**

### 3.3.4 Vertical crossing track scenario

This scenario corresponds to two tracks crossing in the vertical plane. It can be combined with any of the previous scenario in the horizontal plane. A particular case where one of the aircraft climbs above the other aircraft is represented on Figure 6

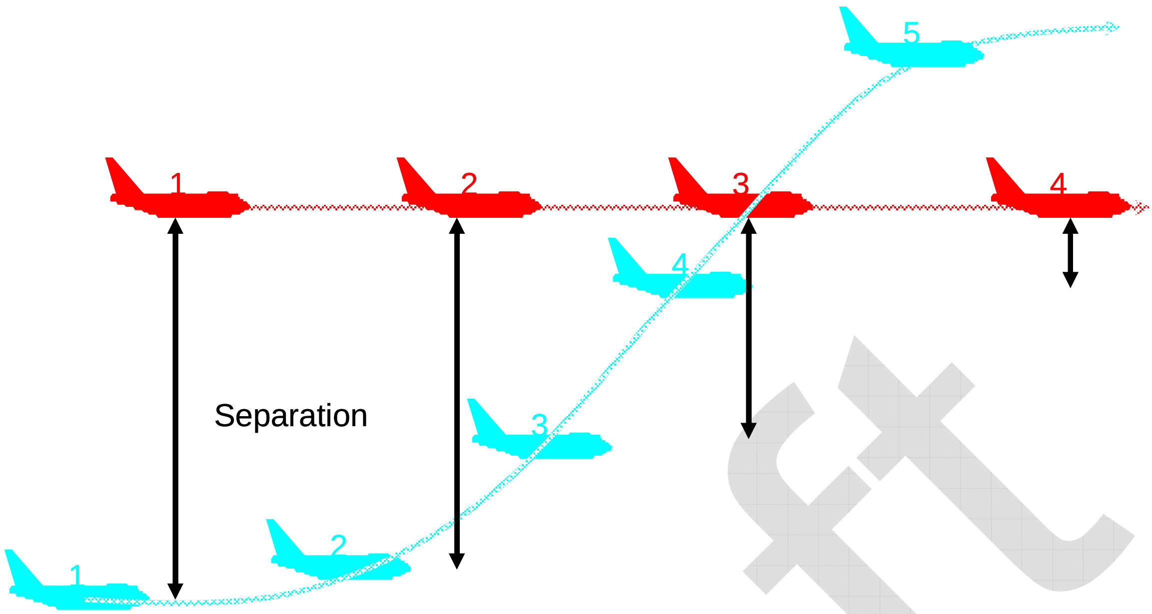


**Figure 6: Same/crossing track climbing scenario**

### 3.3.5 Vertically separated scenario

In addition a scenario where aircraft are only vertically separated (no crossing) is also defined and is represented on Figure 7.

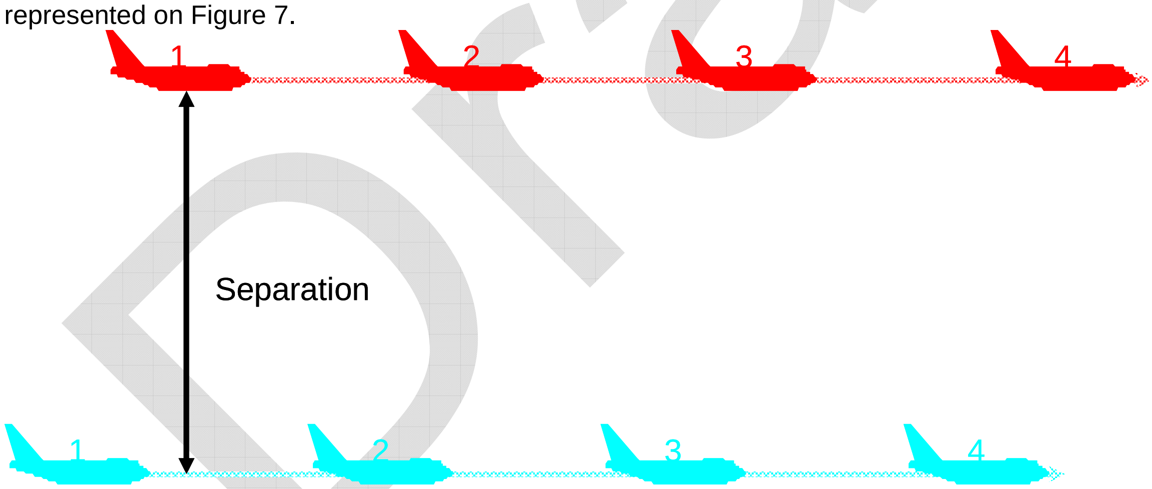


**Figure 7: Vertically separated tracks scenario**

## 3.4 5N_C: 5 NM horizontal separation provided by ATCO using cooperative surveillance system

The following sub-sections describe the Operational Services and Environment Definition (OSED) the required data items and associated performance requirements.

### 3.4.1 Operational Service and Environment Description (OSED)

The operational service is described in § 3.1.

A fundamental assumption of the OSED is that the operational service is provided to cooperative aircraft that are fully compliant with the avionic requirements detailed in the draft SPI IR [RD 32]. These requirements will be further detailed in an EASA Certification Specification.

The local surveillance system safety assessment should therefore address instances in which the aircraft's avionics presents an anomaly as well as the possible intrusion of aircraft that are not equipped in accordance with the requirements detailed in the draft SPI IR [RD 32].

Any differences in local environments from that defined in this sub-section should be accounted for in accompanying analysis prior to local implementation.

The airspace classes in which separation services must be provided are described in Annex D - 4.1.

The airspace structure is further defined in Annex D - 4.2.

### 3.4.2 Required data items

The following information elements are required from the cooperative surveillance system for the provision of surveillance separation. This list does not include flight plan elements.

The following data items shall be provided by the cooperative surveillance system under the form of message-structured and digitised information:

Positional data:

- Horizontal (2D) position;
- Time of applicability of horizontal position(for conformity assessment);
- Vertical position based upon pressure altitude received from the aircraft;
- Time of applicability of vertical position (for conformity assessment).

Operational identification data:

- Aircraft identity (ICAO Aircraft Identification and/or Mode 3/A code) reported by the aircraft.

Supplemental indicators:

- Emergency indicator (General emergency, radio failure and unlawful interference);
- Special Position Identification (or Indicator) SPI.

Surveillance data status:

- Cooperative/non-cooperative/combined;
- Coasted/not coasted (position).

The provision of the above data items is compliant with Annex I § 1.1 and 1.2 of the draft SPI IR ([RD 32]) when using a cooperative surveillance system.

The following data items should be provided:

- Track velocity vector;
- Rate of climb/descent (this data item may be reduced to a trend);
- Flight status (on the ground / airborne / unknown).

These data items are further described in Annex D - 1.

### 3.4.3 Mandatory and recommended performance requirements

A mapping of the performance requirements detailed in Table 4 on the quality of services described in sub-section 2.5 is provided in Table 3 below and additional justifications are provided in section 4. Greyed cells indicate that it was considered not necessary to define corresponding detailed requirements. Empty cells indicate area where no decision has been made yet.

| | **Availability** | **Continuity** | **Integrity** | | | **Time** | **Coherence** |
|---|---|---|---|---|---|---|---|
| | | | Core error | Correlated error | Spurious error | | |
| Horizontal position | R1-R2 | R3 | R4 | R5 & R20 | R19 | Note 1 | R6 |
| Pressure altitude | R1-R7 | R3 | R11 & R1-R7 | Note 2 | R10 | R8 & R9 | R8 & R9 |
| SPI/Emergency indicator | Note 3 | | | | | R12 | - |
| Aircraft identity | R1-R14 | - | R1-R14 | - | R15 | R13 | - |
| Rate of climb/descent | Note 4 | Note 5 | R16 | Note 6 | | Note 1 | - |
| Track velocity | Note 4 | Note 5 | R17 & R18 | Note 6 | | Note 1 | - |
| System | Note 4 | R21 | - | - | - | - | - |

**Table 3: Mapping of performance metrics on quality of service characteristics**

<u>Note 1:</u> Impact of information latency is taken into account within error calculation method.

<u>Note 2:</u> Pressure altitude correlated error is assessed through the RVSM monitoring.

<u>Note 3:</u> Data items are checked procedurally by ATCO.

<u>Note 4:</u> Requirements are to be defined locally.

<u>Note 5:</u> Because of the way these data items are calculated, once started they will continue to be provided so continuity is 100% by design.

<u>Note 6:</u> No specifc requirement when supporting 3 or 5 NM horizontal separation, requirement likely to be needed when supporting safety nets.

These performance requirements are mainly derived from the experience gained in Europe over the last decades on the basis of radar technology.

In addition some specific studies have been undertaken to further refine performance requirement specifications when necessary.

Annex - C provides links between the requirements specified in this document and requirements specified in existing documents, mainly the EUROCONTROL Standard Document for Radar Surveillance in En-route Airspace and Major Terminal Areas ([RD 2]) and the ADS-B specifications developed by the ADS-B Requirement Focus Group ([RD 4], [RD 42]).

Annex - C also provides links with study reports that have been produced to support the development of this document and to decisions of the Surveillance Standard Task Force (SSTF) who was the group in charge of the writing of this document.

The following conventions are applied in the tables below:

- Mandatory performance requirements are in **bold font**
- Recommended performance requirements are in normal font

The 6$^{th}$ column "Ref./Justif." provides the corresponding paragraph of Annex C where further references and justifications can be found.

The last column "Conf. method" provides the corresponding sub-section of section 5 Conformity assessment.

<u>Note 7:</u> The performance of the pressure altitude data-item can be specified in two ways. These depend upon whether the pressure altitude is calculated by the ground based components of the surveillance system or if the value of the data-item was declared by the aircraft and forwarded, unchanged, by the ground based components of the surveillance system.

If the pressure altitude data-item is calculated by the ground based components of the surveillance system then requirement 5N_C-R11 applies.

If the value of the data-item was declared by the aircraft and forwarded by the ground based components of the surveillance system then either requirement 5N_C-R11 applies or the 3 requirements 5N_C-R8/9/10 can be applied.

<u>Note 8:</u> The requirement on the probability of update of the aircraft identity data item is a requirement on the provision of the data item at the output of the system and does not require the systematic extraction of that data item at each update interval.

**Although requirements 5N_C-R9, 5N_C-R12 and 5N_C-R13 are defined for 100 % of the cases, it is recognised that very rare cases may present a data age or a delay greater than the specified value. The occurrence of such events may not invalidate the performance of the surveillance system provided that they have been investigated and that appropriate mitigation and risk reduction measures have been defined to avoid/reduce their re-occurrence in the future.**

| Data items | Req. # | Quality of service | Mandatory performance | Recommended performance | Ref. / Justif. | Conf. method |
|---|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 5N_C-R1 | Applicable update interval | **Less than or equal to 8 seconds** | Less than or equal to 6 seconds | **C - 2.1.1** / C - 2.1.2 | 5.2.1 |
| Horizontal position | 5N_C-R2 | Probability of update | **Greater than or equal to 97% per flight** | Greater than or equal to 97% per flight and Greater than or equal to 99 % global | **C - 2.1.3** / C - 2.1.4 | 5.2.2.1 |
| Horizontal position or pressure altitude | 5N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | | **C - 2.1.5** | 5.2.3 |
| Horizontal position | 5N_C-R4 | RMS error | **Less than or equal to 500 m global and less than 550 m per flight** | Less than or equal to 350 m global and less than 385 m per flight | **C - 2.1.6** / C - 2.1.7 | 5.2.4 |
| Horizontal position | 5N_C-R5 | Ratio of target reports involved in series of at least 3 consecutive correlated errors larger than 926 m - 0.5 NM | | Less than or equal to 0.03 % | C - 2.1.9 | 5.2.5 |
| Horizontal position | 5N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | | Less than or equal to 0.3 second RMS for relative data age | C - 2.1.10 | 5.2.6 |
| Pressure altitude | 5N_C-R7 | Probability of update with valid and correct value | **Greater than or equal to 96 % global** | | **C - 2.1.11** | 5.2.2.2 |
| Forwarded pressure altitude | 5N_C-R8 | Average data age (see Note 7 above) | **Less than or equal to 4 seconds** | | **C - 2.1.12** | 5.2.7 |
| Forwarded pressure altitude | 5N_C-R9 | Maximum data age (see Note 7 above) | **Less than or equal to 16 seconds** | | **C - 2.1.13** | 5.2.7 |
| Forwarded pressure altitude | 5N_C-R10 | Ratio of incorrect pressure altitude (see Note 1 above) | **Less than or equal to 0.1 %** | | **C - 2.1.14** | 5.2.8 |
| Pressure altitude | 5N_C-R11 | Unsigned error (see Note 7 above) | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | | **C - 2.1.15** | 5.2.9 |

| Data items | Req. # | Quality of service | Mandatory performance | Recommended performance | Ref. / Justif. | Conf. method |
|---|---|---|---|---|---|---|
| Change in emergency indicator/SPI report | 5N_C-R12 | Delay | **Less than or equal to 12 seconds** | | **C - 2.1.16** | 5.2.10 |
| Change in Aircraft identity | 5N_C-R13 | Delay | **Less than or equal to 24 seconds** | | **C - 2.1.17** | 5.2.11 |
| Aircraft identity | 5N_C-R14 | Probability of update with valid and correct value (see Note 8 above) | **Greater than or equal to 98 % global** | Greater than or equal to 98 % per flight | **C - 2.1.18** | 5.2.2.2 |
| Aircraft identity | 5N_C-R15 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | | **C - 2.2.19** | 5.2.12 |
| Rate of climb/descent | 5N_C-R16 | RMS error | | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | C - 2.1.20 | 5.2.13 |
| Track velocity | 5N_C-R17 | RMS error | | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | C - 2.1.21 | 5.2.14 |
| Track velocity angle | 5N_C-R18 | RMS error | | Less than or equal to 10° for straight line and less than or equal to 25° for turn | C - 2.1.21 | 5.2.14 |
| False target reports | 5N_C-R19 | Density of uncorrelated false target reports | | Less than 10 false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals | C - 2.1.22 | 5.2.15 |
| False tracks | 5N_C-R20 | Number per hour of falsely confirmed track close to true tracks | | Less than or equal to 2 non-simultaneous falsely confirmed tracks per hour that are closer than 13000 m - 7 NM from true tracks | C - 2.1.23 | 5.2.16 |
| System | 5N_C-R21 | Continuity (probability of critical failure) | | Less than or equal to $2.5\ 10^{-5}$ per hour of operation | C - 2.1.24 | 5.2.17 |

**Table 4: Cooperative surveillance system requirements for supporting 5 NM horizontal separation (5N_C)**

## 3.5 3N_C: 3 NM horizontal separation provided by ATCO using cooperative surveillance system

The following sub-sections describe the Operational Services and Environment Definition (OSED) the required data items and associated performance requirements.

### 3.5.1 Operational Service and Environment Description (OSED)

The operational service is described in § 3.1.

A fundamental assumption of the OSED is that the operational service is provided to cooperative aircraft that are fully compliant with the avionic requirements detailed in the draft SPI IR [RD 32]. These requirements will be further detailed in an EASA Certification Specification.

The local surveillance system safety assessment should therefore address instances in which the aircraft's avionics presents an anomaly as well as the possible intrusion of aircraft that are not equipped in accordance with the requirements detailed in the draft SPI IR [RD 32].

Any differences in local environments from that defined in this sub-section should be accounted for in accompanying analysis prior to local implementation.

The airspace classes in which separation services must be provided are described in Annex D - 4.1.

The airspace structure is further defined in Annex D - 4.2.

### 3.5.2 Required data items

The following information elements are required from the surveillance system for the provision of surveillance separation. This list does not include flight plan elements.

The following data items shall be provided by the surveillance system under the form of message-structured and digitised information:

Positional data:

- Horizontal (2D) position;
- Time of applicability of horizontal position(for conformity assessment);
- Vertical position based upon pressure altitude received from the aircraft;
- Time of applicability of vertical position(for conformity assessment).

Operational identification data:

- Aircraft identity (ICAO Aircraft Identification and/or Mode 3/A code) reported by the aircraft.

Supplemental indicators:

- Emergency indicator (General emergency, radio failure and unlawful interference);
- Special Position Identification SPI.

Surveillance data status:

- Cooperative/non-cooperative/combined;
- Coasted/not coasted (position).

The provision of the above data items is compliant with Annex I § 1.1 and 1.2 of the draft SPI IR ([RD 32]) when using a cooperative surveillance system.

The following data items should be provided:

- Track velocity vector;
- Rate of climb/descent (this data item may be reduced to a trend);
- Flight status (on the ground / airborne / unknown).

These data items are further described in Annex D - 1.

### 3.5.3 Mandatory and recommended performance requirements

A mapping of the performance requirements detailed in Table 6 on the quality of services described in sub-section 2.5 is provided in Table 5 below and additional justifications are provided in section 4.

| | **Availability** | **Continuity** | **Integrity** | | | **Time** | **Coherence** |
|---|---|---|---|---|---|---|---|
| | | | Core error | Correlated error | Spurious error | | |
| Horizontal position | R1-R2 | R3 | R4 | R5 & R20 | R19 | Note 1 | R6 |
| Pressure altitude | R1-R7 | R3 | R11 & R1-R7 | Note 2 | R10 | R8 & R9 | R8 & R9 |
| SPI/Emergency indicator | Note 3 | | | | | R12 | - |
| Aircraft identity | R1-R14 | - | R1-R14 | - | R15 | R13 | - |
| Rate of climb/descent | Note 4 | Note 5 | R16 | Note 6 | | Note 1 | - |
| Track velocity | Note 4 | Note 5 | R17 & R18 | Note 6 | | Note 1 | - |
| System | Note 4 | R21 | - | - | - | - | - |

**Table 5: Mapping of performance metrics on quality of service characteristics**

Note 1: Impact of information latency is taken into account within error calculation method.

Note 2: Pressure altitude correlated error is assessed through the RVSM monitoring.

Note 3: Data items are checked procedurally by ATCO.

Note 4: Requirements are to be defined locally.

Note 5: Because of the way these data items are calculated, once started they will continue to be provided so continuity is 100% by design.

Note 6: No specifc requirement when supporting 3 or 5 NM horizontal separation, requirement likely to be needed when supporting safety nets.

These performance requirements are mainly derived from the experience gained in Europe over the last decades on the basis of radar technology.

In addition some specific studies have been undertaken to further refine performance requirement specifications when necessary.

Annex - C provides links between the requirements specified in this document and requirements specified in similar documents, mainly the EUROCONTROL Standard Document for Radar Surveillance in En-route Airspace and Major Terminal Areas ([RD 2]) and the ADS-B specifications developed by the ADS-B Requirement Focus Group ([RD 4], [RD 42]).

Annex - C also provides links with study reports that have produced to support the development of this document and to decisions of the Surveillance Standard Task Force (SSTF) who is the group in charge of the writing of this document.

The following conventions are applied in the tables below:

- Mandatory performance requirements are in **bold font**
- Recommended performance requirements are in normal font

The 6th column "Ref./Justif." provides the corresponding paragraph of Annex C where further references and justifications can be found.

The last column "Conf. method" provides the corresponding sub-section of section 5 Conformity assessment.

Note 7: The performance of the pressure altitude data-item can be specified in two ways. These depend upon whether the pressure altitude is calculated by the ground based components of the surveillance system or if the value of the data-item was declared by the aircraft and forwarded, unchanged, by the ground based components of the surveillance system.

If the pressure altitude data-item is calculated by the ground based components of the surveillance system then requirement 3N_C-R11 applies.

If the value of the data-item was declared by the aircraft and forwarded by the ground based components of the surveillance system then either requirement 3N_C-R11 applies or the 3 requirements 3N_C-R8/9/10 can be applied.

Note 8: The requirement on the probability of update of the aircraft identity data item is a requirement on the provision of the data item at the output of the system and does not require the systematic extraction of that data item at each update interval.

**Note 9:**

**Although requirements 3N_C-R9, 3N_C-R12 and 3N_C-R13 are defined for 100 % of the cases, it is recognised that very rare cases may present a data age or a delay greater than the specified value. The occurrence of such events may not invalidate the performance of the surveillance system provided that they have been investigated and that appropriate mitigation and risk reduction measures have been defined to avoid/reduce their re-occurrence in the future.**

| Data items | Req. # | Quality of service | Mandatory performance | Recommended performance | Ref. / Justif | Conf. method |
|---|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 3N_C-R1 | Applicable update interval | **Less than or equal to 5 seconds** | Less than or equal to 4 seconds | **C - 2.2.1** / C - 2.2.2 | 5.2.1 |
| Horizontal position | 3N_C-R2 | Probability of update | **Greater than or equal to 97% per flight** | Greater than or equal to 97% per flight and greater than or equal to 99 % global | **C - 2.2.3** / C - 2.2.4 | 5.2.2.1 |
| Horizontal position or pressure altitude | 3N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | | **C - 2.2.5** | 5.2.3 |
| Horizontal position | 3N_C-R4 | RMS error | **Less than or equal to 300 metres global and less than 330 meters per flight** | Less than or equal to 210 metres global and less than 230 meters per flight | C - 2.2.6 / C - 2.2.7 | 5.2.4 |
| Horizontal position | 3N_C-R5 | Ratio of target reports involved in sets of 3 consecutive correlated errors larger than 555 m - 0.3 NM | | Less than or equal to 0.03 % | C - 2.2.9 | 5.2.5 |
| Horizontal position | 3N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | | Less than or equal to 0.3 seconds RMS | C - 2.2.10 | 5.2.6 |
| Valid and correct pressure altitude | 3N_C-R7 | Probability of update with valid and correct value | **Greater than or equal to 96 % global** | | **C - 2.2.11** | 5.2.2.2 |
| Forwarded pressure altitude | 3N_C-R8 | Average data age (see Note 7 above) | **Less than or equal to 2.5 seconds** | | **C - 2.2.12** | 5.2.7 |
| Forwarded pressure altitude | 3N_C-R9 | Maximum data age (see Note 7 above) | **Less than or equal to 16 seconds** | | **C - 2.2.13** | 5.2.7 |
| Forwarded pressure altitude | 3N_C-R10 | Ratio of incorrect pressure altitude (see Note 1 above) | **Less than or equal to 0.1 %** | | **C - 2.2.14** | 5.2.8 |

| Data items | Req. # | Quality of service | Mandatory performance | Recommended performance | Ref. / Justif | Conf. method |
|---|---|---|---|---|---|---|
| Pressure altitude | 3N_C-R1 | Unsigned error (see Note 7 above) | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights Less than or equal to 300 ft in 98.5% of the cases for climbing/descending flights** | | **C - 2.2.15** | 5.2.9 |
| Change in emergency indicator/SPI report | 3N_C-R1: | Delay | **Less than or equal to 7.5 seconds** | | **C - 2.2.16** | 5.2.10 |
| Change in Aircraft identity | 3N_C-R1: | Delay | **Less than or equal to 15 seconds** | | **C - 2.2.17** | 5.2.11 |
| Aircraft identity | 3N_C-R1 | Probability of update with valid and correct value (see Note 8 above) | **Greater than or equal to 98 % global** | Greater than 98% per flight | **C - 2.2.18** | 5.2.2.2 |
| Aircraft identity | 3N_C-R1 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | | **C - 2.2.19** | 5.2.12 |
| Rate of climb/descent | 3N_C-R1 | RMS error | | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | C - 2.2.20 | 5.2.13 |
| Track velocity | 3N_C-R1 | RMS error | | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | C - 2.2.21 | 5.2.14 |
| Track velocity angle | 3N_C-R1 | RMS error | | Less than or equal to 10° for straight line and less than or equal to 25° for turn | C - 2.2.21 | 5.2.14 |
| False target reports | 3N_C-R1 | Density of uncorrelated false target reports | | Less than or equal to 2 false target reports per area of 100 NM² and over a duration of 720 update intervals | C - 2.2.22 | 5.2.15 |
| False tracks | 3N_C-R2 | Number per hour of falsely confirmed track close to true tracks | | Less than or equal to 1 falsely confirmed track per hour that are closer than 16700 m - 9 NM from true tracks | C - 2.2.23 | 5.2.16 |
| System | 3N_C-R2 | Continuity (probability of critical failure) | | Less than or equal to 2.5 $10^{-5}$ per hour of operation | C - 2.2.24 | 5.2.17 |

**Table 6: Cooperative surveillance system requirements for supporting 3 NM horizontal separation (3N_C)**

## 3.6 5N_N: 5 NM horizontal separation provided by ATCO using non-cooperative surveillance system

The following sub-sections describe the Operational Services and Environment Definition (OSED) the required data items and associated performance requirements.

### 3.6.1 Operational Service and Environment Description (OSED)

The operational service is described in § 3.1.

The operational service can be provided to all aircraft provided they have the minimum physical characteristics (e.g. Radar Cross Section) that need to be locally defined in accordance with the specifications of the non cooperative surveillance system. The presence and the possible proximity of aircraft not meeting these minimum physical characteristics should be taken into account in the surveillance system safety assessment.

When a non-cooperative surveillance system is used in stand-alone the traffic environment is assumed to be low density. The local surveillance system safety assessment should define the limit in terms of quantity of traffic that can be managed with a non–cooperative surveillance system. This is locally defined taking into account the complexity of the airspace and the complexity of the environment.

### 3.6.2 Required data items

The following information elements are required from the surveillance system for the provision of surveillance separation. This list does not include flight plan elements.

The following data items shall be provided by the surveillance system under the form of message-structured and digitised information[2]:

Positional data:

- Horizontal position (2D).

Surveillance data status:

- Coasted/not coasted;
- Time of applicability (for conformity assessment).

The provision of the above data items is compliant with Annex I § 1.1 of the draft SPI IR ([RD 32]) when using a non-cooperative surveillance system.

The following data items should be provided:

- Track velocity vector.

These data items are further described in Annex D - 1.

### 3.6.3 Mandatory and recommended performance requirements

A mapping of the performance requirements detailed in Table 8 on the quality of services described in sub-section 2.5 is provided in Table 7 below and additional justifications are provided in section 4.

| | **Availability** | **Continuity** | **Integrity** | | | **Time** | **Coherence** |
|---|---|---|---|---|---|---|---|
| | | | Core error | Correlated error | Spurious error | | |
| Horizontal position | R1/R2 | R3 | R4 | R5 | Note 1 | Note 2 | R6 |
| Track velocity | Note 3 | Note 4 | R7 & R8 | Note 5 | | Note 2 | - |
| System | Note 3 | R9 | - | - | - | - | - |

**Table 7: Mapping of performance metrics on quality of service characteristics**

Note 1: There is not yet an agree criteria for outlier criteria for horizontal position in case of non cooperative system.

Note 2: Impact of information latency is taken into account within error calculation method.

[2] Although excluded for supporting separation application, analogue or digitised video can be presented to ATCO as mitigation and/or as a confidence re-enforcement.

Note 3: Requirements are to be defined locally.

Note 4: Because of the way these data items are calculated, once started they will continue to be provided so continuity is 100% by design.

Note 5: No specifc requirement when supporting 3 or 5 NM horizontal separation, requirement likely to be needed when supporting safety nets.

These performance requirements are identical to the performance requirements specified for a cooperative surveillance system but are adapted to take account for the non-provided data items.

The following conventions are applied in the tables below:

- Mandatory performance requirements are in **bold font**
- Recommended performance requirements are in normal font

The 6th column "Ref./Justif." provides the corresponding paragraph of Annex C where further references and justifications can be found.

The last column "Conf. method" provides the corresponding sub-section of section 5 Conformity assessment.

Note 6: In principle the required probability of update of horizontal position should be the same for cooperative and non-cooperative surveillance system. However, because probability of update of horizontal position of non-cooperative surveillance sytem is a performance characteristic which depends on the environment conditions it is only recommended to apply the same performance specification for non-cooperative surveillance system as for cooperative one's. As matter of consistency the 90 % is being required as it is the usual required value for primary surveillance radars since 1997. In any case this performance characteristic will have to be confirmed by the system safety assessment.

| Data items | Req. # | Quality of service | Mandatory performance | Recommended performance | Ref. / Justif. | Conf. method |
|---|---|---|---|---|---|---|
| Horizontal position | 5N_N-R1 | Update interval | **Less than or equal to 8 seconds** | Less than or equal to 6 seconds | **C - 2.1.1** / C - 2.1.2 | 5.2.1 |
| Horizontal position | 5N_N-R2 | Probability of update | **Greater than 90 % global** | Greater than or equal to 97 % per flight (see Note 6 above) | **C - 2.1.3** / C - 2.1.4 | 5.2.2.1 |
| Horizontal position | 5N_N-R3 | Ratio of missed 2D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | | **C - 2.1.5** | 5.2.3 |
| Horizontal position | 5N_N-R4 | RMS error | **Less than or equal to 500 metres** | Less than or equal to 350 metres | **C - 2.1.6** / C - 2.1.7 | 5.2.4 |
| Horizontal position | 5N_N-R5 | Ratio of target reports involved in series of at least 3 consecutive correlated errors larger than 926 m - 0.5 NM | | Less than or equal to 0.03 % | C - 2.1.9 | 5.2.5 |
| Horizontal position | 5N_N-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m – 10 NM) | | Less than or equal to 0.3 second RMS for relative data age | C - 2.1.10 | 5.2.6 |
| Track velocity | 5N_N-R7 | RMS error | | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | C - 2.1.21 | 5.2.14 |
| Track velocity angle | 5N_N-R8 | RMS error | | Less than or equal to 10° for straight line and less than or equal to 25° for turn | C - 2.1.21 | 5.2.14 |
| System | 5N_N-R9 | Continuity (probability of critical failure) | | Less than or equal to 2.5 $10^{-5}$ per hour of operation | C - 2.1.24 | 5.2.17 |

**Table 8: Non-cooperative surveillance system requirements for supporting 5 NM horizontal separation (5N_N)**

## 3.7 3N_N: 3 NM horizontal separation provided by ATCO using non-cooperative surveillance system

The following sub-sections describe the Operational Services and Environment Definition (OSED) the required data items and associated performance requirements.

### 3.7.1 Operational Service and Environment Description (OSED)

The operational service is described in § 3.1.

The operational service can be provided to all aircraft provided they have the minimum physical characteristics (e.g. Radar Cross Section) that need to be locally defined in accordance with the specifications of the non cooperative surveillance system. The presence and the possible proximity of aircraft not meeting these minimum physical characteristics should be taken into account in the surveillance system safety assessment.

When a non-cooperative surveillance system is used in stand-alone the traffic environment is assumed to be low density. The local surveillance system safety assessment should define the limit in terms of quantity of traffic that can be managed with a non–cooperative surveillance system. This is locally defined taking into account the complexity of the airspace and the complexity of the environment.

### 3.7.2 Required data items

The following information elements are required from the surveillance system for the provision of surveillance separation. This list does not include flight plan elements.

The following data items shall be provided by the surveillance system under the form of message-structured and digitised information[2]:

Positional data:

- Horizontal (2D) position.

Surveillance data status:

- Coasted/not coasted;
- Time of applicability (for conformity assessment).

The provision of the above data items is compliant with Annex I § 1.1 of the draft SPI IR ([RD 32]) when using a non-cooperative surveillance system.

The following data items should be provided:

- Track velocity vector.

These data items are further described in Annex D - 1.

### 3.7.3 Mandatory and recommended performance requirements

A mapping of the performance requirements detailed in Table 10 on the quality of services described in sub-section 2.5 is provided in Table 9 below and additional justifications are provided in section 4.

| | **Availability** | **Continuity** | **Integrity** | | | **Time** | **Coherence** |
|---|---|---|---|---|---|---|---|
| | | | Core error | Correlated error | Spurious error | | |
| Horizontal position | R1/R2 | R3 | R4 | R5 | Note 1 | Note 2 | R6 |
| Track velocity | Note 3 | Note 4 | R7 & R8 | Note 5 | | Note 2 | - |
| System | Note 3 | R9 | - | - | - | - | - |

**Table 9: Mapping of performance metrics on quality of service characteristics**

<u>Note 1:</u> There is not yet an agree criteria for outlier criteria for horizontal position in case of non cooperative system.

<u>Note 2:</u> Impact of information latency is taken into account within error calculation method.

<u>Note 3:</u> Requirements are to be defined locally.

Note 4: Because of the way these data items are calculated, once started they will continue to be provided so continuity is 100% by design.

Note 5: No specifc requirement when supporting 3 or 5 NM horizontal separation, requirement likely to be needed when supporting safety nets.

These performance requirements are identical to the performance requirements specified for an cooperative surveillance system but are adapted to take account for the provided data items.

The following conventions are applied in the tables below:

- Mandatory performance requirements are in **bold font**
- Recommended performance requirements are in normal font

The 6th column "Ref./Justif." provides the corresponding paragraph of Annex C where further references and justifications can be found.

The last column "Conf. method" provides the corresponding sub-section of section 5 Conformity assessment.

Note 6: In principle the required probability of update of horizontal position should be the same for cooperative and non-cooperative surveillance system. However, because probability of update of horizontal position of non-cooperative surveillance sytem is a performance characteristic which depends on the environment conditions it is only recommended to apply the same performance specification for non-cooperative surveillance system as for cooperative one's. As matter of consistency the 90 % is being required as it is the usual required value for primary surveillance radars radars since 1997. In any case this performance characteristic will have to be confirmed by the system safety assessment.

| Data items | Req. # | Quality of service | Mandatory performance | Recommended performance | Ref. / Justif | Conf. method |
|---|---|---|---|---|---|---|
| Horizontal position | 3N_N-R1 | Update interval | **Less than or equal to 5 seconds** | Less than or equal to 4 seconds | **C - 2.2.1** / C - 2.2.2 | 5.2.1 |
| Horizontal position | 3N_N-R2 | Probability of update | **Greater than 90 % global** | Greater than or equal to 97 % per flight (see Note 6 above) | **C - 2.2.3** / C - 2.2.4 | 5.2.2.1 |
| Horizontal position | 3N_N-R3 | Ratio of missed 2D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | | **C - 2.2.5** | 5.2.3 |
| Horizontal position | 3N_N-R4 | RMS error | **Less than or equal to 300 metres** | Less than or equal to 210 metres | C - 2.2.6 / C - 2.2.7 | 5.2.4 |
| Horizontal position | 3N_N-R5 | Ratio of target reports involved in sets of 3 consecutive correlated errors larger than 555 m - 0.3 NM | | Less than or equal to 0.03 % | C - 2.2.9 | 5.2.5 |
| Horizontal position | 3N_N-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | | Less than or equal to 0.3 seconds RMS | C - 2.2.10 | 5.2.6 |
| Track velocity | 3N_N-R7 | RMS error | | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | C - 2.2.21 | 5.2.14 |
| Track velocity angle | 3N_N-R8 | RMS error | | Less than or equal to 10° for straight line and less than or equal to 25° for turn | C - 2.2.21 | 5.2.14 |
| System | 3N_N-R9 | Continuity (probability of critical failure) | | Less than or equal to 2.5 $10^{-5}$ per hour of operation | C - 2.2.24 | 5.2.17 |

**Table 10: Non-cooperative surveillance system requirements for supporting 3 NM horizontal separation (3N_N)**

# 4 JUSTIFICATIONS OF THE SPECIFIED PERFORMANCE METRICS

The following paragraphs explains, on the basis of the operational performance assessment scenarios defined in § 3.3, why the qualities of service specified in Table 3, Table 5, Table 7 and Table 9 have been selected.

Annex - H provides, on the basis of a modelisation of the horizontal position error, a top-down approach for justifying the choice of the following performance metrics:

- Update interval.
- Horizontal position RMS error.
- Probability of update of horizontal position.

It is also based on other performance characteristics that are not specified in this document (e.g. probability to have a second missed target report after a first one and the shape of the tail distribution of the horizontal position error) and on a number of parameters that are specified in Annex - H and further described in the documents [RD 48] and [RD 14].

## 4.1 Update interval

The provision of aircraft separation service is relying on the regular provision, at a given update interval, of surveillance information on the aircraft being separated. The update interval is not a performance requirement but is a technical parameter from which other performance requirements are derived (probability of update of data items).

The required values are copied from the EUROCONTROL Standard Document for Radar Surveillance in En-route Airspace and Major Terminal Areas (see document [RD 2]). They have also been retained for providing 3 and 5 NM separation in the context of the ADS-B RAD (see document [RD 42]) and ADS-B NRA (see document [RD 4]) applications and they have also been specified for WAM system (see document [RD 46]).

## 4.2 Probability of update of horizontal position

The provision of aircraft separation service is relying on the regular provision, at each update interval, of the horizontal position of the aircraft being horizontally separated. Therefore, for cooperative systems, a requirement has been defined for the probability of update of horizontal position of each flight. In addition, this requirement is supplemented with a requirement on the global (i.e. aggregation of all flights) probability of update of aircraft horizontal position.

As the vertical separation is provided in a procedural way there is no requirement on the probability of update of pressure altitude per flight, there is only a global requirement to ensure that the system is providing correct pressure altitude regularly.

For non-cooperative systems, for the time being, the requirement for the probability of update is defined globally. It is however recommended to apply a requirement per flight as for cooperative systems.

The following diagram (Figure 8) clearly shows that updated aircraft horizontal positions are needed to maintain aircraft horizontal separation in the case of the aircraft crossing scenario.

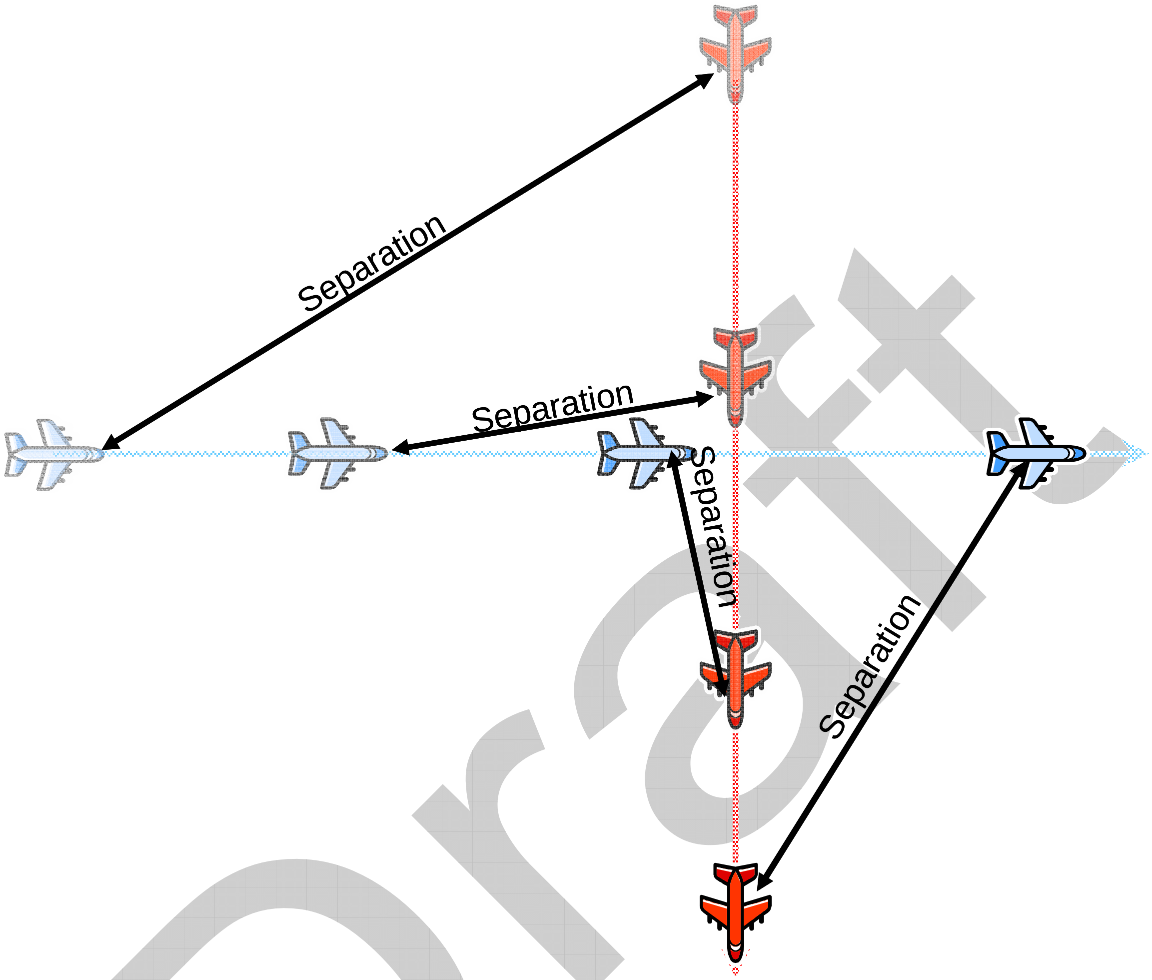


**Figure 8: Aircraft position probability of update**

The required value for the probability of update of horizontal position per flight for cooperative system is derived from the figure specified for horizontal position and pressure data items in [RD 42].

The required value for the global probability of update of horizontal position for non-cooperative system is derived from the figure specified for PSR horizontal position in [RD 2].

## 4.3 Ratio of missed reports involved in long gaps

Whilst some missed positions (in the horizontal dimension and/or in the vertical dimension) can be tolerated, it is considered that the missed positions must not be consecutive. Therefore a requirement has been defined on the ratio of missed target report involved in long gaps.

The diagram below (Figure 9) shows the impact of 3 consecutive missed target reports in the case of the aircraft crossing scenario.

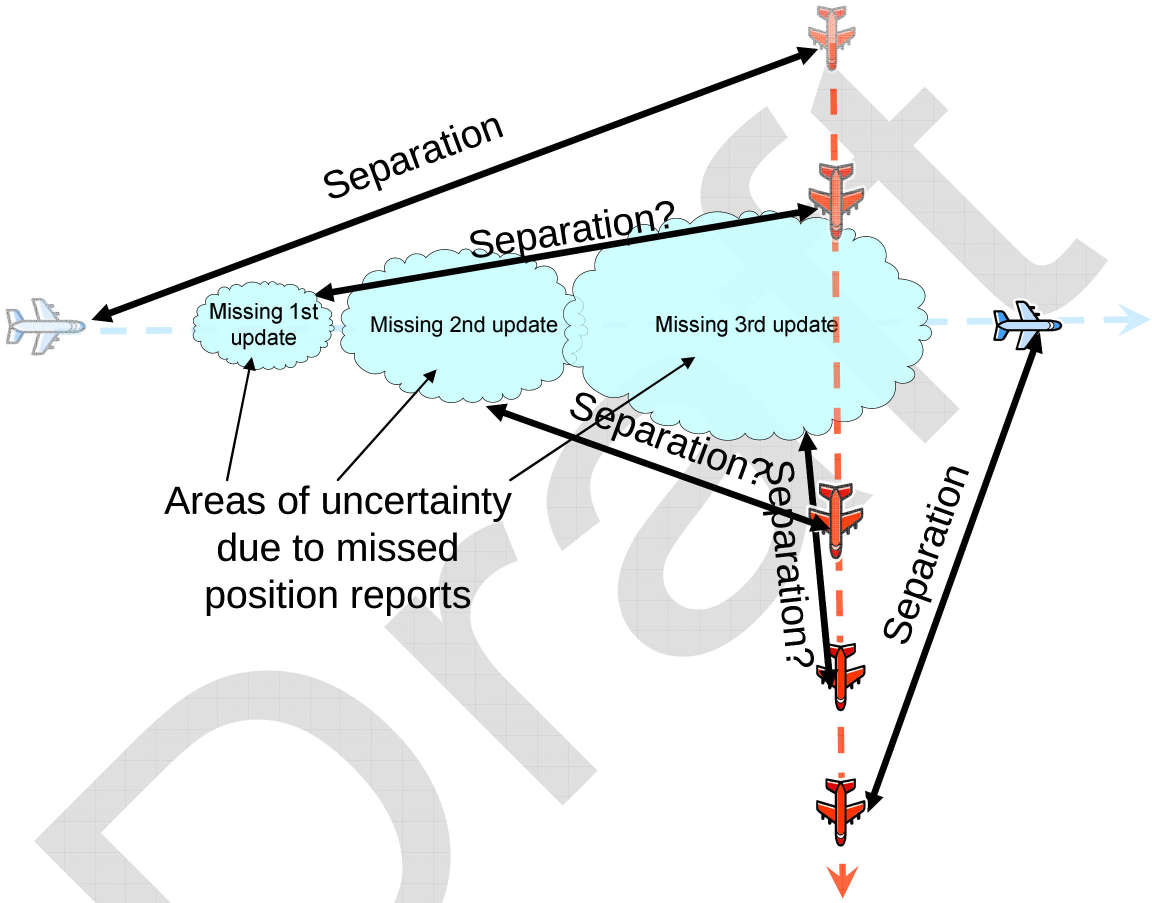


**Figure 9: 3 consecutive missed target reports in aircraft crossing scenario**

The required values have been discussed and agreed by the SSTF members on the basis of their experience.

## 4.4 RMS error of horizontal position

The provision of aircraft separation service is relying on the provision, at each update interval, of accurate positions of the aircraft being separated. Therefore a requirement has been defined for the position accuracy of aircraft at the time it is displayed. A threshold has been defined for global assessment (all target reports) and another threshold has been defined per flight (all target reports corresponding to the same flight. The threshold per flight is slightly greater (i.e. 10%) to take account for the limited number of samples that may increase the RMS assessment per flight compared to the global RMS assessment.

The following diagram (Figure 10) shows the impact of horizontal position accuracy on the horizontal separation service. The uncertainty of the horizontal position is represented by an ellips around the displayed position.

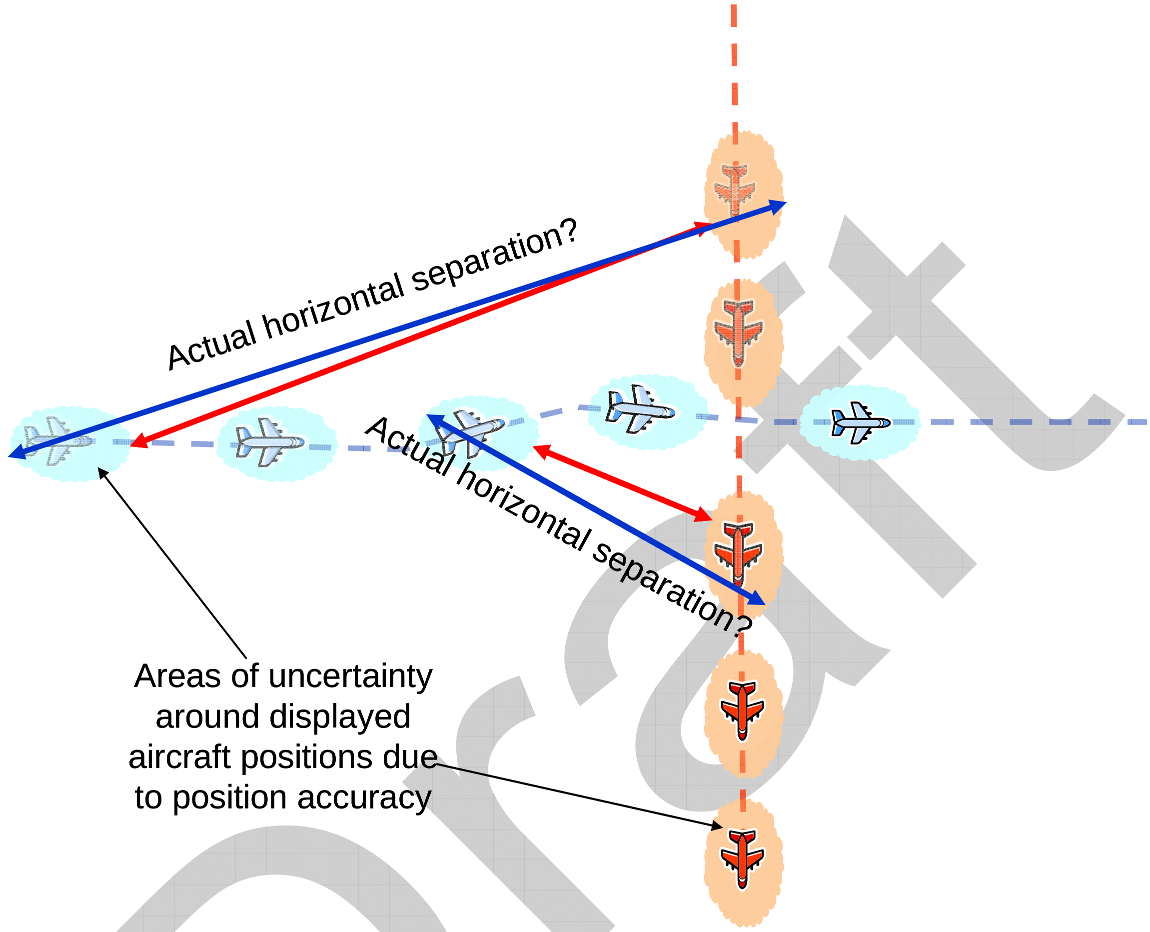


**Figure 10: Impact of position accuracy on separation (aircraft crossing scenario)**

The required global values are copied from the EUROCONTROL Standard Document for Radar Surveillance in En-route Airspace and Major Terminal Areas (see document [RD 2]).

## 4.5 Ratio of target reports involved in sets of consecutive correlated horizontal position errors

The provision of aircraft separation service is relying on the an extrapolation of the future situation by the air traffic controller. A set of consecutive correlated errors in the same direction may invalidate the predictions made by the controller. This can be illustrated on Figure 11 on the basis of the parallel route scenario. On this figure the displayed aircraft position are shown in bright color whereas the real aircraft positions of the blue aircraft are shown in shaded color.

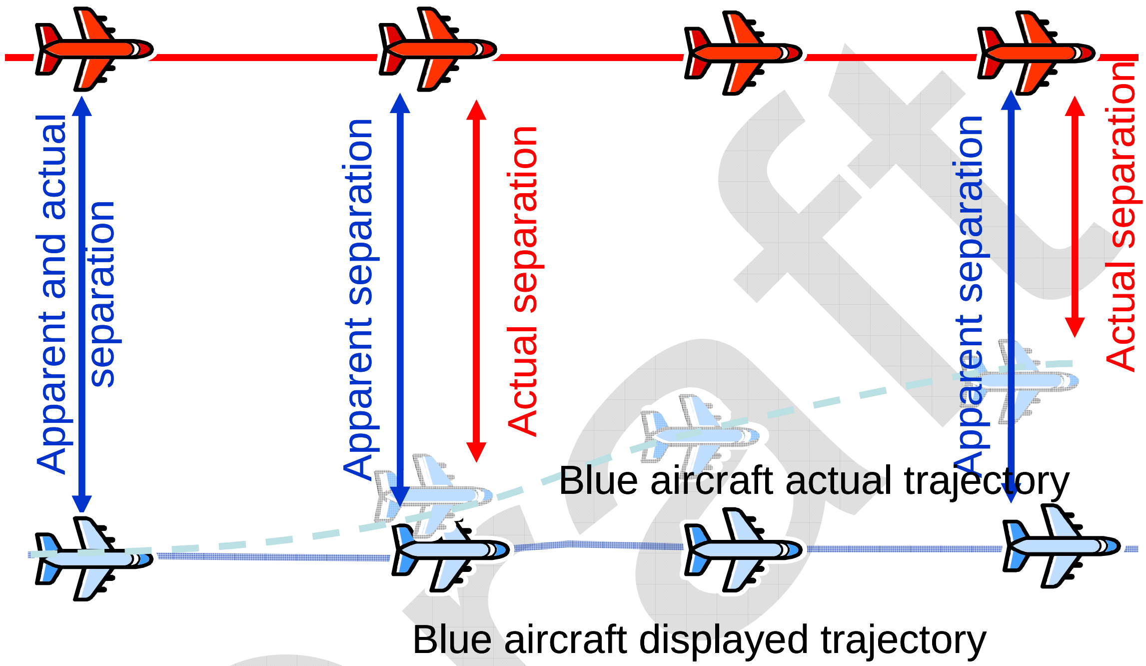


**Figure 11: Correlated error position in parallel route scenario**

In this case, after 3 correlated errors the controller will be convinced that the blue aircraft has kept its initial route whereas, in the reality, it is becoming closer to the red aircraft.

The required values have been derived from the figures specified for 3 and 5 NM separation applications in document [RD 12] for mono radar systems.

## 4.6 Relative time of applicability of close horizontal positions

There is already a requirement on the accuracy of the aircraft position at the time it is displayed nevertheless there is an additional uncertainty which is due to the fact that all aircraft positions are not applicable (e.g. calculated) at the same time. The contribution to the relative position error of this time difference between two aircraft being separated must therefore be limited.

This is illustrated on the basis of the crossing scenario on Figure 12 below where the blue aircraft position is calculated at $T_1$ and the red aircraft position is calculated a little bit later at $T_1 + \Delta T$.

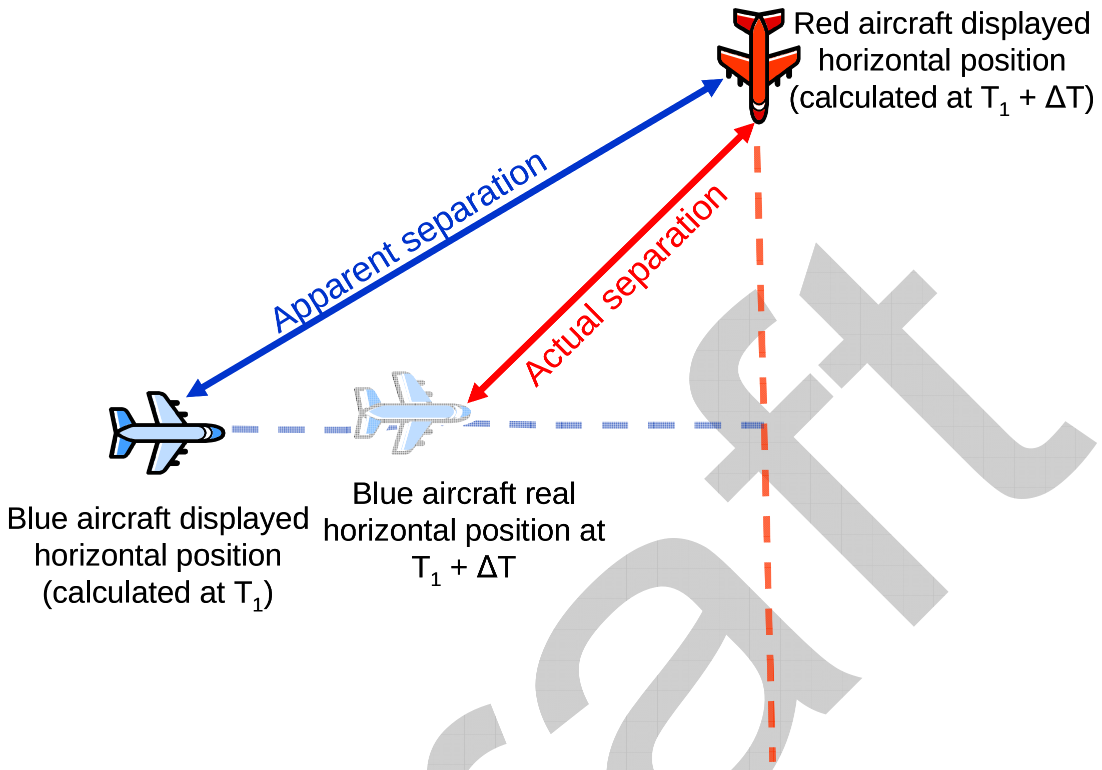


**Figure 12: Impact of relative time difference ΔT on crossing scenario**

The required values have been copied from the figures specified for 3 NM separation applications in document [RD 12]. The SSTF agreed to apply the same figure for 3 and 5 NM separation.

## 4.7 Data age and integrity of pressure altitude

### 4.7.1 Data age of pressure altitude

When the pressure altitude data item provided to the controller is the last valid pressure altitude that has been reported by the aircraft (either in response to an interrogation or through a spontaneous squitter message) it is important for the controller that this data item is provided as quickly as possible to reflect the reality. Therefore a requirement has been defined on the average and maximum data age of the pressure altitude.

The required values have been discussed and agreed by the SSTF members on the basis of their experience.

The diagram below (Figure 13) illustrates the impact of pressure data age on vertical separation.

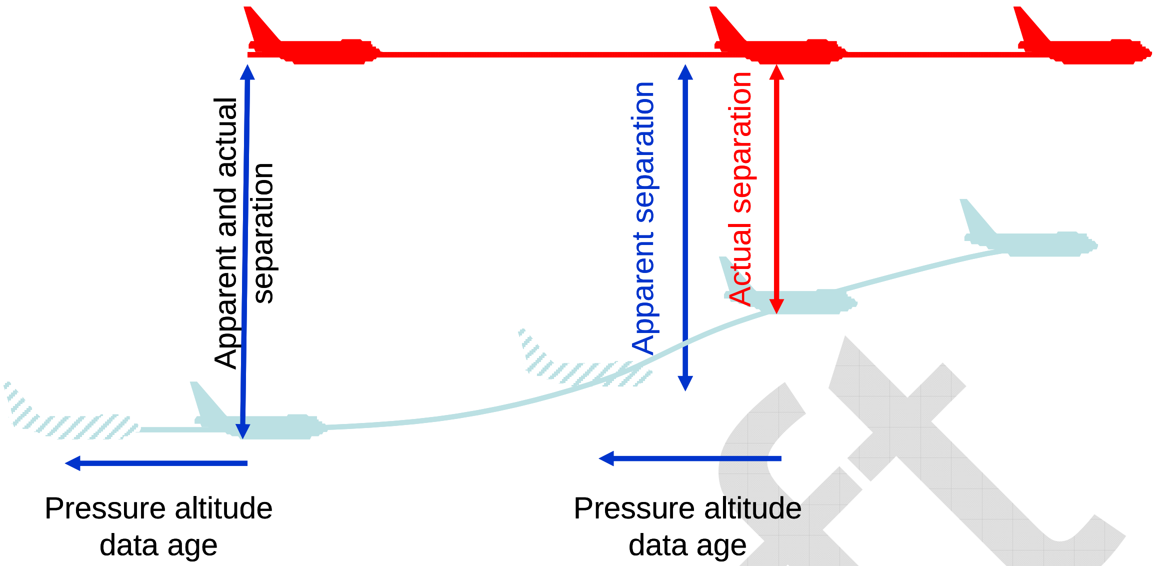


**Figure 13: Impact of pressure altitude data age on vertical separation**

### 4.7.2 Integrity of pressure altitude

In addition to what is stated in previous sub-section 4.7, it is also important to make sure that during the processing of the pressure altitude its value is not corrupted. Therefore a requirement has been defined on the maximum ratio of cases when this data item may be corrupted.

The required value has been derived from the figure specified for a single SSR in document [RD 2]. Single SSR is still used in Europe to provide 3 and 5 NM separation, either in pure stand-alone mode or integrated in a mosaic system.

The diagram below (Figure 14) illustrates the impact that one integrity issue on pressure altitude may have on vertical separation.

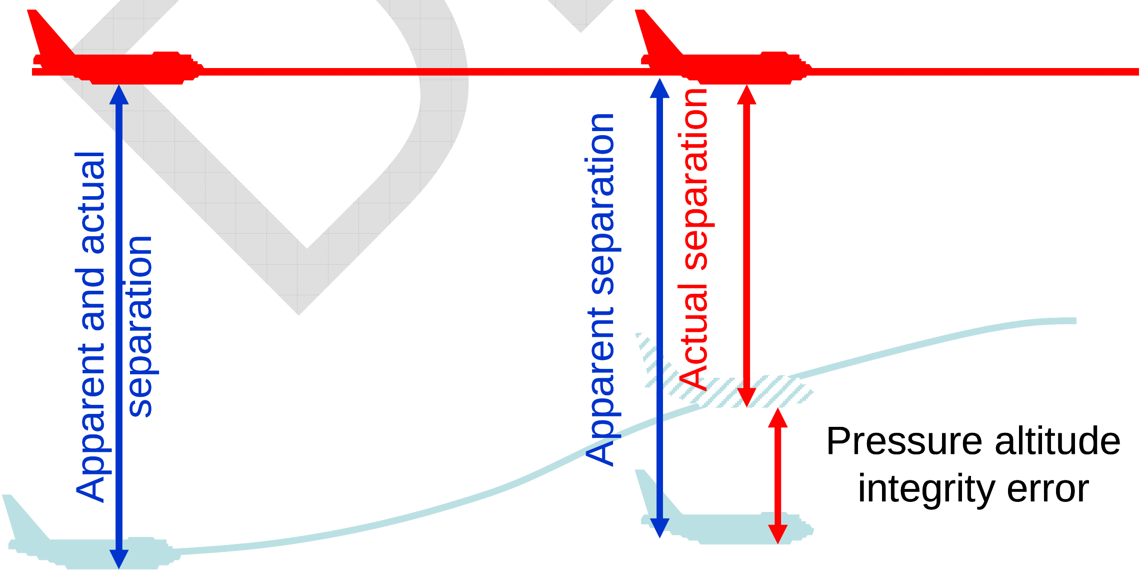


**Figure 14: Impact of pressure altitude integrity issue on vertical separation**

## 4.8 RMS error of pressure altitude

Alternatively to the approach described in section 4.7, the integrity of pressure altitude data item may be assessed on the basis of its accuracy (i.e. similarly as the horizontal position data item). Because the control is performed differently depending whether the aircraft is in vertical evolution or not, there are different criteria for each of the cases.

It is to be noted that this requirement may be applied even though the pressure altitude data item is just forwarded.

The required values have been discussed and agreed by the SSTF members on the basis of actual measurements made by an ANSP on their operational systems.

The diagram below (Figure 15) illustrates the impact that pressure altitude accuracy may have on vertical separation.

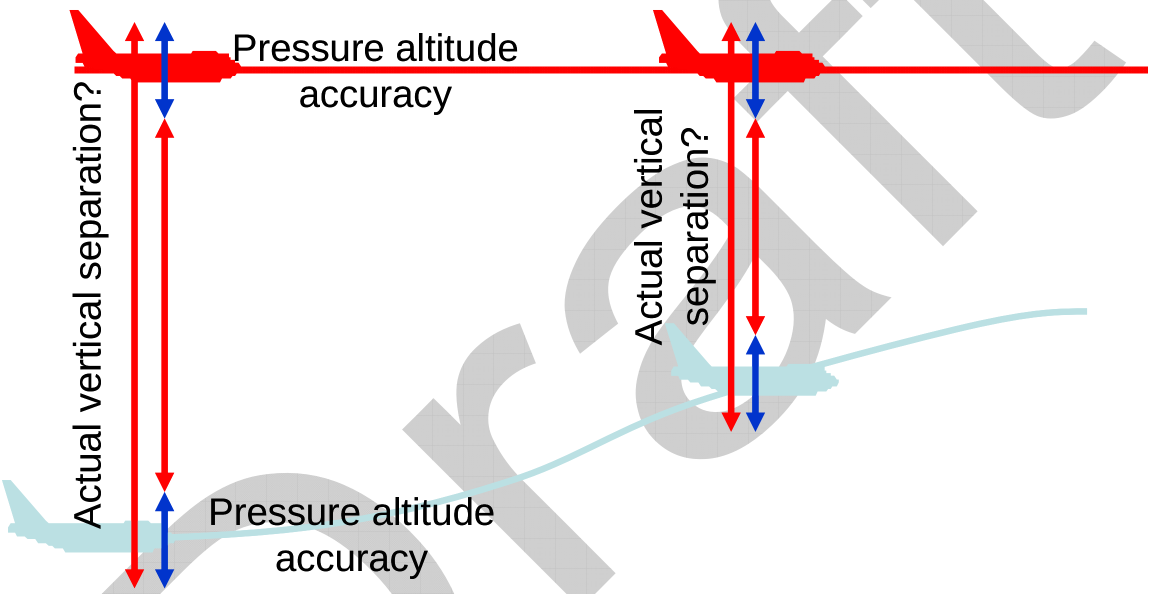


**Figure 15: Impact of pressure altitude accuracy on vertical separation**

## 4.9 Delay of transmission of SPI and emergency indicators

Because it is important for the controller to timely identify SPI and emergency indicators a performance has been defined for the delay to transmit this information from when it is set by the pilot on board the aircraft up to when it is displayed to the controller.

The required value have been discussed and agreed by the SSTF members on the basis of their experience.

## 4.10 Delay of transmission of change of aircraft identity

Because it is important for the controller to timely identify that the operational identity of an aircraft has changed a performance has been defined for the delay to transmit this information from when it is set by the pilot on board the aircraft up to when it is displayed to the controller. As the operational identification can be performed using the Mode A code or the “aircraft identification (ACID)”.

The required values have been discussed and agreed by the SSTF members on the basis of their experience.

## 4.11 Probability of update of correct aircraft identity

The provision of aircraft separation service is relying on the identification of the aircraft being separated. Therefore a requirement has been defined for the probability of update of aircraft identity of each aircraft. Preferably this quality of service should be defined per flight.

It is to be noted that this requirement on the probability of update of the aircraft identity data item is a requirement on the **provision** of the information at the output of the system and does not require the **extraction** from the aircraft at each update interval. Such extraction should only be performed when needed (i.e. when the aircraft notifies a change) and/or periodically but on a the basis of a longer period in order to limit, as far as possible, the occupancy of the 1090 MHz band.

The required value is copied from European Mode S station functional specification (see document [RD 19]). Mode S stations are used in Europe to provide 3 and 5 NM separation.

## 4.12 Integrity of aircraft identity

It is important to timely provide the aircraft identity to the controller when it has changed and it is also important to make sure that during the processing of the aircraft identity its value has not been corrupted. Therefore a requirement has been defined on the ratio of cases when this data item may be corrupted.

The required values have been derived from the figure specified for a single SSR in document [RD 2]. Single SSR is still used in Europe to provide 3 and 5 NM separation, either in pure stand-alone mode or integrated in a mosaic system.

## 4.13 RMS errors track velocity vector

The provision of aircraft velocity vector is recommended to support the provision of separation service. When providing separation between aircraft the intentions of both aircraft are important for the controller to be able to predict that no conflict will happen in the near future. This information can be provided indirectly to the controller under the form of the past aircraft horizontal positions but it is more and more often provided under the form of a velocity vector. In that case it is important to make sure that the quality of this information is good enough for the controller to perform separation. Preferably this quality of service should be defined per flight.

The required values have been discussed and agreed by the SSTF members on the basis of actual measurements made by an ANSP on their operational systems.

The following diagrams (Figure 16 and Figure 17) illustrate the impact that velocity vector (angle and/or amplitude) error may have on the prediction of future separation between aircraft in the case of the parallel route scenario and of the in-trail scenario.

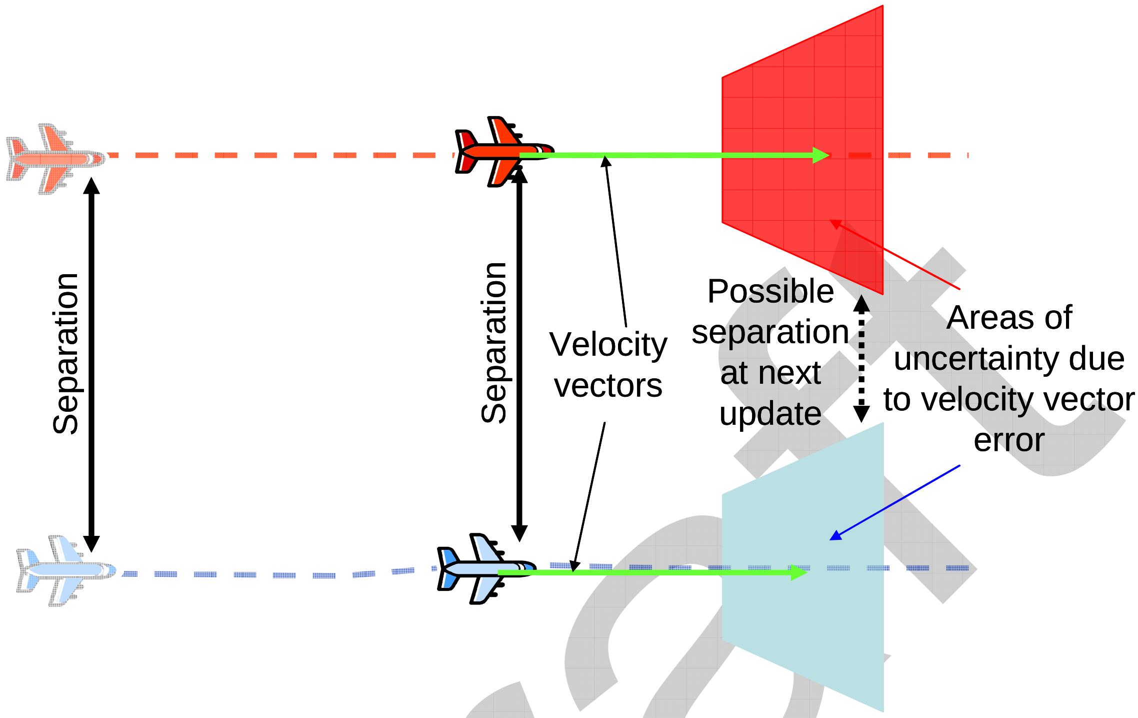


**Figure 16: Impact of velocity vector errors on separation prediction – parallel route scenario**

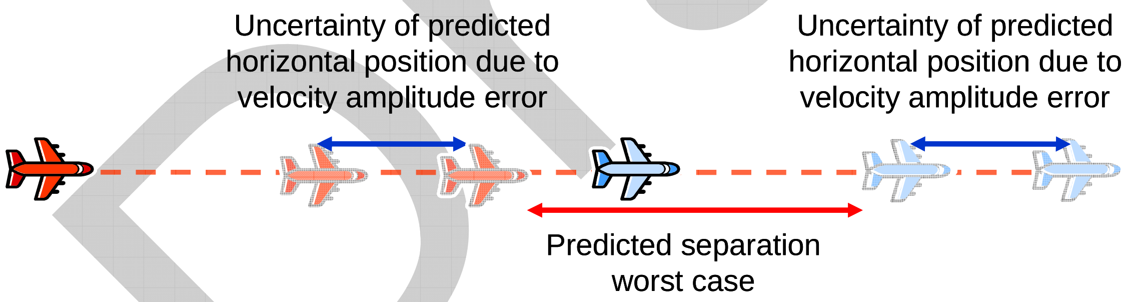


**Figure 17: Impact of velocitity vector amplitude error on separation prediction – in-trail scenario**

## 4.14 Density of uncorrelated false target reports

The provision of aircraft separation by controller requires a careful monitoring of the air situation picture, controller attention must not be disturbed by spurious events as false target reports, i.e. aircraft position reports that are displayed but which do not correspond to actual aircraft positions. In the EUROCONTROL Standard Document for Radar Surveillance in En-route Airspace and Major Terminal Areas the maximum allowable number of false target reports is specified as a maximum ratio over the total number of target reports. This approach was found not appropriate, from an operational point of view, as it allows more false target reports when there are more true target reports, i.e. when the air situation picture is complex.

In order to address this issue, EUROCONTROL sub-contracted a study (see [RD 40]) in 2007-2008 to derive the operational requirements into technical requirements applicable to the output of the surveillance system. One of the requirements proposed by this study is to limit, within an operational sector, the density (per hour) of uncorrelated false target reports being displayed. It order to further refine the requirement it was agreed that the usual size of a sector is 900 NM² (30 NM x 30 NM) and 100 NM² (10 NM x 10 NM) for respectively 5 and 3 NM separation.

The required values have been proposed in document [RD 40]. They were derived from brainstorming with operational staff and were then confirmed on the basis of basic operational scenarios.

## 4.15 Number of falsely confirmed tracks close to true tracks

The provision of aircraft separation by controller requires a careful monitoring of the air situation picture, the presence of an unexpected track in the vicinity of aircraft under control will generate an additional workload to the controller in order to determine whether the displayed track correspond to a true aircraft or not. In the EUROCONTROL Standard Document for Radar Surveillance in En-route Airspace and Major Terminal Areas the maximum allowable number of false target reports is specified as a maximum ratio over the total number of target reports. This approach was found not appropriate, from an operational point of view, as it does not make any difference between correlated false target reports that are critical and uncorrelated false target reports that are more a nuisance.

In order to address this issue, EUROCONTROL sub-contracted a study (see [RD 40]) in 2007-2008 to derive the operational requirements into technical requirements applicable to the output of the surveillance system. The other requirements proposed by this study to address this aspect is to limit the number of falsely confirmed track that are displayed close to true tracks. This is further illustrated on Figure 18 below on the basis of the crossing route scenario.

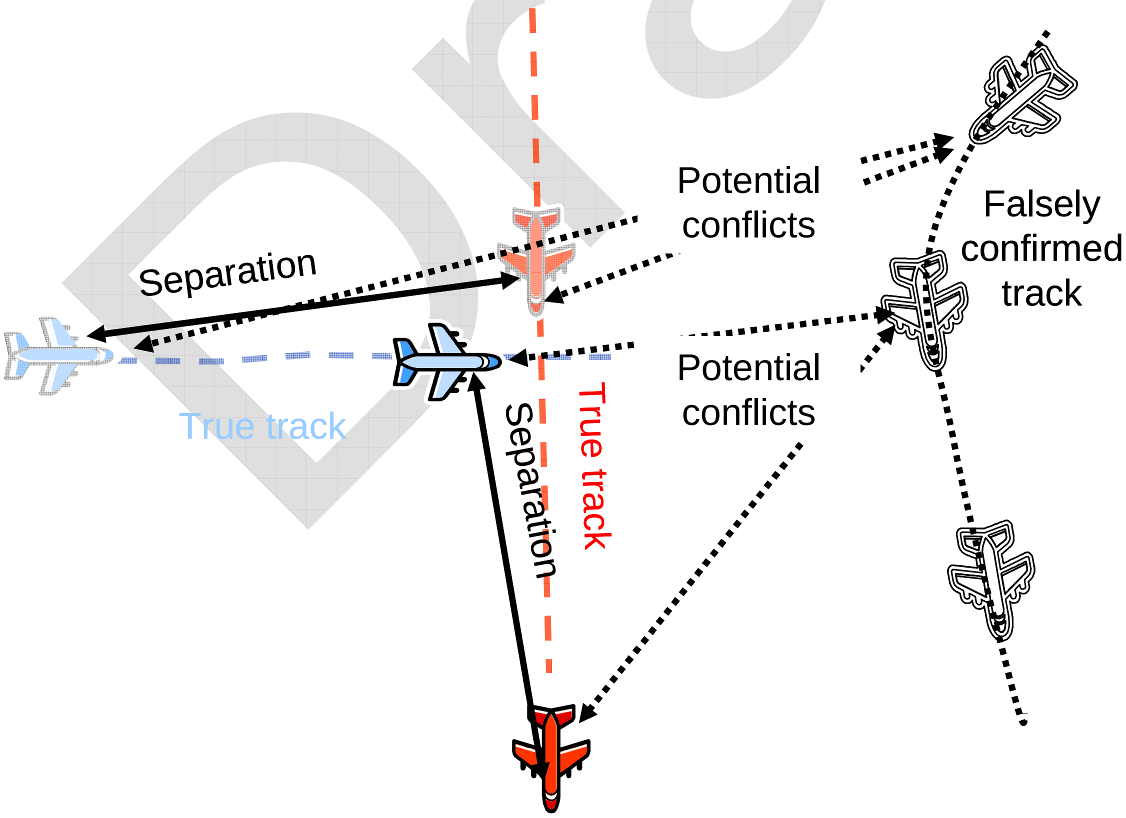


**Figure 18: Falsely confirmed track close to true track**

The required values have been proposed in document [RD 40]. They were derived from brainstorming with operational staff and were then confirmed on the basis of basic operational scenarios.

# 5 CONFORMITY ASSESSMENT

## 5.1 Generalities

### 5.1.1 Conformity assessment approaches

The conformity assessment of surveillance system can be undertaken on the basis of one or more of the five following approaches and in accordance with its associated priority:

- Opportunity traffic (priority 1),
- Flight trials (priority 2),
- Proof offered through system design files or by system design assurance (priority 3),
- Test transponder (priority 3),
- Injected test target (priority 3).

The priorities have been allocated on the basis of the operational relevance of each approach. The approach based on opportunity traffic has priority 1 as it is fully representative of the operational traffic and of the operational environment. The last 3 approaches are rather partially representative of the operational traffic and operational environment and have the lowest priority.

The conformity assessment of a surveillance system against the cooperative surveillance performance requirements shall be performed on the basis of cooperative and, if provided, combined target reports delivered by the system.

The conformity assessment of a surveillance system against the non-cooperative surveillance performance requirements shall be performed on the basis of non-cooperative target reports delivered by the system except for requirements R2 & R3 for which combined target reports, if provided, shall be taken into account as well.

As the OPA scenarios are defined for 2 aircraft, the performance requirements should be verified, where appropriate, on an aircraft per aircraft basis. Such an approach is considered necessary as the performance of cooperative surveillance systems is increasingly reliant upon the performance of the aircraft domain components.

It is to be noted that a statistical measurement uncertainty may be generated if a low number of data samples are used when performing the assessment of an individual aircraft. The application of an additional measurement margin or concession may be required to address such an eventuality.

### 5.1.2 Conformity assessment volume

The conformity assessment measurements shall be performed within the volume of airspace where the corresponding application/service is supported/provided and **limited to the aircraft to which the service is provided** (see Annex D - 4.1 for the identification of these aircraft with respect to airspace classes). This set of aircraft target reports is called the Conformity Assessment Volume (CAV).

A target report without pressure altitude or with a non-valid pressure altitude shall be assessed within or outside the CAV on the basis of its horizontal position only.

Some aircraft, although located within the CAV, may be excluded from the conformity assessment process:

- Aircraft to which the corresponding service is not provided based on individual aircraft or on specific temporary area (e.g. military exercise).
- Aircraft whose avionics exhibit a functional anomaly (with respect to applicable regulations), when assessing a cooperative surveillance system and if anomaly is confirmed by data analysis.

The aircraft to which the service is provided (IFR or VFR) can be identified taking into account the class of the airspace (see Annex D - 4.1 and Figure 34).

For example, when analyzing the performance to support the 3/5NM separation service, aircraft not expected to be in the controlled airspace (e.g. intruding non-equipped VFR) may be excluded of the conformity assessment process. The detection of intrusion within the controlled airspace is a separate application requiring a different level of performance.

Aircraft whose avionics exhibit a functional anomaly shall be analysed separately to verify that the assumptions of the system safety assessment remain valid. Such cases and their consequences (assessed or assumed) on the performance of the surveillance system shall be reported to the local safety monitoring process. Additionally, as foreseen in the draft SPI IR [RD 32] Article 3(4), ANSP will inform aircraft operators of any aircraft whose avionics exhibit a confirmed functional anomaly. Similar requirements are placed upon the aircraft operator to investigate and resolve anomalies identified in this manner.

In case of association of cooperative and non-cooperative surveillance systems to support the service, the cooperative and non-cooperative surveillance performance may be assessed in different CAV’s.

### 5.1.3 Conformity assessment datasets

Assuming an assessment is made periodically (as opposed to continuously) using opportunity traffic data, the performance requirements should be assessed on the basis of opportunity traffic datasets containing at least 50.000 position reports from the system under assessment obtained from flight trajectories for which the system has provided target reports during at least 50 update intervals.

This approach is valid for the majority of the requirements, however for requirements related to infrequent events (i.e. emergency indicator / SPI provision, change of aircraft identity) the statistic assessment will have to rely on a continous monitoring and to extend on a longer time period (e.g. one week or even longer).

### 5.1.4 Conformity assessment periodicity

The assessment shall be made periodically on each ground surveillance system and after each system or environment modification that may have an impact on its performance characteristics.

The periodicity of the conformity assessment is to be defined depending on the system design and the type of technology used.

When assessing the surveillance system performance on the basis of opportunity traffic, the system is only evaluated where there are flights. If airspace design modifications are to be implemented, a study will have to be undertaken to check that the system will still meet the required performance with the new traffic and specific flight trials may be needed.

#### 5.1.5 Definition

A valid data item means that the data item (e.g. horizontal position or pressure altitude) is provided to the user and can be used to perform the application. It could be that specially tagged data items (e.g. a coasted horizontal position) may not be allowed to be used to maintain separation, in that case the data item is considered as not "valid", although it has been delivered by the surveillance system.

The precise criteria, for deciding whether a data item is valid or not, are assumed to be defined locally in accordance with the local procedures.

On top of the local criteria, the following common criterion has been agreed for declaring valid an horizontal position data item:

> If an horizontal position data item presents an error greater or equal to the outlier criteria, it shall be considered as a non valid horizontal position data item and it shall be classified as a false target report.

The outlier criteria are:

- horizontal position error greater than 2100 m for 5 NM separation service.
- horizontal position error greater than 1690 m for 3 NM separation service.

The local criteria for declaring valid an horizontal position may be more stringent but cannot be less stringent.

Requirements on false target reports and false tracks implicitely limit the number of horizontal position outliers and therefore provide requirement on horizontal position error tail distribution.

Further justification on the definition of these thresholds are provided in Annex C - 2.1.8 and C - 2.2.8.

In addition it is recommended that cases of horizontal position outlier should be subject to an investigation to determine the causes and apply corrective and/or risk reduction measures.

#### 5.1.6 Specific events to be investigated

As a supplement to the conformity assessment procedure defined in the following paragraphs, it is recommended to investigate the following cases in order to determine the causes and apply corrective and/or risk reduction measures:

- horizontal position error above the outlier criteria,
- pressure altitude data item with a data age greater than the specified value,
- delay of a change in aircraft identity data item greater than the specified value,
- delay of a change in emergency indicator or special position indicator (SPI) greater than the specified value,
- falsely confirmed track close to true traffic.

### 5.2 Conformity assessment procedures and criteria

The following sections detail for each performance indicator how it shall be calculated.

**<u>Note on the assessment of the quality of pressure altitude data item</u>**

Two alternative requirement approaches are defined to address the performance of pressure altitude data item.

Within the first approach, which is only applicable to forwarded pressure altitude, the integrity and the latency of the pressure altitude are assessed independently (see § 5.2.7 & 5.2.8).

Within the second approach, which is applicable to both forwarded and calculated pressure altitude, the accuracy of the pressure altitude is assessed, which combines in a single performance indicator both the error due to integrity issue and the error due to latency (see § 5.2.9).

### 5.2.1 Update interval

The update interval is a technical parameter that is used to assess the probability of update of data items.

The periodicity of the surveillance system is not a performance but a design feature; therefore it is not assessed as such. The actual surveillance system update interval will be used to assess the probability of update of horizontal position, pressure altitude and aircraft identity data items (§ 5.2.2).

### 5.2.2 Data item(s) probability of update

#### *5.2.2.1 Horizontal position probability of update*

**Method**

In order to verify that a surveillance system achieves the required probability of update (PU) of horizontal position in accordance with the applicable update interval (UI), then the following measurement procedure shall be applied:

- Consider one flight reconstructed trajectory.
- Subdivide reconstructed trajectory into portions of time frames of length UI. The first valid position data-item is located in the middle of an UI. + resymchro
- Consider the trajectory portions that are entirely located within the CAV and count them ($N_T$).
- Count the number of these portions in which there is at least one valid horizontal position data item ($N_R$).
- Calculate the probability of update for a given flight (PU) as the ratio $N_R$ / $N_T$ (see Equation 1) if $N_T$ is greater than or equal to 100.
- Or calculate the probability of update for a given flight (PU) in accordance with Equation 2) if $N_T$ is smaller than 100.
- Or calculate the global probability of update (PU) as in Equation 3 where n is the number of flights.

$$PU = \frac{N_R}{N_T}$$ **Equation 1**

$$PU = 1 - \frac{N_T - N_R}{100}$$ **Equation 2**

$$PU = \frac{\sum_n N_R}{\sum_n N_T}$$ **Equation 3**

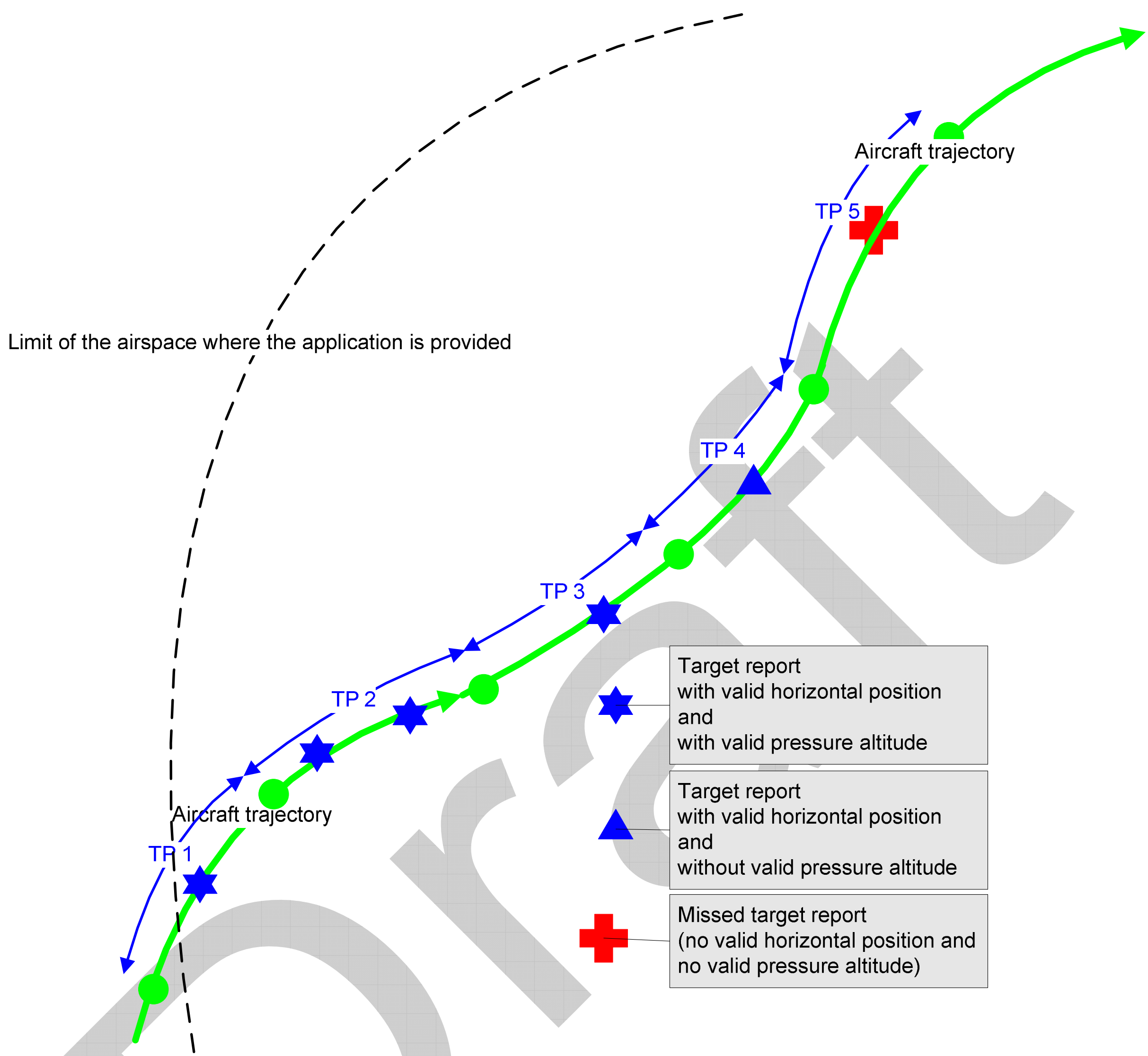


**Figure 19: Illustration of horizontal position probability of update calculation**

In the example provided in Figure 19 above and assuming that for the remaining of the flight there is at least one valid horizontal position data item in each of the other UIs and a total of 70 UIs then $N_T$ = 70 and $N_R$ = 69, therefore PU = 99% for that flight for the horizontal position.

Assuming there are 120 UIs for that flight then $N_T$ = 120 and $N_R$ = 119 and PU = 119/120 = 99,2 %.

**Population**

The verification of the horizontal position probability of update shall be performed for all flight trajectories; provided that the associated target reports have a valid horizontal position data item and have 3D position (horizontal position data item + pressure altitude data item) located in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Note**

This method does not allow detecting small areas where there is no detection or lack of detection. This issue could be addressed with a requirement for cellular calculation of update probability.

In order to make a calculation of the PU that is as less sensitive as possible to the possible variations of the actual update interval between consecutive target reports it is recommended to ensure that the first target report is time-located in the middle of the first UI, like it is shown on Figure 19.

#### *5.2.2.2 Correct and valid data item probability of update*

**Method**

In order to verify that a surveillance system achieves the required probability of update of correct and valid (PUCV) data items (pressure altitude or aircraft identity) in accordance with the actual surveillance system update interval (UI), then the following measurement procedure shall be applied:

- Consider one aircraft reconstructed trajectory.
- Subdivide reconstructed trajectory into portions of time frames of length UI. The first valid and correct information is located in the middle of an UI.
- Count the number of these portions in which there is at least one valid horizontal position data item ($N_R$).
- Count the number of these portions in which there is at least one valid and correct[3] data item ($N_C$).
- Calculate the probability of update for a given flight (PUCV) as the ratio $N_C$ / $N_R$ (see Equation 4) if $N_R$ is greater than or equal to 100.
- Or calculate the probability of update for a given flight (PUCV) in accordance with Equation 5) if $N_R$ is smaller than 100.
- Calculate the global probability of update of correct data item (PUCV) as in Equation 6 where n is the number of flights.

$$PUCV = \frac{N_C}{N_R}$$ **Equation 4**

$$PUCV = 1 - \frac{N_R - N_C}{100}$$ **Equation 5**

$$PUCV = \frac{\sum_n N_C}{\sum_n N_R}$$ **Equation 6**

[3] Correctness criteria for pressure altitude and aircraft identity are respectively defined in § 0 and § 0.

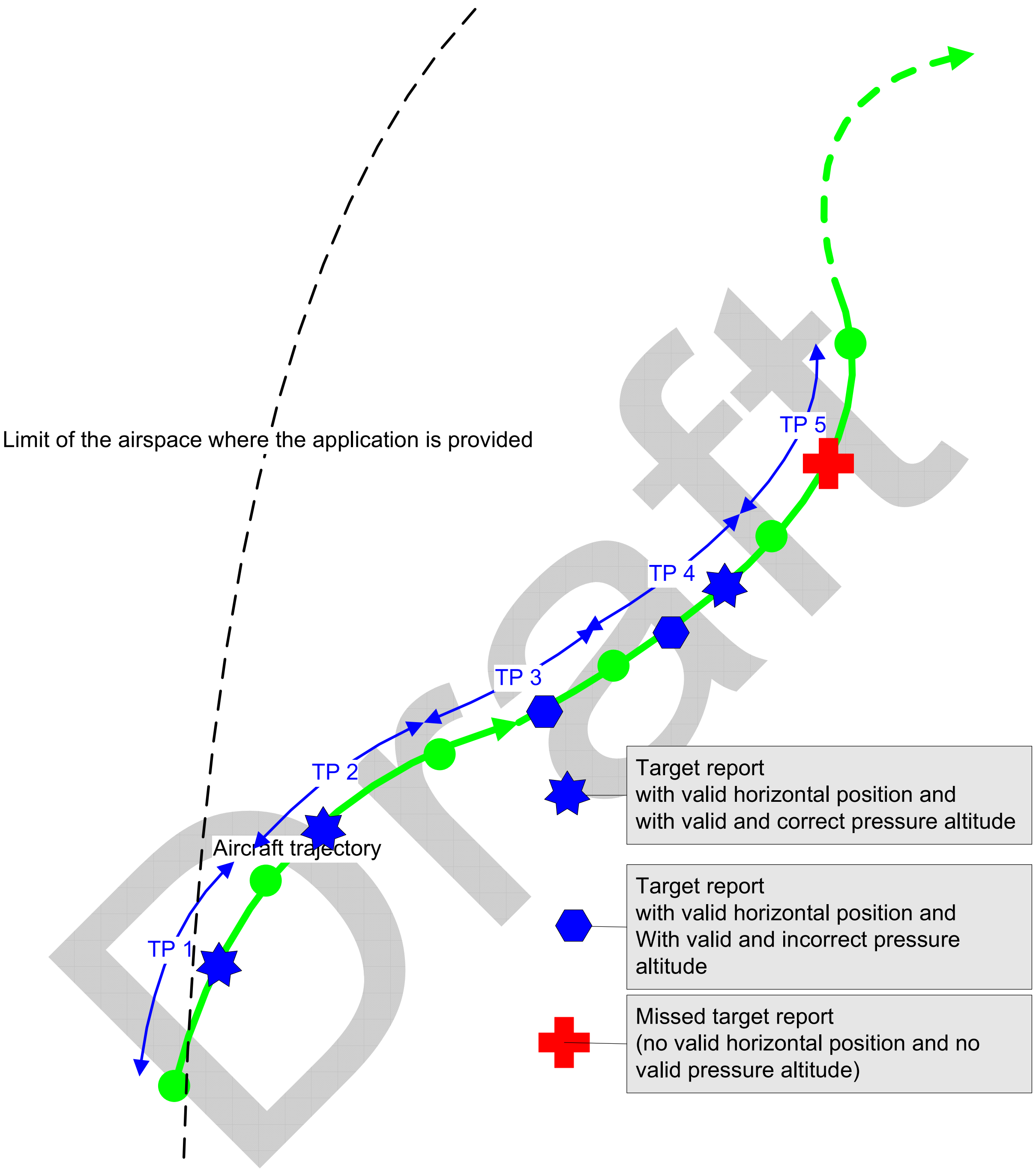


**Figure 20: Illustration of calculation of probability of update of correct pressure altitude**

In the example provided in Figure 20 above and assuming that for the remaining of the flight there is at least one valid pressure altitude data item in each of the other UIs and a total of 70 UIs then $N_T$ = 70, $N_R$ = 69 and $N_C$ = 68, therefore PUCV = 99% for that flight for the pressure altitude.

Assuming there are 120 UIs for that flight then $N_T$ = 120 and $N_R$ = 119, Nc = 118 and PUCV = 118/119 = 99,2 %.

**Population**

The verification of the horizontal position probability of update shall be performed globally for all aircraft trajectory; provided that the aircraft 3D position updates are valid and in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Note**

The requirement on the probability of update of the aircraft identity data item is a requirement on the provision of correct and valid information at the output of the system and does not require the extraction from the aircraft at each update interval. The rate of incorrect and valid and processing delay of these two data items are assessed through other requirements (see § 5.2.7, 5.2.8, 5.2.11 and 5.2.12)

In order to make a calculation of the PUCV that is as less sensitive as possible to the possible variations of the actual update interval between consecutive target reports it is recommended to ensure that the first target report is time-located in the middle of the first UI, like it is shown on Figure 20.

### 5.2.3 Ratio of missed 3D/2D position involved in long gaps

A gap is a portion of aircraft reference trajectory between 2 target report updates including full update of the position (i.e. with valid horizontal position and valid pressure altitude for cooperative surveillance system and with valid horizontal position for non-cooperative surveillance system). The size of the gap is the time difference between the first and the last target reports. If the gap is partially located outside the CAV, it shall not be taken into account.

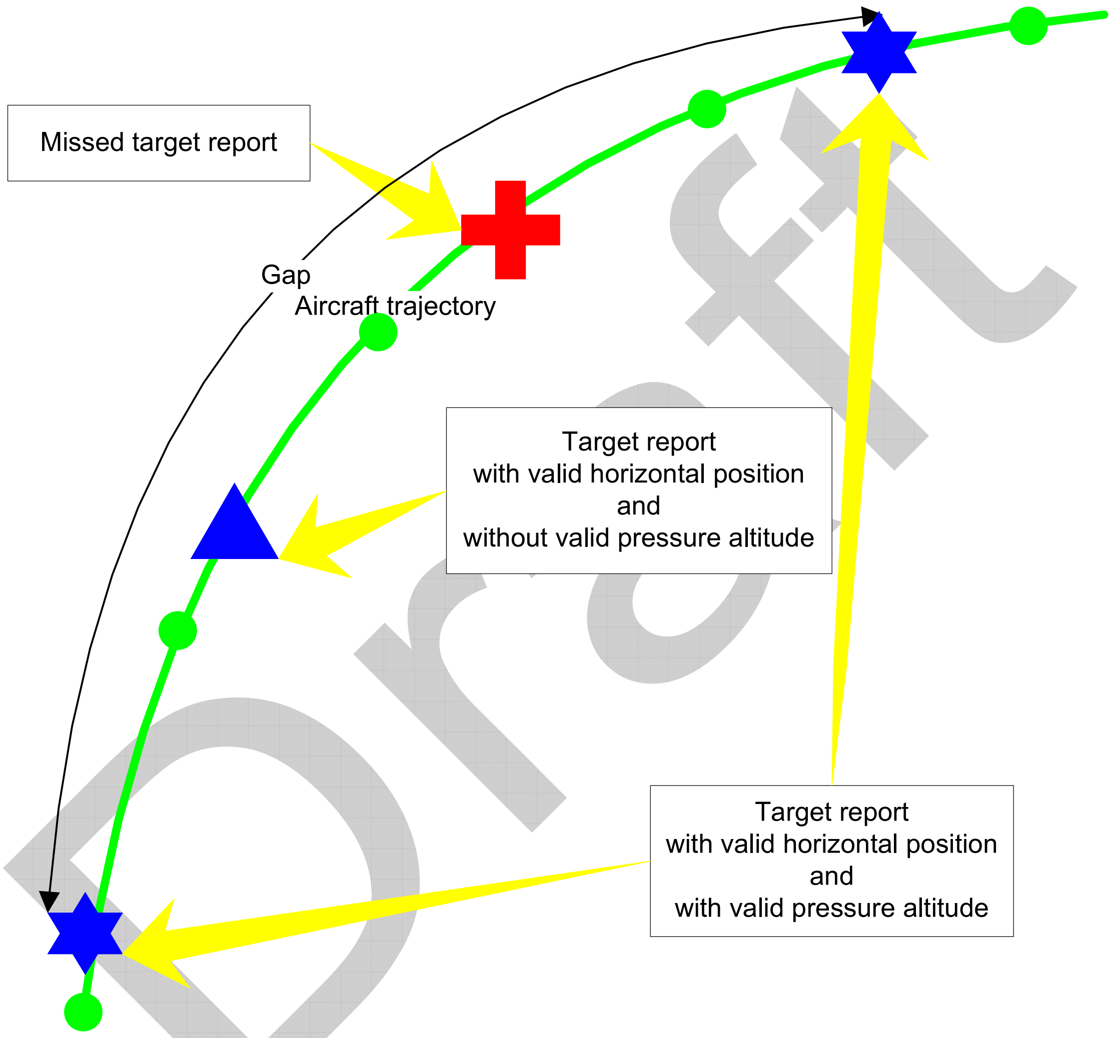


**Figure 21: Illustration of gap for cooperative system**

**Method**

Determine the gaps of a size ($G_S$) larger than 3 times the maximum update interval (8 s for 5 NM separation, 5 s for 3 NM separation) + 10% (i.e. long gap).

Count the number ($N_G$) of reconstructed/expected aircraft updates located in the CAV and included in these gaps. $N_G$ can be calculated as the integer value of $G_S$/UI where UI is the applicable system update interval.

Calculate $N_A$ as the sum of all the $N_T$ calculated for the update probability.

Calculate the long gap ratio as $R_G$ in accordance with Equation 7 where n is the number of flights and g the number of long gaps.

$$R_G = \frac{\sum_g N_G}{N_A = \sum_n N_T} \qquad \textbf{Equation 7}$$

This ratio does not depend on the applicable update interval of the system both $N_G$ and $N_A$ are proportional to 1/UI.

**Population**

This verification shall be performed for all trajectory reference updates within the CAV and all provided target reports within the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

### 5.2.4 RMS error of the horizontal position

The error on the provided horizontal position is the 2D Euclidian distance between the horizontal position provided by the surveillance system and the reference horizontal position of the corresponding aircraft at the time when the updated position was delivered/displayed (see Figure 22 above). This error takes into account any uncompensated latency between the time of applicability of the provided horizontal position and the time when the horizontal position was delivered to another system or displayed (i.e. delivered to the ATCO).

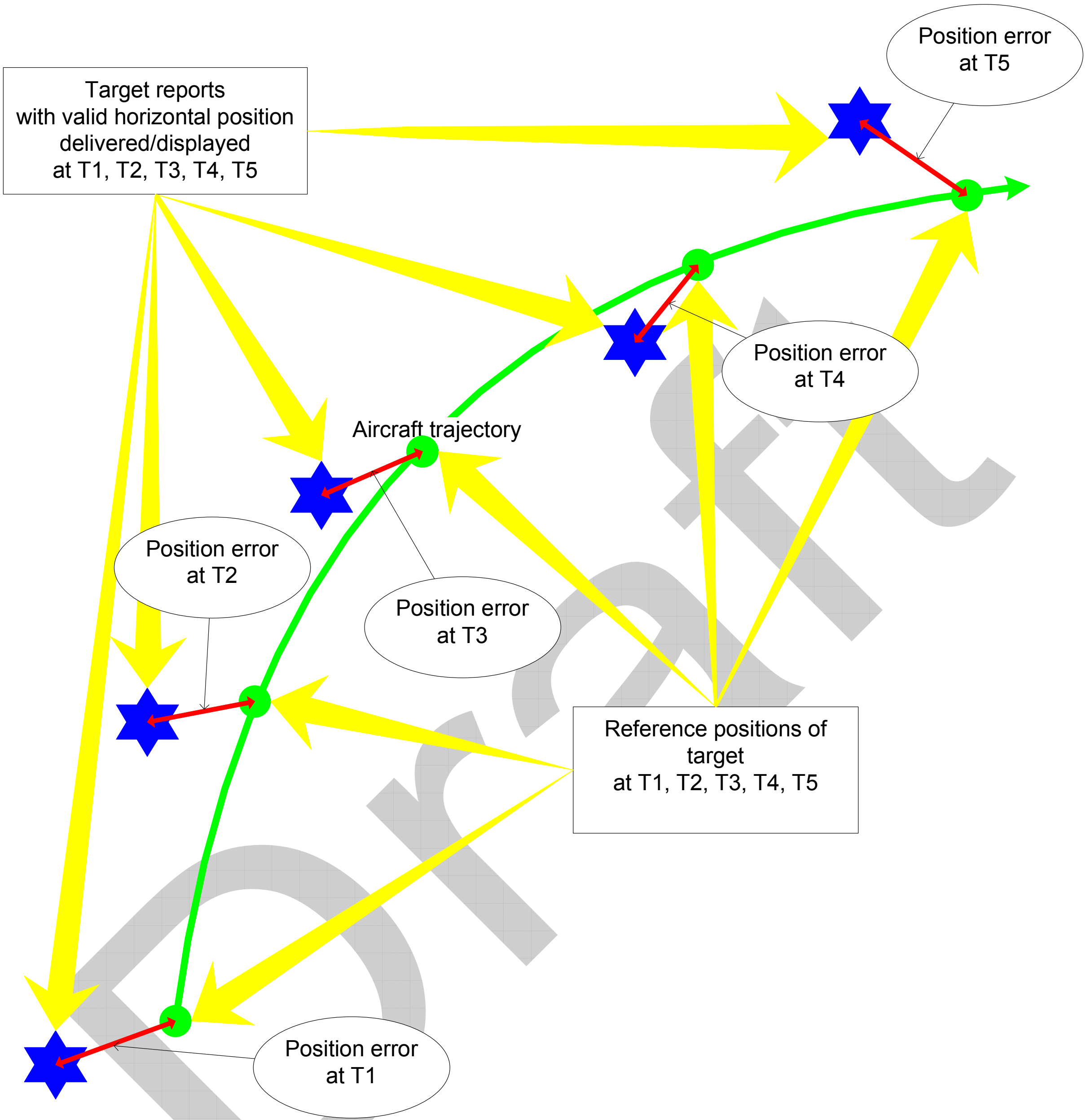


**Figure 22: Horizontal position error assessment**

The above method is independent of the time at which the information is used, which is in general not known. In case there is an intermediate sub-system in between the surveillance system output and the user (e.g. the HMI sub-system) an additional fixed delay may be considered to take account of the additional delay added by this sub-system, if the HMI simply display the provided position. If the HMI compensate for its own latency by extrapolating further the provided position, then the assessment shall be done on the basis of the position provided to the ATCO (i.e. the one displayed on his screen).

It is to be noted that the option of modelling the HMI sub-system as a fixed delay has limitations that will need careful consideration. A possible value of this fixed delay is the average HMI processing delay as defined on . This average delay can be measured independently or derived from the display sub-system design characteristics.

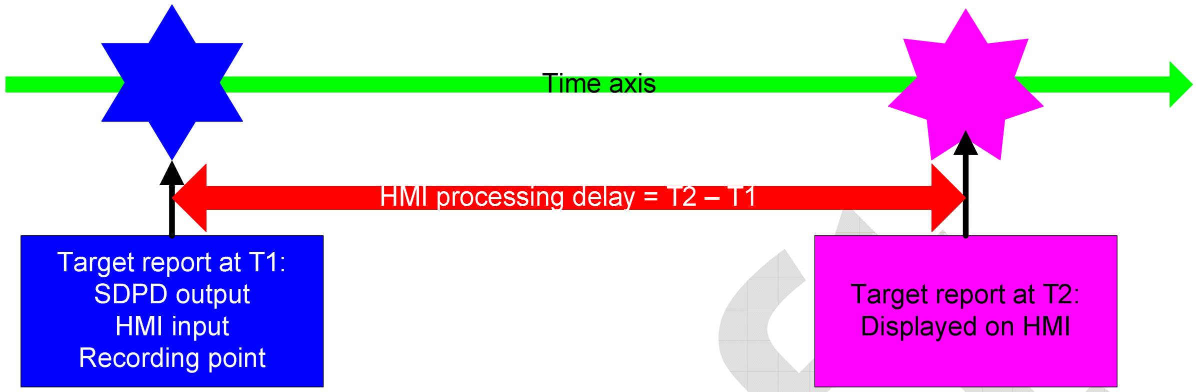


**Figure 23: HMI sub-system processing delay**

**Note**

The horizontal position error shall be calculated in accordance with the coordinate system in which the horizontal position is displayed to the ATCO. Should this calculation not being practically possible, an additional error budget should be taken into account when assessing this performance characteristic.

**Method**

The horizontal position error shall be calculated for each target report, then the RMS shall be calculated for all target reports corresponding to the same flight and/or for all target reports globally.

The Equation 8 below provides the definition of the RMS value of n samples $E_i$, in our case the horizontal position errors.

$$RMS = \sqrt{\frac{\sum_{1}^{n} E_i^2}{n}} \qquad \textbf{Equation 8}$$

**Population**

The verification of the horizontal position RMS error shall be performed for all valid horizontal position data items located in the CAV.

It is also required that this requirement is verified on a per flight basis, but with a different threshold. I.e. to make the RMS calculation on the basis of all the horizontal position data items of an individual flight. In Equation 8 n will be equal to the number of target reports corresponding to that particular flight.

### 5.2.5 Ratio of correlated horizontal position errors

The horizontal position error shall be calculated as specified in § 5.2.4 above.

A correlated position error is a series of at least 3 consecutive valid horizontal positions showing errors in the same direction and above the specified threshold.

For the specific purpose of this conformity assessment method any missed target report, either not delivered or declared invalid (e.g. presenting an horizontal error greater than the outlier criteria) will be considered to present the same horizontal position error as the previous valid target report from the same flight, provided it is followed by a target report with a valid horizontal position (i.e. lack of detections at the end of a flight will not be taken into account).

**Method**

Each horizontal position error vector shall be decomposed in an along (i.e. along the reference ground speed vector) position error component and an across (i.e. perpendicular to the reference ground speed vector) position error component.

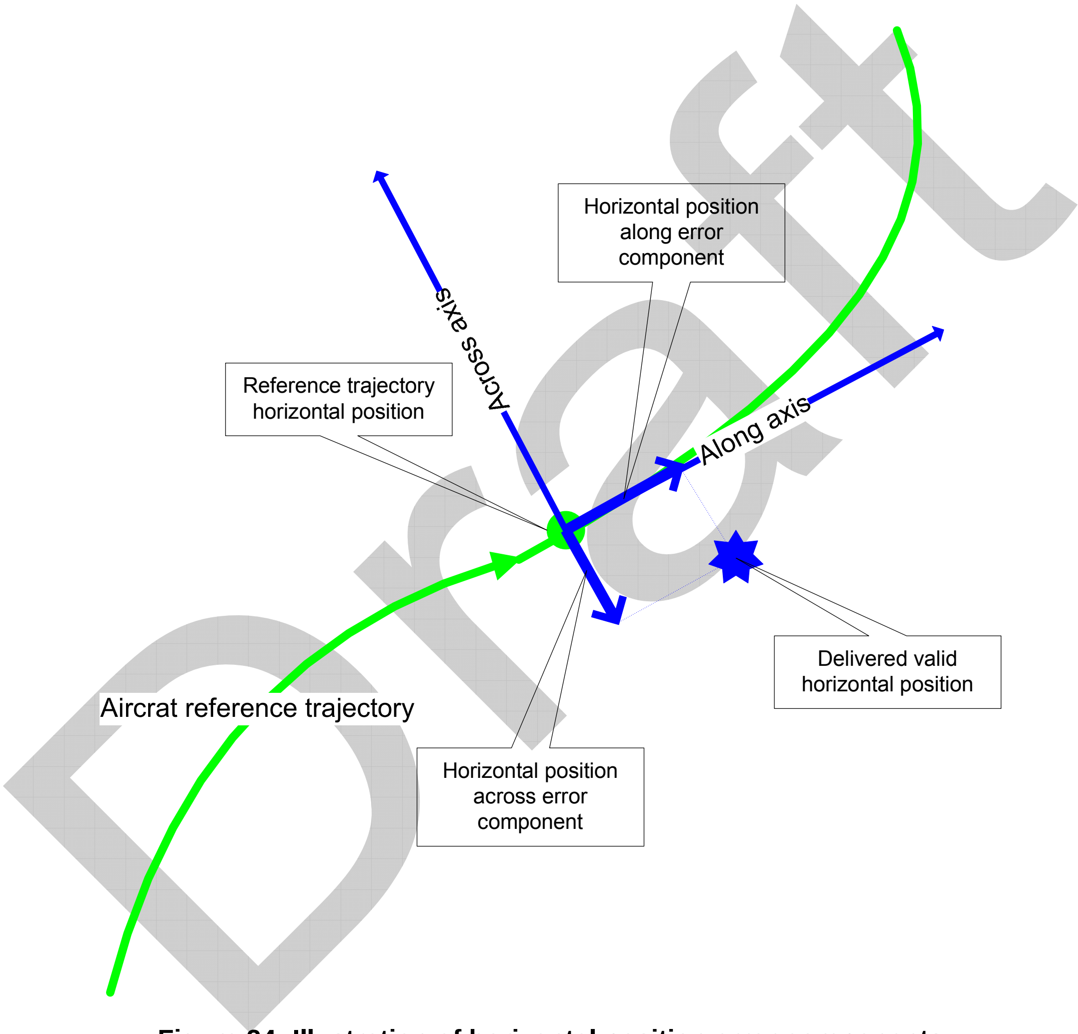


**Figure 24: Illustration of horizontal position error components**

Four (4) main directions shall be considered: positive across error, negative across error, positive along error, negative along error.

Identify sets of at least 3 consecutive errors in the same main direction greater than the specified value. Count the number of target reports involved in such scenario and divide it by the total number of target reports.

**Population**

The percentage shall be calculated for all target reports with valid horizontal position and located in the CAV.

**Note**

As this kind of event may be relatively rare, it could be difficult to collect a reasonable number of samples in dataset of opportunity traffic so as to get a reliable statistical figure.

### 5.2.6 RMS value of the relative time of applicability of target reports in close proximity

The time to be considered is the time of applicability (e.g. the time data item of the Asterix message).

**Method**

Identify pair of target reports that are close in horizontal position (less than 18520 m - 10 NM horizontally) and close in time (less than half the applicable update interval).

For each pair calculate the unsigned difference between times of applicability of the two target reports. Then calculate the RMS (see Equation 8) of these values.

**Population**

The calculation shall be performed for all relevant pairs of target reports located in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Note**

In case of rotating surveillance system the population may be limited to discard target reports located near the rotation axis.

### 5.2.7 Average and maximum data age of forwarded pressure altitude

**Method**

The age of forwarded pressure altitude shall be the time difference between when it was displayed and when it was time stamped by the receiving sensor (it is assumed that in the case of the pressure altitude data item the airborne latency and the transmission latency are negligible).

In case of a single sensor system, the age is the difference between the time of display and the pressure altitude time of applicability reported within the sensor target report.

In the case of a tracker, this age shall be derived from the time of display and from information provided by the tracker (e.g. MFL sub-field of data item I062/295 “Track Data Ages” and “Time of Track Information” data item I062/070 of Asterix category 062 for system track data ([RD 47])).

In both cases the average HMI sub-system processing delay (see § 5.2.4 above) shall be taken into account.

**Population**

The average and maximum shall be calculated for all target reports with valid pressure altitude located in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Important note**

Although the corresponding requirement for pressure altitude maximum data age is defined for 100 % of the cases, it is recognised that this transmission delay may, in very rare cases, be greater than the specified value. The occurrence of such events may not invalidate the performance of the surveillance system provided that they have been investigated and that appropriate mitigation and risk reduction measures have been defined to avoid/reduce their re-occurrence in the future.

### 5.2.8 Ratio of incorrect forwarded pressure altitude

**Definitions**

To determine correctness of the forwarded pressure altitude, the value at the output of the surveillance system shall be compared with the value provided by the aircraft at the input of the surveillance system from which the output value is derived.

This value is the altitude of the reference trajectory sampled at the time the target report was displayed minus the pressure altitude data age (as defined in § 5.2.7).

The tolerance being +/- 200 ft for aircraft located in airspace where VSM = 1000 ft and +/- 300 ft for aircraft located in airspace where VSM = 2000 ft.

**Method**

The percentage of valid and incorrect pressure altitude shall be calculated as the ratio between the number of target reports including a valid and incorrect (see definitions above) pressure altitude and the total number of target reports including a valid pressure altitude.

**Population**

The percentage shall be calculated for all target reports located in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Notes**

In case it is not possible to calculate pressure altitude date age, it will not be possible to perform the assessment of pressure altitude correctness.

The assessment of the correctness of pressure altitude does not take into account the time needed to process the information (i.e. its latency or data age); pressure altitude data age is assessed in accordance with a specific performance characteristic (see § 5.2.7 above).

Therefore this method does not apply to extrapolated/calculated pressure altitude. Should an extrapolated/calculated pressure altitude be provided, the requirement detailed in § 5.2.9 should be verified.

### 5.2.9 Unsigned error of pressure altitude

**Definitions**

This assessment can be performed for whatever type of pressure altitude (e.g. forwarded or calculated).

The error of pressure altitude shall be calculated in accordance with the principle applicable for horizontal position error (see 5.2.2 above).

**Method**

Unsigned pressure altitude error = |Displayed pressure altitude – Reference trajectory pressure altitude at the time it was displayed|

**Population**

The calculation shall be performed for all target reports corresponding to true aircraft, located in the CAV and with valid pressure altitude.

The percentage of cases within the containment value shall be calculated separately for stable flights and for climbing/descending flights.

Stable flight means with climbing/descending speed that is lower than or equal to 300 ft/mn.

Climbing/descending flight means with reference trajectory climbing/descending speed that is greater than or equal to 200 ft/mn and is lower than or equal to 8000 ft/mn.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Note**

There is some overlapping of target reports between stable flights and climbing/descending flights. This is deliberate because trajectory reconstruction of transition between stable and climbing/descending flights may be difficult; in any case the number of target reports belonging to the overlapping area is in general very small and would not influence the measurements.

### 5.2.10 Delay of change in emergency indicator / SPI report

**Definition**

The delay of forwarded emergency indicator / SPI report shall be calculated as the difference between the time when the new information is present on the display and the time when the emergency indicator / SPI report has been set on board the aircraft.

**Method**

On opportunity traffic it is not possible to measure the complete delay between the time at which the information has been set in the aircraft and the time at which the information is available at the output of the system.

This delay can be subdivided in 4 parts:

- The airborne delay due to the airborne equipment in between the pilot setting the information and the availability of the information for transmission by the transponder.
- The transmission delay in between the availability of the information for transmission by the transponder and the first actual transmission to the ground system.
- The RF delay due to the RF transmission.
- The ground delay in between the reception of the first transmission of the information and its output of the ground system.

The airborne delay can not be measured but may be estimated on the basis of the airborne equipment specifications.

The transmission delay will depend on the ground surveillance system design and the position of the aircraft with respect to the surveillance sensors and cannot be measured. It can be estimated using proof offered through system design files or by system design assurance.

The RF delay is assumed to be negligeable.

The ground delay can be measured on the basis of traffic of opportunity.

In order to overcome the above limitations, it could be also envisaged to use a test transponder or an injected test target to perform the verification.

Another option could be to measure the performance during flight trials.

In these 3 cases, the delay can be calculated accurately without any approximation.

**Population**

The calculation shall be performed for all events located in the CAV i.e. the aircraft reference trajectory portion in between the start and the end of the event is located in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Important note**

Although the corresponding requirement is defined for 100 % of the cases, it is recognised that his transmission delay may, in very rare cases, be greater than the specified value. The occurrence of such events may not invalidate the performance of the surveillance system provided that they have been investigated and that appropriate mitigation and risk reduction measures have been defined to avoid/reduce their re-occurrence in the future.

#### 5.2.11 Delay of change in aircraft identity

**Method**

The delay of change in aircraft identity shall be calculated as the difference between the time when the new aircraft identity data item is present and valid at the output of the surveillance system and the time when the new aircraft identity has been set on board the aircraft (the time taken by the pilot to input the new value is not to be taken into account). The entry of an aircraft into the CAV shall be considered as a change of the aircraft identity.

On opportunity traffic it is not possible to measure the complete delay between the time at which the information has been changed in the aircraft and the time at which the information is available at the output of the system.

This delay can be subdivided in 4 parts:

- The airborne delay due to the airborne equipment in between the pilot setting the information and the availability of the information for transmission by the transponder.
- The transmission delay in between the availability of the information for transmission by the transponder and the first actual transmission to the ground system.
- The RF delay due to the RF transmission.
- The ground delay in between the reception of the first transmission of the new information and its output of the ground system.

The airborne delay can not be measured but may be estimated on the basis of the airborne equipment specifications.

The transmission delay will depend on the ground surveillance system design and the position of the aircraft with respect to the surveillance sensors and cannot be measured. It can be estimated using proof offered through system design files or by system design assurance.

The RF delay is assumed to be negligeable.

The ground delay can be measured on the basis of traffic of opportunity.

In order to overcome the above limitations, it could be also envisaged to use a test transponder or an injected test target to perform the verification.

Another option could be to measure the performance during flight trials.

In these 3 cases, the delay can be calculated accurately without any approximation.

**Population**

The calculation shall be performed for all events located in the CAV i.e. the aircraft reference trajectory portion in between the start and the end of the event is located in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Note**

The reference assessment shall be performed on the specified data item, which is the aircraft identity reported by the aircraft and which is not to be confused with the aircraft identity reported by the Flight Data Processing System (FDPS). Further explanations are provided in Annex A - 2.

**Important note**

Although the corresponding requirement is defined for 100 % of the cases, it is recognised that his transmission delay may, in very rare cases, be greater than the specified value. The occurrence of such events may not invalidate the performance of the surveillance system provided that they have been investigated and that appropriate mitigation and risk reduction measures have been defined to avoid/reduce their re-occurrence in the future

### 5.2.12 Ratio of incorrect aircraft identity

Aircraft identity (Mode A code or Aircraft Identification) shall be considered correct if the provided value is matching (exactly no tolerance) one of the values of the reference trajectory within the last update interval.

The following Figure 25 and Figure 26 provide examples of correct and incorrect aircraft identity based on the method above.

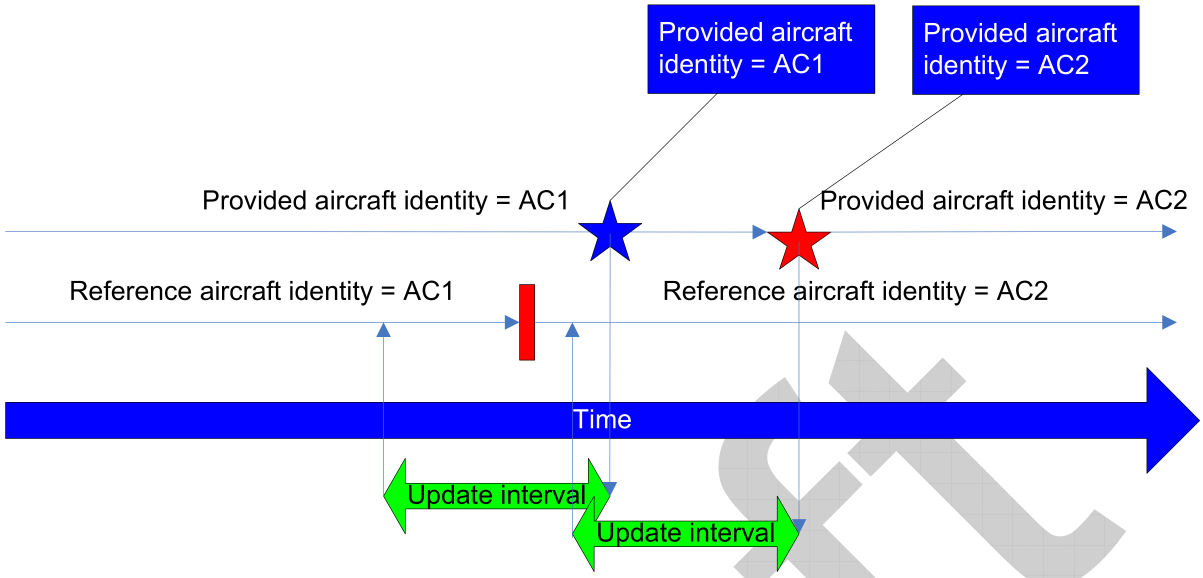


**Figure 25: Examples of correct aircraft identity**

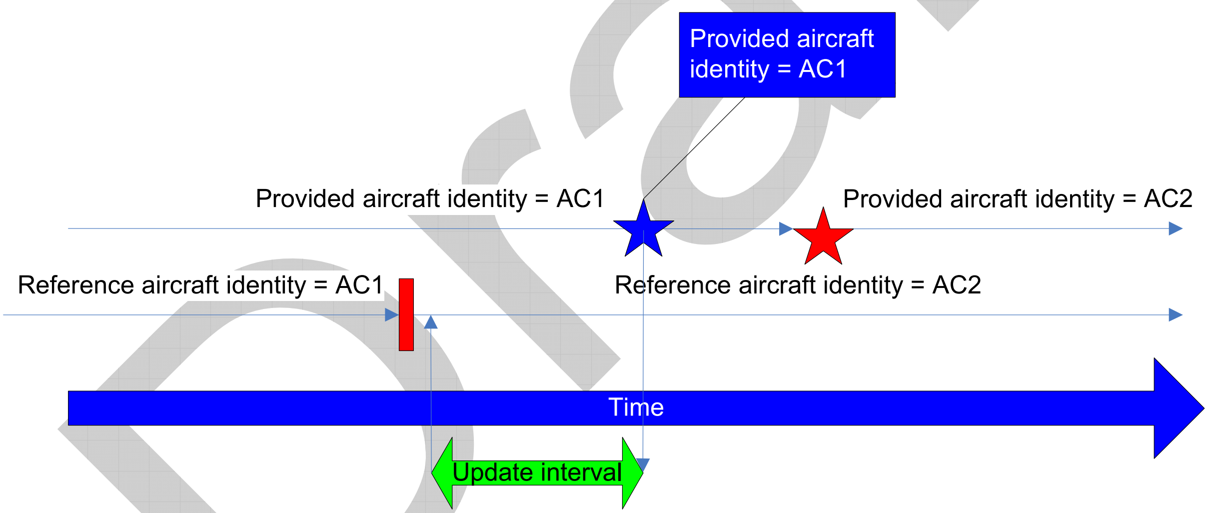


**Figure 26: Example of incorrect aircraft identity**

**Note**

The reference assessment shall be performed on the specified data item, which is the aircraft identity (Mode A code or Aircraft Identification) reported by the aircraft and which is not to be confused with the aircraft identity reported by the Flight Data Processing System (FDPS). Further explanations are provided in Annex A - 2.

### 5.2.13 RMS error of rate of climb/descent

This is applicable when rate of climb/descent data item is provided, when only the trend is provided there is not yet a conformity assessment procedure defined.

**Method**

The calculation of the reference aircraft rate of climb/descent will follow the same principle as for horizontal position error (§ 5.2.2). I.e. the provided value will be compared with the reference value at the time the target report including the rate of climb/descent data item was displayed.

For a target report, the rate of climb/descent error is the difference, in absolute value, between the reference aircraft rate of climb/descent (as defined above) and the aircraft rate of climb/descent provided in the target report.

**Population**

The calculation of the RMS (see Equation 8 above) values shall be performed separately for stable flights and for climbing/descending flights provided that the target report is located in the CAV.

The reference trajectory rate of climb/descent shall be used to determine if the flight is stable and/or climbing/descending.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

**Comment**

If the system is only providing a trend and not the actual value of the rate of climb/descent then a specific conformity assessment procedure will have to be defined.

### 5.2.14 RMS error of track velocity characteristics

This is applicable when track velocity data item is provided by the surveillance system.

**Method**

The calculation of the reference aircraft velocity amplitude and angle will follow the same principle as for horizontal position error (§ 5.2.2). I.e. the provided value will be compared with the reference value at the time the target report including track velocity data item was displayed.

For a target report, the track velocity error is the difference between the reference aircraft velocity amplitude (as defined above) and the aircraft velocity amplitude provided in the target report.

For a target report the track velocity angle error is the difference between the reference aircraft velocity angle (as defined above) and the aircraft velocity angle provided in the target report. The calculation of that error shall be performed in the system of coordinates in which the track velocity data item has been provided.

The portion of trajectories considered in this document are defined below:

- Straight line: reconstructed trajectory transversal acceleration is less than or equal to 1.5m/s².
- Turn: reconstructed trajectory transversal acceleration is greater than 1.5 m/s².

The table below provides the turn rate corresponding to 1.5 m/s² acceleration at different speeds.

| Speed (knots) | Turn rate (°/s) |
|---|---|
| 100 | 1,67 |
| 200 | 0,84 |
| 300 | 0,56 |
| 400 | 0,42 |
| 500 | 0,33 |
| 600 | 0,28 |
| 700 | 0,24 |
| 800 | 0,21 |
| 900 | 0,19 |
| 1000 | 0,17 |

**Table 11: Turn rate as a function of speed for an acceleration of 1.5 m/s²**

**Population**

The calculation of the RMS (see Equation 8 above) values shall be performed for target reports located on portion of trajectories corresponding to each criteria, located in the CAV and containing track velocity data item.

Target reports showing an horizontal position error larger than the outlier criteria shall not be considered.

### 5.2.15 Density of uncorrelated false target reports

**Definitions**

A false target report is either an outlier target report meeting the criteria defined in § 5.1.5 or a target report that does not correspond to the position of a true aircraft (no corresponding reference aircraft trajectory at this position and at that time) and that contains at least the following data items:

- Valid horizontal position,
- Aircraft identity (Mode A or Aircraft Identification),
- Time of applicability.

At this stage, the mechanism (e.g. reflection) providing the false target information is not addressed. It is to be noted that false target reports are not necessarily duplicate target reports. It may happen that, in case of reflections, the aircraft is not in radar line of sight whereas the reflected path is free of obstacle.

**Method**

Identify the false target reports.

For each false target report count, over a period of one hour, how many other false target reports are located in a circular area (900 $NM^2$ or 100 $NM^2$) centred on the initial false target report and in the CAV. The initial false target report shall be counted as well.

The maximum value is the performance indicator.

**Population**

The indicator assessment shall be performed for all false target reports located in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall be considered as false target reports.

### 5.2.16 Number of falsely confirmed tracks near to true tracks

**Definitions**

A falsely confirmed track is a time (during at least 16/10 seconds for respectively 5/3 NM separation) and space (maximum the horizontal outlier criteria) correlated set of at least 3 false target reports with the same aircraft identity. The identification of falsely confirmed tracks shall be performed independently of the tracking information that may be provided by the surveillance system. For that reason, these 3 false target reports may not necessarily belong to the same track as declared by the surveillance system.

**Method**

Identify the falsely confirmed tracks.

Once the falsely confirmed tracks are identified; then select those that are close to the true tracks (corresponding to a true aircraft trajectory) and count them per time frames of one hour.

To determine if a falsely confirmed track is closed to true tracks, the following process is proposed:

- Select a falsely confirmed track.
- Around each update of the falsely confirmed track open an analysis window of the specified distance and of +/- half the applicable update interval.
- Identify the true tracks that have at least one track update located within this window.
- Repeat the operation for each update of the falsely confirmed track.
- If a true track has been identified at the third stage for at least two updates, the falsely confirmed track is considered as close to that real track.
- Repeat the operation for each falsely confirmed track.
- Count, for each hour of operation, the number of falsely confirmed tracks that are close from at least one real track and record the start and end times of these falsely confirmed tracks.
- Falsely confirmed tracks are simultaneous if the time difference between the first update of the later track and the last update of the earlier false track is less than the applicable update interval.

**Population**

The indicator assessment shall be performed for all falsely confirmed tracks located in the CAV.

Target reports showing an horizontal position error larger than the outlier criteria shall be considered as false target reports, therefore they may contribute to the identification of falsely confirmed tracks.

### 5.2.17 Surveillance system continuity

The continuity of the surveillance system shall be verified by design and if sufficient data is available on the basis of operations. The definition of continuity is provided in Annex D - 2.4.

## 5.3 Common requirement for time reference

As the time is an essential element when exchanging, comparing or assessing data items provided by a surveillance system, it is required to define a common time reference.

Absolute time information within surveillance target reports shall be provided in UTC.

## 5.4 Conformity assessment framework

When developing conformity assessment methodology it is necessary to insure that an appropriate combination of test techniques is applied. Use of opportunity traffic and of dedicated flight trials is of particular value as they demonstrate system performance in the actual operational environment.

### 5.4.1 Conformity assessment framework based on opportunity traffic

Assessing opportunity traffic provides a relatively cheap means to access a potentially large data set exhibiting the ‘real life’ characteristics in the real environment that are beyond the most complex simulations. However, to utilise the data for a specific trajectory it is necessary to construct a reference against which comparisons can be made. There are test tools available which can be used for this purpose.

To permit an accurate assessment it is essential to ensure that the reference aircraft trajectories that are created in the analysis tool are of better quality than the trajectories that could be derived from the surveillance system outputs. This can be achieved as the construction of the reference trajectory can be conducted off-line and can thereby benefit by using information from future plot data.

An accurate assessment requires a sufficiently large data sample to reduce the impact of spurious data that could otherwise introduce statistical anomalies. The data sample used shall be of sufficient duration to examine all the characteristics of the surveillance system under assessment. It is recognised that to be able to assess some of the parameters identified in this document a significant amount of time and data recording would be required in order to obtain a statistically relevant assessment. To assess the parameters described in this document it is recommended that a minimum of 50 000 target reports from the system under assessment are used in the analysis. To assess some parameters through the use of opportunity traffic would need considerably larger data sets. The introduction of cheaper memory and improved processing has allowed many ANSPs assess data sets significantly larger than 50 000 reports. It is recognised that in areas of low traffic density additional tests using simulated data can be used to supplement the verification process.

All portions of flights belonging to the CAV shall be taken into account within the assessment. This is necessary to ensure that the Surveillance system is safe, ‘fit for purpose’ and capable of supporting the service. However if anomalies are noted, stemming from identified avionic failings or a lack of data arising from a valid exemption, then the anomalous data may be discounted from the scope of the performance assessment of the ground based surveillance system components if such events are covered by the system safety assessment. Similarly the CAV may vary with time. For example if there is a military exercise in a portion of the system coverage. In that case the CAV will be temporarily reduced or the aircraft involved will be filtered out.

A valid exemption is an exemption that has been granted by an NSA of one of the EUROCONTROL member states or on behalf of one of these NSA by a recognised and appropriate body (e.g. the European Commission).

When conducting an assessment based upon targets of opportunity it is recommended that:

- The conformity assessment process shall remove possible side effects due to the limited duration of datasets (at the beginning and at the end).
- The conformity assessment process shall remove possible side effects due to analysing data at the boundary edges of the CAV (e.g. performing the trajectory reconstruction over a larger volume than the CAV).

It is advised that data is recorded at various points in the system to permit traceability of cause of anomalies.

### 5.4.2 Conformity assessment framework based on flight trials

Flight trials are normally conducted to address the performance of a specific sensor and its input into the existing surveillance infrastructure rather than a test of an entire multi-sensor surveillance system. Their extensive use is limited due to their high cost.

An objective of the flight trials is to check the performance of the system:

- in specific volume of airspace (e.g. areas of low traffic density);
- against specific aircraft characteristics (e.g. transponder power, radar cross section);
- to establish a repeatable baseline.

The objective of a flight trial is to validate the performance simulations particularly in areas where difficulties are predicted.

The route flown by the trials aircraft is chosen to probe specific points of weak coverage at various heights and locations within the CAV. It should be noted that these may not only be at extremes of instrumented range. Flights over or near wind farms and motorways can also provide an ANSP with an improved appreciation of the impact such environments could introduce to surveillance operations.

The trials should be designed to address the specific characteristics of the surveillance sensors under test. A different approach to flight trial design may be necessary when testing a Mode S SSR type of system compared with a WAM system.

The flight trials should be designed to address the case when the aircraft presents the worse but still compliant characteristics, e.g. smallest radar cross section (RCS) in case or primary radar, lowest transponder transmitter power output, least transponder receiver sensitivity.

Flight trials aircraft may be equipped with an accurate position recording device to permit a comparison of the surveillance data with the trajectory actually flown.

Flight trials may be used to prove performance when the system is configured to replicate failure conditions e.g. if a WAM receiver is unserviceable. Such an approach can confirm the impact of a degraded mode of operation.

Further information, mostly concerning radar systems but that can be generalised to surveillance system in general, can be found in document [RD 45] and its Appendix A and in particular about the different combinations of transponder transmitter output power and transponder receiver sensitivity.

### 5.4.3 Conformity assessment framework based on proof offered through system design files or by system design assurance

The use of design files may be appropriate where demonstration of parameters is either difficult, expensive or if it is destructive. Design files may also be considered if the aspect has being tested before and no significant changes have been introduced.

Design files may also be assembled using previous tests based on injected test targets – E.g. simulations conducted using large Monte Carlo runs or software loading may not change from one configuration to another.

### 5.4.4 Conformity assessment framework based on test transponder

Cooperative surveillance systems often utilize remote static mounted transponders to support the Built in test equipment and may also be used to provide the Air Traffic Controller with a visual confidence check regarding the performance of the system. Similar techniques exist for non cooperative surveillance systems.

Whilst the support offered by simple remote transponders is very limited an ‘intelligent’ remote transponder may provide a more comprehensive yet non-intrusive means of verifying certain performance characteristics, such as the time taken to recognise a change of the Mode A code within the system, without the need to take an operational system off line.

### 5.4.5 Conformity assessment framework based on injected test target

Within surveillance sensors a self generated test target is often used to support Built In Test (BIT) assessments to provide a general indication of the ‘health’ of the system and to ensure that the system is operating as required. This aspect of conformity assessment does not include the use of BIT signals but refers to injected test targets and similar signals that are generated by laboratory equipment that is not an integral part of the surveillance sensor. It is typically referring to tests conducted by the manufacturer to demonstrate system performance against specific requirements.

The benefit of an injected test target is that it permits detailed and specific tests to be conducted relatively cheaply and consistently. This approach can be of particular use in proving load testing (peak and average) or performance against complex scenarios that are not possible for cost and/or safety reasons to be proven through flight trials.

The use of detailed software controlled scenarios allows for the introduction of slight variations to established test configurations. It also permits the introduction of a parameter change at a specific point in time with the subsequent assessment of how long the system takes to reflect the change. Through such an approach it can also be used to optimize system performance.

Test targets are typically injected at the RF front end of the system however they may also be injected at opportune points within the system chain where they can be used to assess in detail the performance of a specific element of a surveillance sub-system.

As the antenna and several other front end components are ‘by-passed’ or simulated, such testing may not reflect real life site effects nor exercise the entire surveillance chain. However, with that limitation established, the use of an injected test target provides a comprehensive method of conducting a detailed performance assessment of numerous system characteristics that it would not be possible to test in any other way.

Such testing, which is to be conducted using appropriately calibrated test equipment, is to be considered as supplementary testing and whilst acceptable for specific aspects of performance it is insufficient for determining actual total system performance achieved on site.

# ANNEX - A SURVEILLANCE SYSTEM FUNCTION AND SCOPE

## A - 1 Surveillance system function

The function of an ATM Surveillance System is to provide to local users information on remote aircraft located within its responsibility domain including:

- Aircraft position (i.e. Horizontal and altitude), i.e. where it is;
- Aircraft identity (including SPI and emergency state), i.e. who it is;
- Aircraft short term intentions (i.e. horizontal and vertical velocity); where it will be.

These 3 sets of data items are linked together by the time parameter.

All these data items are regrouped under the term surveillance information.

This surveillance information is used to provide air traffic services (e.g. horizontal separation) and/or to perform ATC functions (e.g. safety nets).

## A - 2 Surveillance system scope

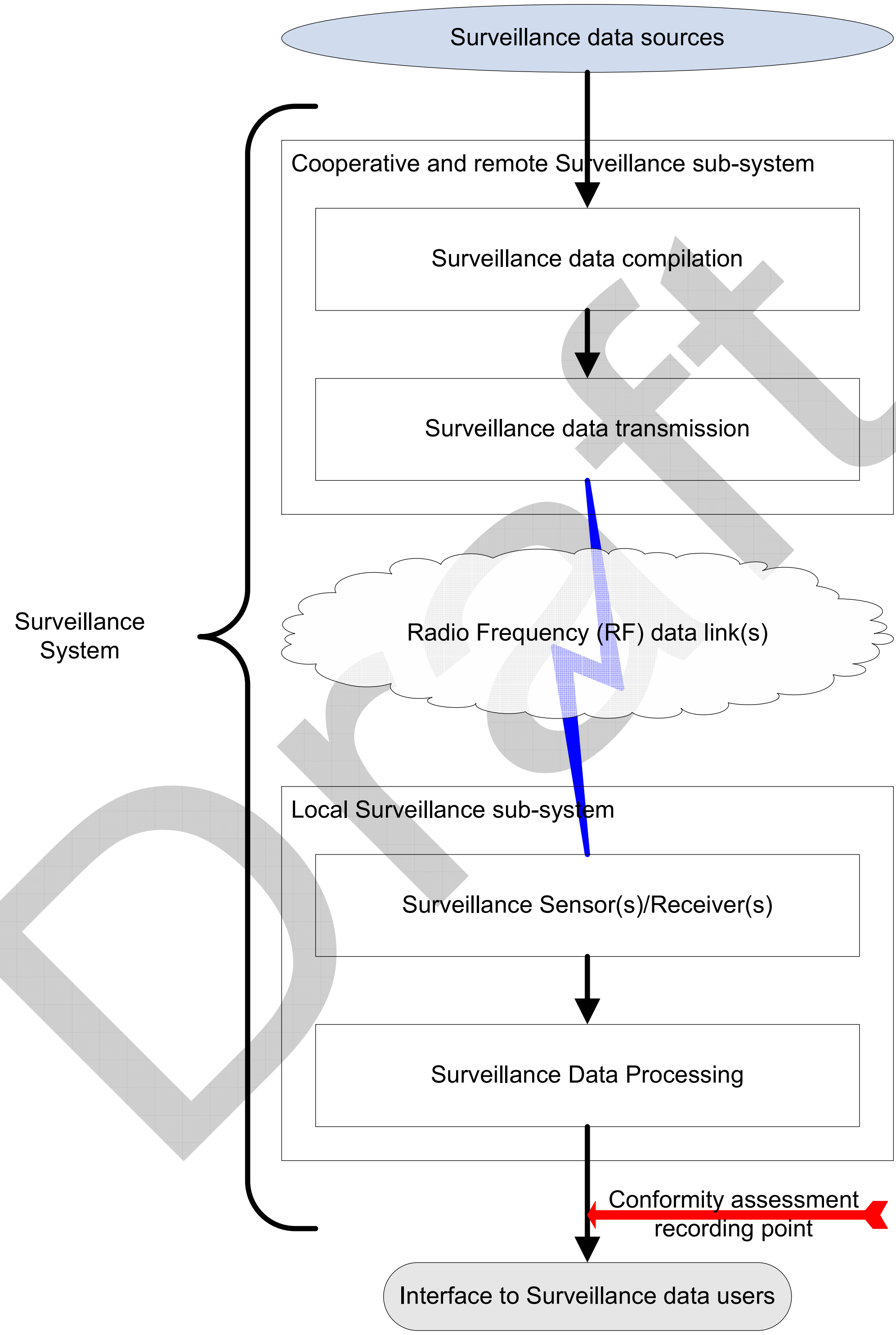


**Figure 27: Generic functional diagram of a surveillance system**

The diagram on Figure 27 provides a generic functional decomposition of a Surveillance system in charge of providing surveillance data items (see Annex A - 3 - Surveillance data items).

It is to be noted that the correlation function between the surveillance information and the flight plan information is considered outside the scope of the surveillance system. Similarly the function providing QNH/QNE corrected altitude on the basis of the pressure altitude is also considered outside the scope of the surveillance system. It is nevertheless recognised that the inputs of these functions can be provided to the surveillance data users through the surveillance system.

Within some surveillance system architecture it may happen that the aircraft identity as reported by the aircraft is sent to the Flight Data Processing System (FDPS) which sends back a “flight plan correlated aircraft identity”. This latter information is then send to the controller by the surveillance system. As specified in the SPI IR [RD 32], the aircraft identity data item to be provided by the surveillance system is the aircraft identity reported by the aircraft, therefore it is not the aircraft identity reported by the FDPS.

In the case of such architecture, the conformity assessment shall be adapted in such a way that the performance indicators corresponding to the aircraft identity data items are based on the aircraft identity reported by the aircraft and not the aircraft identity reported by the FDPS.

The next figures (Figure 28 and Figure 29) provide examples of current and future physical implementations of local airborne and ground surveillance systems based on 1030/1090 MHz data link. Figure 29 is fully consistent with the Generic RFG ADS-B Functional Architecture as described in EUROCAE ED-126 (document [RD 4]) and in EUROCAE ED-161 (document [RD 42]).

If the remote aircraft is not cooperative, there is no remote surveillance sub-system.

The cooperative and remote surveillance sub-system receives information acquired locally (sensors or HMI) and compiles these data items to make them consistent before to be transmitted to the local surveillance sub-system through RF data links.

The local surveillance sub-system is performing measurements (sensors) and is receiving (receivers) the data items transmitted by remote surveillance sub-systems. The surveillance data processing function compile all these data items to make them consistent and to adapt them to the needs of the local users (synchronisation, format, etc.).

The surveillance system performance is considered end-to-end, therefore the performance measurements are undertaken at the interface with the surveillance data users so as to be compared with the corresponding needs/requirements.

The functional components of the previous diagram are still shown; in addition physical elements are shown with a folded corner and examples of surveillance data sources and surveillance data users are provided. On Figure 29 optional items are shown dotted.

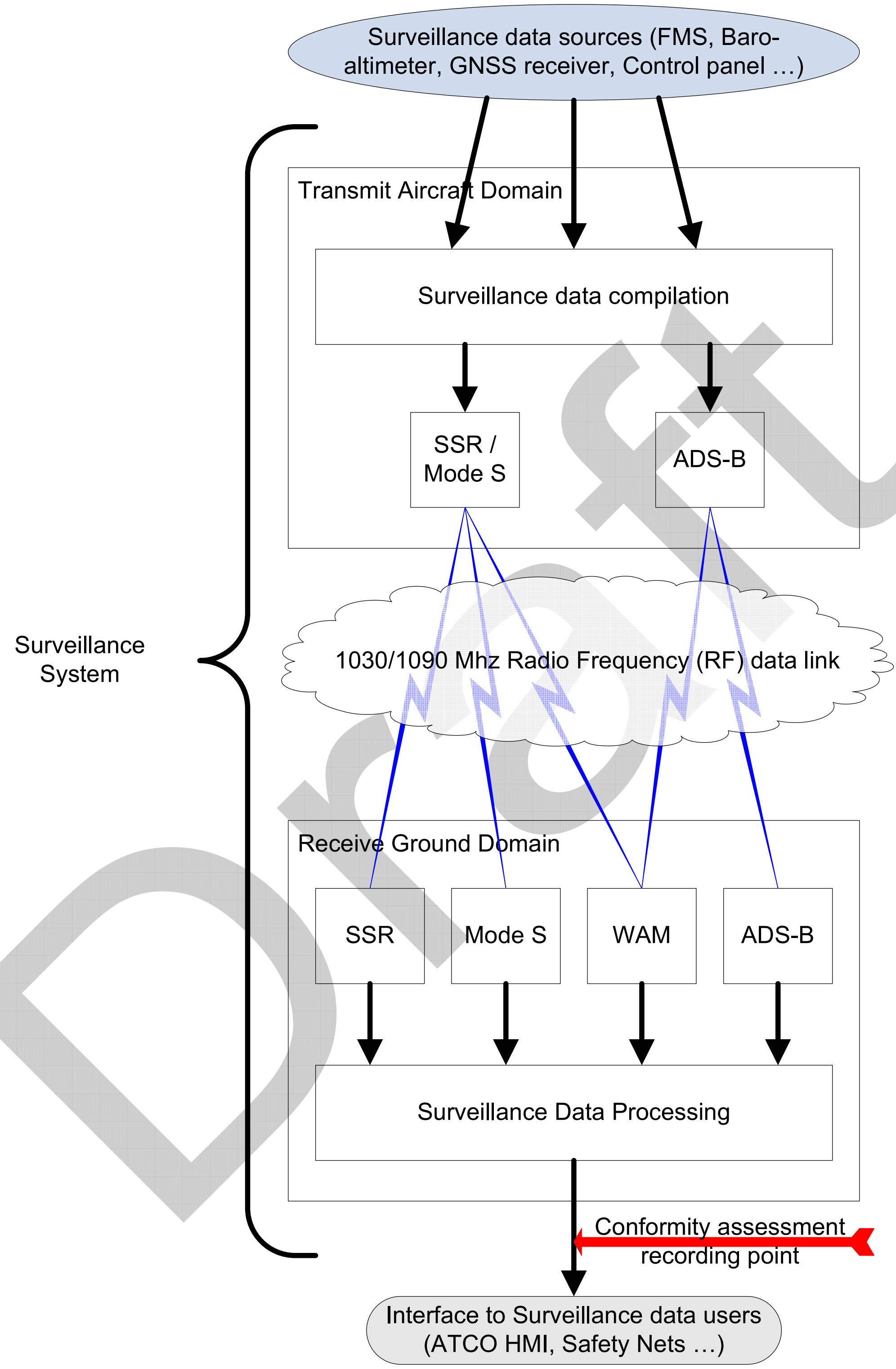


**Figure 28: Current Air-Ground Surveillance systems implementation based on 1030/1090 MHz data link**

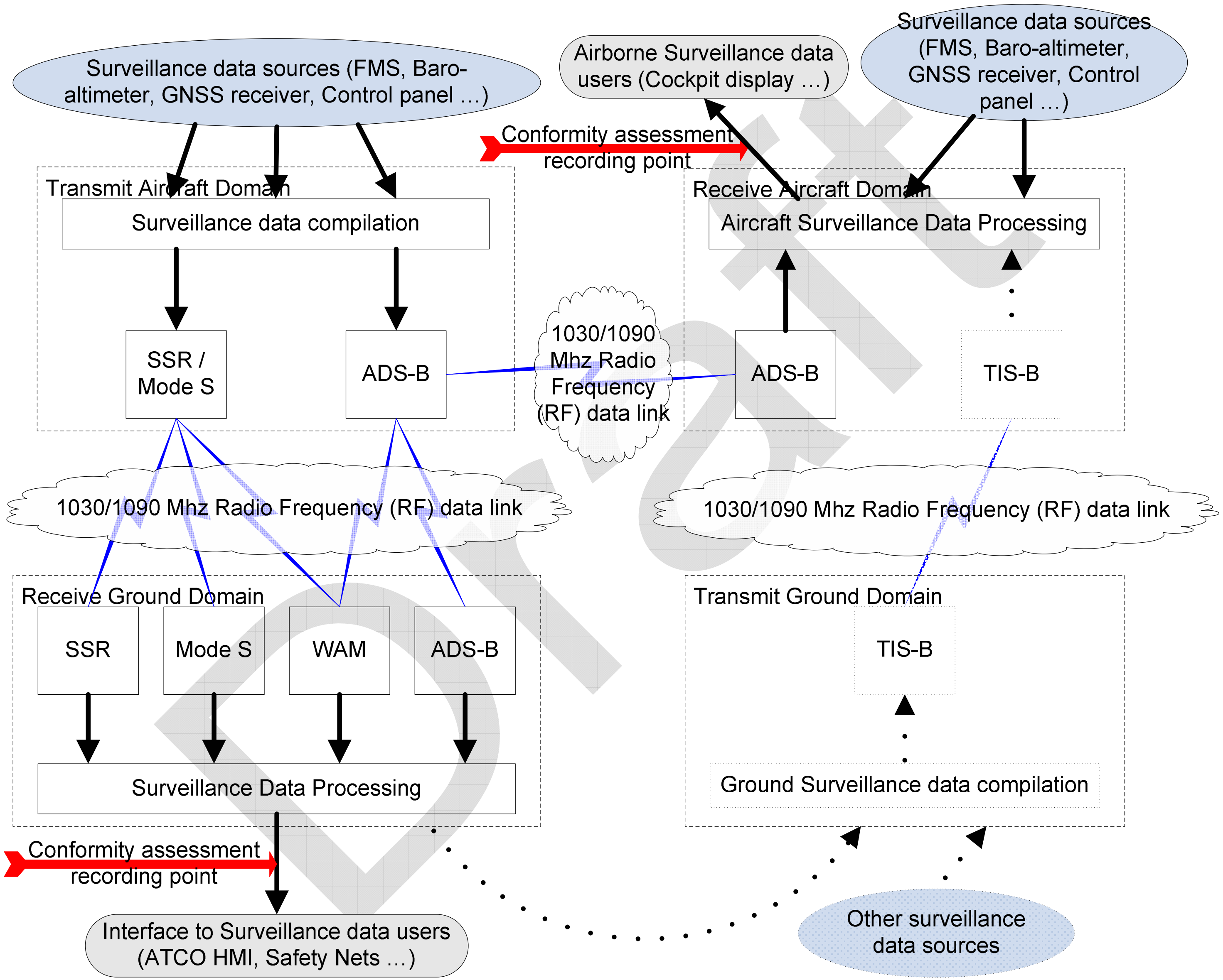


**Figure 29: Future Air-Ground, Ground-Air and Air-Air Surveillance system implementation based on 1030/1090 MHz data link**

In the frame of this document the considered Surveillance system encompasses all the components and elements (either functional or physical) shown on the above figures and the used RF data links.

This document is independent of the environment; it is up to the surveillance system designer to ensure that the designed system is capable to provide the required performance when operated under the range of local environments.

For instance, the weather conditions may impact the quality of the RF data link; they will have to be taken into account in the frame of the surveillance system design process to make sure that the required performance can be met under all the locally specified weather conditions.

Ideally the performance of the surveillance system should be measured at the input interface of the system using surveillance data. The measured performance characteristics can then be compared to the required performance characteristics.

In some cases, this option may not be feasible and artefacts could be put in place. For instance, in the case of the 3 or 5 NM horizontal separation performed by ATCO, the conformity assessment recording point is at the electronic input interface of the ATCO HMI system, which may degrade or improve the surveillance data that is displayed to the ATCO. In that case this further improvement/degradation will have to be taken into account when making the assessment of the surveillance data recorded at an earlier stage than surveillance data provided to the ATCO.

From these diagrams one can see that the performance of the surveillance system not only depends of the performance of its different components and elements but also of the performance characteristics of its inputs.

Concerning the quality of the inputs to the aircraft domain it is assumed that they are in accordance with the requirements specified in the Annex IV of the draft SPI IR [RD 32]. When such standard does not exist, assumptions are explicitly stated.

## A - 3 Surveillance data items

### A - 3.1 Surveillance data item categories

When looking in details to the different pieces of surveillance information, one can sub-divide them into two categories, which correspond to two different types of processing by the surveillance system:

- Calculated surveillance data items, i.e. data items that are calculated and/or that are re-calculated at a given time and for a given time on the basis of externally/internally provided data (e.g. horizontal position). These two times are not necessarily equal.
- Forwarded data items, i.e. data items that are received by the surveillance system and which are provided without modification of its value at the output of the surveillance system. This in particular the case of the identification data item (e.g. Mode A or Aircraft Identification). In case of forwarded data item the system may apply integrity checking. In that case the output of a new value may not be immediate (e.g. the system may delay the output of a new Mode A awaiting for a stable reporting from the aircraft).

These two categories were taken into account when defining the ATM surveillance system key performance characteristics and associated indicators.

When the surveillance system extrapolates or transforms (e.g. from geodetic to Cartesian) input data, the resulting data item is falling under the calculated data item category.

When the surveillance system just decodes a data item to reformat it (e.g. an Aircraft Identification from IA-5 to ASCII characters); the data item is falling under the forwarded data item category.

When providing a calculated data item, the objective of the surveillance system is to produce a piece of information that is as close as possible to the reality at the time it is provided.

When providing a forwarded data item the objective of the surveillance system is to output the same value as in input with the shortest possible delay.

Because the objectives of the surveillance system when processing one category or the other are rather different, the performance characteristics and indicators will also be different depending on the data item category.

### A - 3.2 Calculated surveillance data item

The data items that are calculated by surveillance system are:

- Calculated horizontal position
- Calculated velocity
- Calculated rate of climb/descent
- Calculated mode of movement
- Calculated acceleration
- Calculated geometric altitude
- Calculated pressure altitude (e.g. smoothed or extrapolated)
- Any data item which is specified as “calculated” by the system even though it is extrapolated on the basis of an airborne provided data item.

### A - 3.3 Forwarded surveillance data item

The data items that are forwarded by surveillance system are:

- Airborne Standard pressure altitude, e.g. Mode C.
- Mode 1, 2, 3/A codes.
- Target identification, e.g. Aircraft Identification, SPI, emergency states.
- Any Downlink Aircraft Parameter (DAP), e.g. Selected Altitude, True Track Angle, Ground Speed, Track Angle Rate, Magnetic Heading.
- Any data item provided to the system and which is directly output without any modification of its value.

### A - 3.4 Extraction/calculation of surveillance data items

Depending on their nature, surveillance data items are either extracted/calculated periodically or on event.

All the data items related to the trajectory (position, velocity, etc.) of the aircraft that are constantly changing with time are calculated periodically.

On the other hand, data items like the identity of the aircraft, which are not changing or very rarely, are only extracted from the aircraft on event, i.e. when there is a change.

It is to be noted that in order to avoid possible misses of a change, the system may be designed to also extract periodically these data items that are in principle “event driven”.

# ANNEX - B REFERENCE DOCUMENTS AND ACRONYMS

## B - 1 Applicable documents

**[AD1]** Document XXX Ref YYY Dated DD/MM/YYYY

## B - 2 Other referenced documents

**[RD 1]** ICAO Procedures for Air Navigation Services – Air Traffic Management. Doc 4444 ATM/501 fifteenth edition Amendment 5 Dated 22/11/2007

**[RD 2]** EUROCONTROL Standard Document for Radar Surveillance in En-Route Airspace and Major Terminal Areas SUR.ET1.ST01.1000-STD-01-01 Ed. 1.0 March 1997

**[RD 3]** Guidance Material for Required Surveillance Performance QINETIQ /05/00819 Dated May 2005

**[RD 4]** Safety, Performance and Interoperability Requirements Document for ADS-B NRA Application ED-126 Dated December 2006 (EUROCAE)

**[RD 5]** Information technology – Quality of service: Framework ISO/IEC 13236 First Edition Dated 15/12/1998

**[RD 6]** International Standard Information Technology – Vocabulary Part 14 ISO/IEC 2382-14:1997(E/F) 2nd Edition Dated 01/12/1997

**[RD 7]** Electronic Reliability Design Handbook MIL-HDBK-338b 01 October 1998

**[RD 8]** Surveillance and Conflict Resolution System Panel (SCRSP) SCRSP-2/WG-B WP B8-07 26 May 2005 Agenda Item 5.2

**[RD 9]** ICAO Annex 10 Vol I Radio Navigation Aids (including Amendment 80) 24/11/05

**[RD 10]** ICAO SASP – Assessment of ADS-B Surveillance to support air traffic services and state implementation roadmap

**[RD 11]** Verification procedures of surveillance system applied by DSNA/France – Information paper V1 11/05/2006

**[RD 12]** Référentiel technique pour l'établissement d'un Dossier relatif à un Minimum de Séparation Radar (DMSR) DO/DTI/MSQS/NT05-572 Décembre 2005 V2

**[RD 13]** Review of horizontal surveillance performance – Final Report (D3) CSS/C1853/TRS99_D3_V1.0 11/08/2006

**[RD 14]** Study to Analyse Horizontal Positional Performances Draft Version 3.2 22/12/2006

**[RD 15]** Study on Maximum Data Age Required at the Output of a Surveillance System Draft Version 2.2 12/12/2006

**[RD 16]** Manual on Airspace Planning Methodology for the Determination of Separation Minima Doc 9689-AN/953 First Edition 1998

**[RD 17]** Assessment Report Surveillance Standards 200300-REP-07-0090 version 2.3 dated 16/07/2007

**[RD 18]** Surveillance Standards Performance Characteristics P740D005 version 1.0 dated 10/10/2007

**[RD 19]** European Mode S Station Functional Specification SUR/MODES/EMS/SPE-01 version 3.11 dated 9 May 2005

**[RD 20]** ICAO Annex 10 Aeronautical Telecommunications Vol IV Surveillance radar and Collision Avoidance System 3rd Edition July 2002

**[RD 21]** ICAO Annex 6 Operation of Aircraft Part 1 International Commercial Air Transport – Aeroplanes 8th Edition July 2001

**[RD 22]** JAA Administrative and Guidance Material. Section 3: General Part 1: Temporary Guidance Leaflets. Leaflet N° 6 Revision 1 Guidance Material on the Approval of Aircraft and Operators for Flight in Airspace above Flight Level 290 where a 300 m (1000 ft) Vertical Separation Minimum is Applied. Dated 1/10/1999.

**[RD 23]** ICAO Document Manual on Implementation of a 300 m (1 000 ft) Vertical Separation Minimum between FL 290 and FL 410 Inclusive. 2nd Edition 2002 Document 9574 AN/934.

**[RD 24]** ICAO Document 9536, Review of the General Concept of Separation (RGCSP).

**[RD 25]** ICAO Annex 15 Aeronautical Information Services 12th Edition July 2004.

**[RD 26]** ICAO Document 8168, Aircraft Operations Volume 1 Flight Procedures Fifth Edition 2006

**[RD 27]** ICAO Document 8168, Aircraft Operations Volume 2 Construction of Visual and Instrument Flight Procedures Fifth Edition 2006

**[RD 28]** ICAO Annex 11 Air Traffic Services Thirteenth Edition July 2001

**[RD 29]** SESAR – The ATM target concept D3 DLM-0612-001-02-00a - September 2007

**[RD 30]** SESAR – The Performance target D2 DLM-0607-001-02-00a December 2006

**[RD 31]** JAA Administrative and Guidance Material Section 1 Part 3 Leaflet 13 Revision 1 Certification of Mode S Transponder Systems for Elementary Surveillance date 01 May 2001

**[RD 32]** Draft regulation on SPI (Surveillance Performance and Interoperability) Dated 10/06/2011 Submitted by the European Commission at the Single Sky Committee #52 (6-7 July 2011) SSC/11/42/3

**[RD 33]** Air Navigation System Safety Assessment Methodology (SAM), SAF.ET1.ST03.1000-MAN-01, Edition 2.1 Dated 2007

**[RD 34]** "Safety Assessment Made Easier" Part 1 - Safety Principles and an introduction to Safety Assessment Edition 0.8 Dated 9 January 2008

**[RD 35]** “Safety Assessment Made Easier” Part 2 – A Practical Guide to Safety Assurance, throughout the Safety Lifecycle Edition 0.18 Dated 9 January 2008

**[RD 36]** Preliminary Safety Case for Enhanced Air Traffic Services in Non-Radar Areas using ADS-B surveillance PSC ADS-B-NRA Edition 1.1 Dated 12 December 2008

**[RD 37]** Generic Safety Assessment for ATC Surveillance using Wide Area Multilateration Edition 6.0 Dated 13/08/2009

**[RD 38]** ARTAS V7 Safety Assessment Report CF407/01/102 Edition 3.0 Dated 31/08/2006

**[RD 39]** Mode S Controller Working Position Preliminary System Safety Assessment Edition 1.1 Dated October 2007

**[RD 40]** Comparative study of Surveillance performance indicators for false target performance P890D004 Dated 30/09/2008 Version 1.1

**[RD 41]** RSP for surveillance systems supporting 3 and 5 NM separations Working paper reported to the Aeronautical Surveillance Panel Working Group of the Whole (ASP WGW) 1st meeting Montreal 8-12/12/2008 Agenda Item 5

**[RD 42]** Safety, Performance and Interoperability Requirements Document for ADS-B RAD Application ED-161 Dated September 2009 (EUROCAE)

**[RD 43]** ICAO, Manual of the ICAO Standard Atmosphere Doc 7488/3, Third Edition, 1993

**[RD 44]** EASA Decision N° 2003/11/RM of the Executive Director of the Agency of 5 November 2003 on definitions and abbreviations used in certification specifications for products, parts and appliances (« CS-Definitions »)

**[RD 45]** Manual of testing radio navigation aids – Testing of surveillance radar systems ICAO Document 8071 Volume III 1st Edition – 1998 including amendment N° 1 19/10/2002

**[RD 46]** Technical specification for Wide Area Multilateration (WAM) systems ED-142 Dated September 2010 (EUROCAE)

**[RD 47]** EUROCONTROL standard document for surveillance data exchange. Part 9: Category 062 SDPS track messages Ref. SUR.ET1.ST05.2000-STD-09-01 Edition 1.13 Dated October 2010

**[RD 48]** A surveillance performance model incorporating dynamic factorsVersion 1 Dated 12/06/2009

## B - 3 Acronyms

| Acronym | Definition |
|---|---|
| ACID | AirCraft IDentification |
| ANSP | Air Navigation Service Provider |
| ATC | Air Traffic Control |
| ATCO | Air Traffic COntroller |
| ATM | Air Traffic Management |
| ATS | Air Traffic Service |
| ATSU | Air Traffic Service Unit |
| CAV | Conformity Assessment Volume |
| CND | Cooperative Network Design |
| DAP | Downlink Aircraft Parameter |
| DSNA/DTI | Direction des Services de la Navigation Aérienne/Direction de la Technique et de l'Innovation |
| EASA | European Aviation Safety Agency |
| EATMN | European Air Traffic Management Network |
| EC | European Commission |
| ECAC | European Civil Aviation Conference |
| FCU | Flight Control Unit |
| FHA | Functional Hazard Analysis |
| FL | Flight Level |
| FMS | Flight Management System |
| HMI | Human Machine Interface |
| HSM | Horizontal Separation Minima |
| IAS | Indicated Air Speed |
| ICAO | International Civil Aviation Organisation |
| IFR | Instrument Flight Rules |
| ISA | International Standard Atmosphere |
| ISO | International Standardisation Organisation |
| JAA | Joint Aviation Authorities |
| MCP | Mode Control Panel |
| MRT | Mean Response Time |
| MSPSR | Multi-Static Primary Surveillance Radar |
| MTBCF | Mean Time Between Critical failure |
| MTBF | Mean Time Between Failure |
| MTTR | Mean Time to Repair/Restore |
| NM | Nautical Mile |
| NRA | Non Radar environment (in the context of the ADS-B RFG) |
| NSA | National Supervisory Authority |
| OHA | Operational Hazard Analysis |
| PSR | Primary Surveillance Radar |
| PSSA | Preliminary System Safety assessment |
| PU | Probability of Update |
| PUCV | Probability of Update with Correct and Valid value |
| RAD | RADar environment (in the context of the ADS-B RFG) |
| RCS | Radar Cross Section |
| RF | Radio Frequency |
| RFG | Requirement Focus Group |
| RMS | Root Mean Square |
| RPS | Radar Position Symbol |
| RSP | Required Surveillance Performance |
| RVSM | Reduced Vertical Separation Minimum |
| SDP | Surveillance Data Processing |

| Acronym | Definition |
|---|---|
| SDPS | Surveillance Data Processing System |
| SES | Single European Sky |
| SPI | Special Position Identification |
| SPI IR | Surveillance Performance and Interoperability Implementing Rule |
| SSR | Secondary Surveillance Radar |
| SSTF | Surveillance Standard Task Force |
| TAS | True Air Speed |
| TBC | To Be Confirmed |
| TBD | To Be Defined |
| TMA | Terminal Manoeuvring Area |
| UI | Update Interval |
| UTC | Coordinated Universal Time |
| VFR | Visual Flight Rules |
| VSM | Vertical Separation Minima |
| WGS | World Geodetic System |

**Table 12: Acronym list**

# ANNEX - C TRACEABILITY AND JUSTIFICATION MATRIX

## C - 1 Conventions

Shading:

Light green shading means mandatory requirements

Light yellow shading means recommended requirements

Framing:

Blue framing means referenced requirement is identical to requirement

Sky blue framing means referenced requirement is very close to requirement (+/- 10%)

Green framing means referenced requirement is more demanding than requirement

Red framing means referenced requirement is less demanding than requirement

Pink framing means referenced requirement is different than requirement

# C - 2 Traceability, justification and links to equivalent requirement statement

## C - 2.1 5N_C: 5 NM horizontal separation

### C - 2.1.1 Update interval mandatory requirements

| Ref | Performance requirement statement/ Comment | Requirement threshold<br>1000 ft VSM | <br>2000 ft VSM |
|---|---|---|---|
| **5N_C-R1** | The nominal update interval for horizontal position, pressure altitude and aircraft identity data items shall be set to **8** s or less. | 8 s | |
| [RD 2] § 5.2.4 | Requirement:<br>Surveillance information updates shall enable the display updates to be less than or equal to 8 seconds in en-route airspace. | 8 s | |
| [RD 4] SPR 19 § 3.5.2 | Requirement:<br>For 5 NM separation – The update interval for Surveillance Reports containing any new ADS-B position data associated with any single aircraft shall be no longer than 10s with a probability of 95%.<br>Comment:<br>For ADS-B only. | 10 s | |
| [RD 12] Exigence 18 | Requirement:<br>The duration separating two screen refreshes relating to the same aircraft shall not in principle exceed the following:<br>• 8 s for a target separation minimum M, if 3 NM < M ≤ 5 NM | 8 s | |

| Ref | Performance requirement statement/ Comment | Requirement threshold | |
|---|---|---|---|
| | | 1000 ft VSM | 2000 ft VSM |
| **5N_C-R1** | The nominal update interval for horizontal position, pressure altitude and aircraft identity data items shall be set to **8** s or less. | 8 s | |
| [RD 18] § 6.3.3 | Proposed requirement:<br>The maximum data age of pressure altitude measured at the output of the ground system is:<br>• 1000ft separation = 5s<br>• 2000ft separation = 8s | 5 s | 8 s |
| [RD 42] SPR 49 | Requirement:<br>For 5 NM separation – The probability of providing a Surveillance Report containing newly received ADS-B Position data of sufficient quality associated with any aircraft in En Route airspace within 8 seconds shall be 97%.<br>Comment:<br>For ADS-B only. | 8 s | |
| [RD 46] § 3.3.1 | Requirement:<br>The defined *Update Interval* ***shall*** not exceed the following:<br>• 8 seconds for the En-route application<br>Comment:<br>For WAM only. | 8 s | |

### C - 2.1.2 Update interval recommended requirements

| Ref | Performance requirement statement/ Comment | Requirement threshold | |
|---|---|---|---|
| | | 1000 ft VSM | 2000 ft VSM |
| 5N_C-R1 | The update interval for horizontal position, pressure altitude and aircraft identity data items should be set to **6** s or less. | 6 s | |
| SSTF #12 | It was agreed during SSTF meeting #12 that to take into account the future traffic increase in Europe it is needed to align the update interval for future system to the update interval currently applied in high-medium density airspace. | 6 s | |

### C - 2.1.3 Horizontal position probability of update mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R2** | The probability of update of the horizontal position in accordance with the applicable update interval shall be equal to or higher than **97 %** per flight. | 97 % (per flight) |
| [RD 2] § 6.3.2.1 | Requirement:<br>Target Position Detection<br>Overall probability of detection: > 97 %<br>Comment:<br>For 1 SSR only.<br>For 2 independent SSR's the requirement should be 99.91 %.<br>Not possible to derive a requirement per flight. | 97 % or 99.91 % (global) |
| [RD 4] SPR 19 § 3.5.2 | Requirement:<br>For 5 NM separation – The update interval for Surveillance Reports containing any new ADS-B Position data associated with any single aircraft shall be no longer than 10s with a probability of 95%. | 95 % (per flight) |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R2** | The probability of update of the horizontal position in accordance with the applicable update interval shall be equal to or higher than **97 %** per flight. | 97 % (per flight) |
| [RD 12] Exigence 18 | <u>Requirement:</u><br>The duration separating two screen refreshes relating to the same aircraft shall not in principle exceed the following:<br>• 8 s for a target separation minimum M, if 3 NM < M ≤ 5 NM<br>Any exceeding of these limits shall be considered individual cases and shall accordingly be the subject of a detailed analysis included in the Radar Separation Minimum Dossier (RSMD).<br>Such analysis will make it possible to ascertain the cause of the occurrence, the potential operational implications, its classification in the seriousness table, a theoretical estimation of its frequency, the possible proposal of mitigating measures and its acceptability vis-à-vis regulations.<br><u>Comment:</u><br>According to the above, any missed target report should be very rare as it will require a specific analysis. Although it is not expressed as a probability of update per flight, it is deemed that this requirement is more demanding. | ? |
| [RD 42] SPR 49 | <u>Requirement:</u><br>For 5 NM separation – The probability of providing a Surveillance Report containing newly received ADS-B Position data of sufficient quality associated with any aircraft in En Route airspace within 8 seconds shall be 97%.<br><u>Comment:</u><br>For ADS-B only. It is assumed that “ADS-B Position data” encompasses all the data items listed in SPR 27which include aircraft horizontal position data and pressure altitude. | 97 % (per flight) |
| [RD 46] § 3.3.3 & 3.3.6 | <u>Requirement:</u><br>The *Probability of position detection* within the defined *Update Interval* ***shall*** be greater than or equal to **97%** for any target. | 97% (per flight) |

### C - 2.1.4 Horizontal position probability of update recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R2 | The probability of update of the horizontal position in accordance with the applicable update interval (see **Req. 01**) should be equal to or higher than **99** % globally and equal or higher than **97 %** per flight. | 99 % (global)<br>97 % (per flight) |
| SSTF #12 | It was agreed during SSTF meeting #12 that to take into account the future traffic increase in Europe it is needed to align the probability of update of positional information for future system to the probability of update of positional information currently achieved in high-medium density airspace. | 99 % (global) |
| SSTF #21 | It is proposed to supplement mandatory requirement of 97 % per flight with 99% global. | 99 % (global)<br>97 % (per aircraft) |

### C - 2.1.5 Ratio of missed 3D position involved in long gaps mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R3** | The ratio of missed 3D position (either horizontal position or pressure altitude missing) involved in long gaps (3 times the maximum update interval + 10% = 26.4 s) shall be equal to or less than **0.1 %**. | 0.1 % |
| SSTF #12-15 | The objective of this requirement is to limit the size of trajectory gaps without full 3D position information. The inclusion of the requirement was agreed at SSTF meeting #12 and the length of long gap was agreed during STTF meeting #15. | 0.1 % |
| [RD 46] § 3.3.4 | Requirement:<br><br>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%.<br><br>Comment:<br><br>Assumed to be equivalent when WAM system provides synchronous outputs. | 0.1% |

### C - 2.1.6 Horizontal position error mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **500 m** RMS globally and shall be equal to or less than **550 m** RMS per flight. | 500 m (global)<br><br>550 m (per flight) |
| [RD 2] § 5.2.3 | Requirement:<br><br>The positional accuracy of the surveillance radar data available, at the control position, shall have an error distribution with a root mean square (RMS) value equal to or less than **500 metres (m)** for en-route airspace. | 500 m (global) |
| [RD 4] SPR 1 § 3.4.2.1 | Requirement:<br>For ADS-B Airborne, the 95% accuracy of the horizontal position shall be less than **0.5 NM** (i.e. $NAC_P \geq 5$).<br><br>Quality indicators that are transmitted in ADS-B messages shall account for any uncompensated latency on-board the aircraft.<br><br>***NOTE1:*** *Quality Indicators, particularly accuracy, as used in this document include all contributing factors for the uncertainty of position data with respect to the time of applicability for that data. These factors include the uncertainty of the position measurement and any uncompensated latency prior to transmission of the data.*<br><br>Comments:<br><br>Equivalent requirements for ADS-B only (926 m converted in RMS, assuming Rayleigh distribution, gives 535 m), but does not take into account position error due to latency of the information on the ground. There are separated requirements for specifying information latency (Airborne part: less than 1.5 second for 95%, ground part: less than 0.5 second for 95%).<br><br>In [RD 4] Appendix B.1.3 it is further stated: *"Finally, any uncompensated on-board latency or timing uncertainties that are not known to the ground will have the effect of degrading the position accuracy (predominantly in the along-track direction) of the ADS-B information received by the ground."*<br><br>Therefore it is unclear whether or not the error due to uncompensated latency is included or not in requirement SPR 1. | 535 m (global)<br><br>535 m (per flight) |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **500 m** RMS globally and shall be equal to or less than **550 m** RMS per flight. | 500 m (global)<br><br>550 m (per flight) |
| [RD 12] Exigence 12 | <u>Requirement:</u><br><br>The overall RMS shall not exceed the following thresholds:<br><br>• **500 m** for a target separation minimum of 5 NM<br><br><u>Comment:</u><br><br>It should be noted that the requirement shall also be met when the measurement is made on the basis of turning aircraft trajectories only. | 500 m (global) |
| [RD 13] § 6.4 Tables 15 & 16 | <u>Proposed requirement:</u><br><br>Position error standard deviation shall be less than 1852 m.<br><br><u>Comment:</u><br><br>Even though it is not possible to convert this value to RMS it is deemed less demanding. | ? m |
| [RD 14] § 10.13 Table 3 & § 10.15 Table 4 | <u>Proposed requirement:</u><br><br>Proposed values for 95% containment value is 556 m (0.3 NM) with a standard deviation of 185 m (0.1 NM).<br><br><u>Comment:</u><br><br>Even though it is not possible to convert these values to RMS it is deemed more demanding. | ? m |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **500 m** RMS globally and shall be equal to or less than **550 m** RMS per flight. | 500 m (global)<br><br>550 m (per flight) |
| [RD 19] § 4.2.6.2 & 4.2.6.3 | Requirements:<br><br>(i) All SSR Random errors shall be less than 30 m RMS (1 sigma)<br><br>(ii) All Mode S Random errors shall be less than 15 m RMS (1 sigma)<br><br>All azimuth error standard deviations shall be less than 0.068° (one sigma)<br><br>Comment:<br><br>For a single Mode S sensor and without taking into account information latency (maximum 2 s).<br><br>Assuming no bias and that the azimuth error is Gaussian and is the main component of the position error and taking into account that maximum operational range for 5 NM separation is 200 NM. | 440 m (global) |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **500 m** RMS globally and shall be equal to or less than **550 m** RMS per flight. | 500 m (global)<br><br>550 m (per flight) |
| [RD 42] SPR 8 | <u>Requirement:</u><br><br>For 5 NM separation – The 95% accuracy of the measured horizontal position shall be less than 308 metres ($NAC_P$ = 7).<br><br><u>Comment:</u><br><br>More demanding requirement for ADS-B only (308 m @95% converted in RMS, assuming Rayleigh distribution, gives 178 m), but does not take into account position error due to information latency. There are separated requirements for specifying horizontal position latency (Airborne part: less than 0.6 second (uncompensated) for 95% SPR 24, ground part: less than 0.5 second for 95% SPR 35). It is also stated that these latencies are partially compensated (airborne) or fully compensated (ground), such compensation will introduce a budget error that is not possible to quantify without further assumptions. | 178 m (per flight) |
| [RD 46] § 3.3.8 & 3.3.11 | <u>Requirement:</u><br><br>The Horizontal position errors ***shall*** not exceed:<br><br>• 350 m RMS for the En-route application<br><br>**NOTE1:** The horizontal position error is calculated for the time of applicability provided by the target report.<br><br>In *Periodic Predicted Mode*, when the *Predicted Position* at time of output is transmitted, the maximum *Processing delay* ***shall*** be 0.5 second.<br><br><u>Comment:</u><br><br>Horizontal position error due to processing delay has to be added. | 350 m |

### C - 2.1.7 Horizontal position error recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R4 | Horizontal position error, **including measurement error and error due to information latency**, should be equal to or less than **350** m RMS global equal to or less than 385 m RMS er flight. | 350 m (global)<br><br>385 m (per flight) |
| SSTF #12 | It was agreed during SSTF meeting #12 that to take into account the future traffic increase in Europe it is needed to align the horizontal position core accuracy for future system to the horizontal position core accuracy currently achieved in high-medium density airspace. | 350 m (global) |
| SSTF #21 | At SSTF #21 it was agreed to supplement the global requirement on RMS horizontal position error with a requirement per flight with an additional margin to take account of the limited number of samples when performing an assessment per flight. | 385 m (per flight) |

### C - 2.1.8 Horizontal position outlier criteria

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **§ 5.1.5** | The criteria on horizontal position error for declaring a target report as outlier, **including measurement error and error due to information latency**, shall be equal to **2100 m**. | 2100 m |
| [RD 41]<br>§ 1.2.2.1.2.1 | Requirement:<br><br>Maximum horizontal position error shall be less than half of the chosen separation minimum minus a specified safety buffer.<br><br>Note 1: The maximum horizontal position uncertainty is assumed to occur at the end of the update interval.<br><br>Comment:<br><br>The above value of 2100 m has been derived from the 4630 m value assuming a maximum aircraft speed (Vmax) of 600 knots (D - 4.3.1), an update interval of 8 s and an aircraft size of 60 m. This is further illustrated on Figure 30 below. | 4630 m |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| § 5.1.5 | The criteria on horizontal position error for declaring a target report as outlier, **including measurement error and error due to information latency**, shall be equal to **2100 m**. | 2100 m |

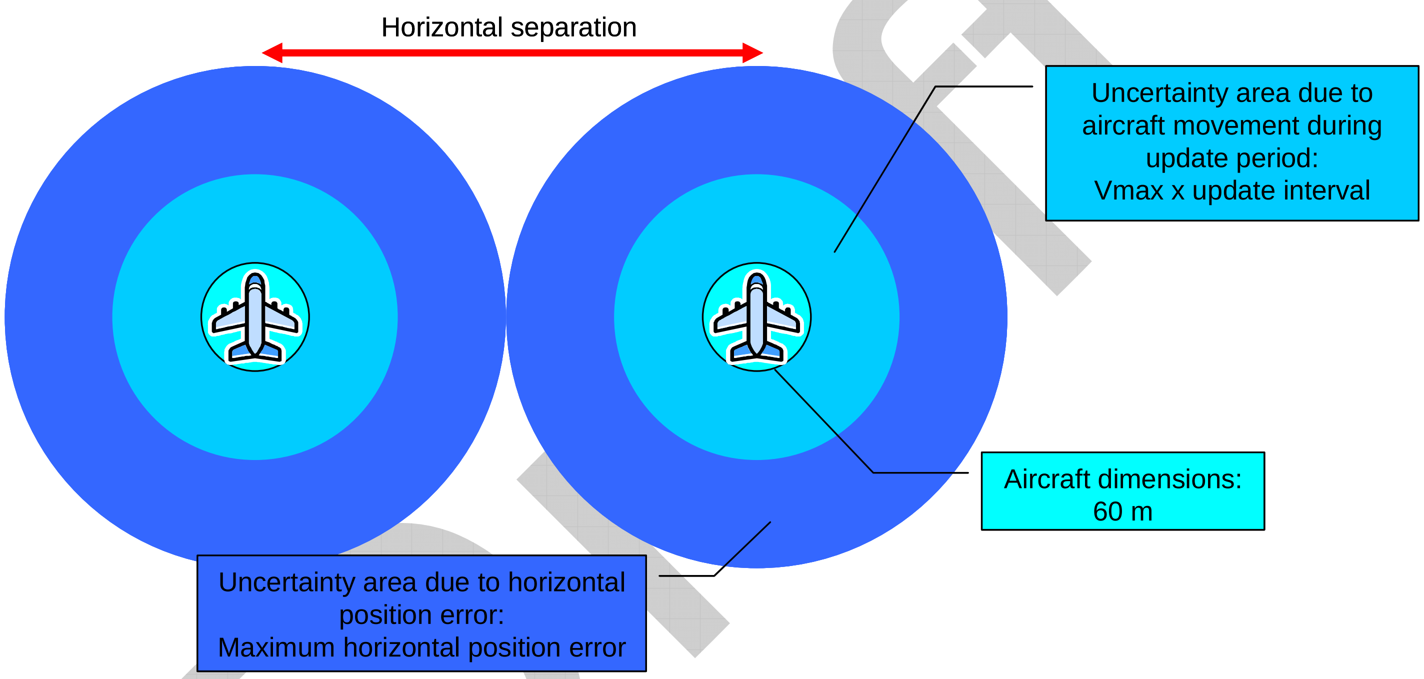


Figure 30: Maximum horizontal position

Provided that the position error remains in the dark blue area  the probability to be in collision during the period of display is null, even in the worst case of the two aircraft heading on. This simple approach does not address the evolution of the aircraft trajectory during the next updates.

### C - 2.1.9 Ratio of correlated horizontal position errors recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R5 | There should be no more than **0.03 %** of position reports included in a series of correlated horizontal position errors in the same direction, larger than **926 m** and during more than **3 update intervals**. | 0.03 %<br>926 m<br>3 updates |
| [RD 12] Exigence 5 | Requirement:<br>The ratio of plots with a correlated deviation (i.e. the plots with an across deviation greater than **M/10** immediately preceded or followed (i.e. on the preceding or subsequent antenna revolutions) by two plots with an across deviation in the same direction greater than **M/20**) in the area of interest of the control unit served by the image evaluated shall not exceed **0.03%**.<br>Comment:<br>**M** is the applicable separation minima (i.e. 5 NM)<br>Statement derived from SSR only requirements. The amount of error to declare correlated errors is smaller but is limited to across error. | 0.03 %<br>926-463-463 m<br>463-463-926 m<br>3 updates |

### C - 2.1.10 Horizontal position relative time of applicability recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
| --- | --- | --- |
| 5N_C-R6 | The relative time of applicability of horizontal position of close aircraft (separated by less than 10 NM horizontally) should be equal to or less than **0.3 s** RMS. | 0.3 s |
| [RD 12] Exigence 16 | Requirement:<br>The RMS of the time deviations separating the position update of the aircraft in proximity shall not exceed the following thresholds:<br>• 0.5 s for a target separation minimum M, if M = 5 NM<br>Comment:<br>The requirement is put on the relative time of display between aircraft separated by less than 10 NM.<br>In the frame of SSTF#12 it was agreed to keep the same requirement (0.3 s) for both applications. | 0,5 s |

### C - 2.1.11 Correct and valid pressure altitude probability of update mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R7** | The probability of update of correct and valid pressure altitude in accordance with the applicable update interval shall be equal to or higher than **96 %.** | 96 % |
| [RD 2] § 6.3.2.4 | Requirement:<br><br>Overall Mode C probability of code detection: > 96 %<br><br>Comment:<br><br>For 1 SSR only. | 96 % |
| [RD 4] SPR 19 § 3.5.2 | Requirement:<br><br>For 5 NM separation – The update interval for Surveillance Reports containing any new ADS-B Position data associated with any single aircraft shall be no longer than 10s with a probability of 95%.<br><br>Comment:<br><br>For ADS-B only, it is considered that ADS-B target reports always contain horizontal position and pressure altitude so the ratio should be 100 % minus the cases of pressure altitude integrity error. | 100- % |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R7** | The probability of update of correct and valid pressure altitude in accordance with the applicable update interval shall be equal to or higher than **96 %**. | 96 % |
| [RD 42] SPR 49 | Requirement:<br><br>For 5 NM separation – The probability of providing a Surveillance Report containing newly received ADS-B Position data of sufficient quality associated with any aircraft in En Route airspace within 8 seconds shall be 97%.<br><br>Comment:<br><br>For ADS-B only. It is assumed that “ADS-B Position data” encompasses all the data items listed in SPR 27which include aircraft horizontal position data and pressure altitude so the ratio should be 100 % minus the cases of pressure altitude integrity error. | 100- % |
| [RD 46] § 3.3.3 & 3.3.6 | Requirement:<br><br>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%.** | 96% |

### C - 2.1.12 Forwarded pressure altitude average data age mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R8** | The average data age of the forwarded pressure altitude reported in all target reports shall be equal to or less than **4 s**. | 4 s |
| SSTF #12 | The objective of this requirement is to limit the latency of pressure altitude (forwarded data item) inside the surveillance system. There is currently no equivalent requirement in any standard from which this requirement can be traced. This value has been proposed during STTF meeting #12 and is based on current surveillance system experience. | 4 s |
| [RD 4] SPR 12 § 3.4.2.2 – SPR 16 § 3.5.2 | Requirement:<br>For pressure altitude, aircraft identification, mode A code, SPI and Emergency indicators, the Airborne Transmit Domain shall have a latency no greater than specified in current implementations for SSR.<br>The 95% latency for ADS-B Surveillance Reports (measured between points D and E2) shall be no greater than 0.5s.<br>Comment:<br>Airborne and transmission latencies are assumed to be negligible, therefore the global performance is better than the above specification. | 0.5 + s |
| [RD 41] SPR 35 § 3.4.2 | Requirement:<br>The 95% latency for ADS-B surveillance reports (measured between points D and E2 – output of the “Ground ADS-B Receive” function) **shall** be no greater than 0.5 seconds, excluding communication latency to the ATC processing system.<br>Comment:<br>Airborne latency is assumed to be the same as for SSR (as for NRA) and is therefore negligible, therefore the global performance is better than the above specification. | 0.5 + s |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R8** | The average data age of the forwarded pressure altitude reported in all target reports shall be equal to or less than **4 s**. | 4 s |
| [RD 46] § 3.3.11 | Requirement:<br>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.<br>Comment:<br>It is assumed that the WAM system under nominal condition will meet the requirement. | Max 9 s |

### C - 2.1.13 Forwarded pressure altitude maximum data age mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5.1.5** | The maximum data age of the forwarded pressure altitude reported in all target reports shall be equal to or less than **16 s**. | 16 s |
| SSTF #21 | Assuming that a large proportion (to be quantified) of the aircraft vertical movements are performed at a rate of climb/descent less than or equal to 3000 ft/mn, 16 s corresponds to the delay for a climbing descending aircraft to leave its initial flight level but to not have yet reached the next (above or below) flight level. In accordance with ICAO Document 4444 [RD 1] an aircraft is at a given flight level if its pressure altitude is within +/- 200 ft from that flight level (VSM = 1000 ft). 16 seconds is derived from 1000 ft minus 200 ft divided by the considered normal vertical speed 3000 ft/mn (or 50 ft/s).<br><br>At SSTF #21 it was agreed that this delays must be applicable for 100% of the cases, however it is also recognised that cases of higher data age may happen in rare cases. These cases should be analysed to avoid/minimise their re-occurence. | 16 s |
| [RD 46] § 3.3.11 | <u>Requirement:</u><br>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. | Max 9 s |

### C - 2.1.14 Forwarded pressure altitude correctness

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R9** | The ratio of valid forwarded pressure altitudes that are incorrect shall be equal to or less than **0.1 %.** | 0.1 % |
| [RD 1] § 8.5.4.1 | Statement:<br><br>If the ATC displayed Mode C differs of more than 200 ft (1000 ft vertical separation) / 300 ft (2000 ft vertical separation) the controller shall verify the correctness of Mode C with the pilot. | |
| [RD 2] § 6.3.3.2 | Requirement:<br><br>Validated false Mode C codes: < 0.1 %<br><br>Comment:<br><br>For SSR only, in SASS-C the threshold to declare incorrect Mode C is set to 300 ft. | 0.1 % |
| [RD 4] SPR 10 § 3.4.2 & SPR 13 § 3.5.2 | Requirements:<br><br>The likelihood that the Aircraft Transmit Domain corrupts ADS-B information shall be no more than $10^{-5}$ per flight-hour<br><br>The likelihood that the ADS-B receive subsystem corrupts ADS-B information through the reception, processing or delivery of data (E2) shall be no more than 5 x $10^{-6}$ per ATSU hour.<br><br>Comment:<br><br>These requirements are aggregating all provided data items, not only the pressure altitude data item. There is a need to get traffic load to convert these figures in %; nevertheless they are assumed to be more demanding. | ? |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R9** | The ratio of valid forwarded pressure altitudes that are incorrect shall be equal to or less than **0.1 %.** | 0.1 % |
| [RD 12] Exigences 19-1 & 19-2 | Requirement:<br>The ratio of Mode C codes displayed with a deviation equal to or greater than 300 ft shall not exceed 0.1% of the sub-population of aircraft stable in level flight.<br>The ratio of Mode C codes displayed with a deviation equal to or greater than 300 ft shall not exceed 1.5% of the sub-population of aircraft which are climbing/descending. | 0.1% for stable flights (< 300 ft/mn)<br>1.5 % for vertically moving (> 200 ft/mn) |
| [RD 18] § 6.2.3 | Requirement:<br>The probability of false pressure altitude output from the ground surveillance system is ≤ $1.\ 10^{-3}$ per target report.<br>Comment:<br>Criteria for correctness are in line with [RD 1] § 8.5.4.1: 200 ft for 1000 ft VSM and 300 ft for 2000 ft VSM. | 0.1% |
| [RD 42] SPR 22 & SPR 33 | Requirements:<br>The likelihood of the Aircraft ADS-B function system integrity failure shall be $10^{-5}$ or less per flight-hour<br>The likelihood of an ADS-B Ground Domain system integrity failure shall be $2 \times 10^{-5}$ or less per hour.<br>Comment:<br>These requirements are aggregating all provided data items, not only the pressure altitude data item. There is a need to get traffic load to convert the aircraft domain figure in % of target reports; nevertheless they are assumed to be more demanding. | - |
| [RD 46] § 3.3.7 | Requirement:<br>The Probability of False pressure altitude ***shall*** be less than or equal to **0.1%.** | 0.1 % |

### C - 2.1.15 Pressure altitude unsigned error mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R10** | The pressure altitude unsigned error shall be less than or equal to 200/300 ft in **99.9%** of the cases for stable flights and less than or equal to 300 ft in **98.5%** of the cases for climbing / descending flights. | 99.9 %<br>98.5 % |
| [RD 12] Exigences 19-1 and 19-2 | This requirement is an alternative to the requirements addressing forwarded pressure altitude data age and correctness. It limits the error on pressure altitude, at its time of display, in the same way as the horizontal position error. | 99.9 %<br>98.5 % |
| SSTF #17 | At SSTF #17 it was agreed to put a maximum limit to the vertical speed of 8000 ft/mn and to not address pressure altitude data items corresponding to portion of trajectories exceeding 8000 ft/mn as climbing of descending rate. | |
| | Usually the pressure altitude that is provided to the users is the last valid measured altitude (see § 5.2.5 [RD 2]) because an extrapolated altitude is not enough reliable. However new systems could provide reliable calculated pressure altitude and a new requirement is now defined to cover this type of implementation. | |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R10** | The pressure altitude unsigned error shall be less than or equal to 200/300 ft in **99.9%** of the cases for stable flights and less than or equal to 300 ft in **98.5%** of the cases for climbing / descending flights. | 99.9 %<br>98.5 % |
| [RD 1] § 8.5.5.1.1-2 | For stable flights inside RVSM, respectively non-RVSM, airspace the threshold has been set to 200 ft, respectively 300 ft, because of the requirements specified in ICAO document 4444 [RD 1] § 8.5.5.1.1-2 where it is stated:<br><br>*"8.5.5.1.1 The tolerance value used to determine that pressure-altitude-derived level information displayed to the controller is accurate shall be ±60 m (±200 ft) in RVSM airspace. In other airspace, it shall be ±90 m (±300 ft), except that the appropriate ATS authority may specify a smaller criterion, but not less than ±60 m (±200 ft), if this is found to be more practical. Geometric height information shall not be used for separation.*<br><br>*8.5.5.1.2 Verification of pressure-altitude-derived level information displayed to the controller shall be effected at least once by each suitably equipped ATC unit on initial contact with the aircraft concerned or, if this is not feasible, as soon as possible thereafter. The verification shall be effected by simultaneous comparison with altimeter-derived level information received from the same aircraft by radiotelephony. The pilot of the aircraft whose pressure-altitude-derived level information is within the approved tolerance value need not be advised of such verification. Geometric height information shall not be used to determine if altitude differences exist."*<br><br>It is assumed that when an aircraft is transferred from one ATC centre to another it stays at a stable flight level. | |
| [RD 1] § 8.5.5.2.3-4 | For climbing/descending flights, and irrespective of the airspace, the threshold has been set to 300 ft because of the requirements specified in ICAO document 4444 [RD 1] § 8.5.5.2.3-4 where it is stated:<br><br>*"8.5.5.2.3 Aircraft vacating a level. An aircraft cleared to leave a level is considered to have commenced its manoeuvre and vacated the previously occupied level when the pressure-altitude-derived level information indicates a change of more than 90 m (300 ft) in the anticipated direction from its previously assigned level.*<br><br>*8.5.5.2.4 Aircraft passing a level in climb or descent. An aircraft in climb or descent is considered to have crossed a level when the pressure-altitude-derived level information indicates that it has passed this level in the required direction by more than 90 m (300 ft)."* | |

### C - 2.1.16 Change in emergency indicator/SPI report delay mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R11** | The time between changing the emergency indicator / SPI report on board the aircraft and availability of the new value at the output of the surveillance system shall be equal to or less than **12 s**. | 12 s |
| **SSTF#14** | Calculations have been made on the basis of single radar and multi-radar tracker configurations and the figure of 12 s has been agreed for this requirement. | 12 s |
| **SSTF#21** | At SSTF #21 it was agreed that this delays must be applicable for 100% of the cases, however it is also recognised that cases of higher delay may happen in rare cases. These cases should be analysed to avoid/minimise their re-occurence. | 12 s |
| [RD 4] SPR 22 § 3.5.2 | <u>Requirement:</u><br>For 5 NM separation – The time to alert for a change in Surveillance Emergency/SPI Reports measured at point E2 shall be no longer than 10s for with a probability of 95%.<br><u>Note:</u><br>The point E2 is at the input of the ATC Processing System before the ATC Display System. | 10 s |
| [RD 42] SPR 50 | <u>Requirements:</u><br>For 5 NM separation – The time interval between a change of emergency and SPI information provided by the ADS-B aircraft domain and an ADS-B surveillance report containing the new emergency and SPI information at interface E2 shall be no longer than 8 seconds (95%) En Route.<br><u>Comment:</u><br>Interface E2 is between Ground ADS-B Receive Function and Ground ADS-B Surveillance Processing Function. Interface E2 is inside the ADS-B Ground Domain, therefore the performance at the ATCO level should be worse. It is not possible to compare these requirements | 8 s |

### C - 2.1.17 Change in aircraft identity delay mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R12** | The time between changing the aircraft identity on board the aircraft and availability of the new value at the output of the surveillance system shall be equal to or less than **24 s**. | 24 s |
| SSTF #12-15 | The objective of this requirement is to limit the latency of a change of aircraft identity (forwarded data item) inside the surveillance system. There is currently no equivalent requirement in any standard (except SPR 25 in [RD 4]) from which this requirement can be traced. The inclusion of the requirement was agreed at SSTF meeting #12 and the threshold value was agreed during STTF meeting #15. | 24 s |
| SSTF #21 | At SSTF #21 it was agreed that this delays must be applicable for 100% of the cases, however it is also recognised that cases of higher delay may happen in rare cases. These cases should be analysed to avoid/minimise their re-occurence. | 24 s |
| [RD 4] SPR 25 § 3.5.2 | <u>Requirement:</u><br>The update interval for Surveillance Reports containing only ADS-B Identity data associated with any single aircraft shall be less than 100s with a probability of 95%.<br><u>Comment:</u><br>This requirement is not clear and not further explained in document [RD 4]. | 100 s |
| [RD 41] § 1.2.2.1.1.3 | <u>Requirement:</u><br>Any change of Identity shall be reported at the output of the surveillance system in less than 20s. | 20 s |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R12** | The time between changing the aircraft identity on board the aircraft and availability of the new value at the output of the surveillance system shall be equal to or less than **24 s**. | 24 s |
| [RD 42] SPR 51 | Requirements:<br><br>For 5 NM separation – The time interval between a change of Mode A code provided by the ADS-B aircraft domain and an ADS-B surveillance report containing the new Mode A code at interface E2 shall be no longer than 8 seconds (95%) En Route.<br><br>Comment:<br><br>Interface E2 is between Ground ADS-B Receive Function and Ground ADS-B Surveillance Processing Function. Interface E2 is inside the ADS-B Ground Domain, therefore the performance at the ATCO level should be worse. It is not possible to compare these requirements. | 8 s |

### C - 2.1.18 Correct and valid aircraft identity probability of update mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R13** | The probability of update of correct and valid aircraft identity (Mode A or aircraft identification) shall equal or greater than 98% globally.. | 98 % |
| SSTF #19 | At SSTF #19 it has been agreed that this type of requirement was lacking and the value of 98 % was agreed. | 98 % |
| [RD 2] § 6.3.2.4 | Requirement:<br>Overall Mode A probability of code detection: > 98 %<br>Comment:<br>For 1 SSR only and for Mode A only. | 98 % |
| [RD 42] SPR 49 | Requirement:<br>For 5 NM separation – The probability of providing a Surveillance Report containing newly received ADS-B Position data of sufficient quality associated with any aircraft in En Route airspace within 8 seconds shall be 97%.<br>Comment:<br>For ADS-B only. It is assumed that “ADS-B Position data” encompasses all the data items listed in SPR 27 which include aircraft identity. As the requirement is on the proportion of target reports with horizontal position therefore the achieved ADS-B performance should be 100 % minus the cases of pressure altitude integrity error. | 100 - % |
| [RD 46] § 2.8.2 | Requirement:<br>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%**. | 98 % |
| [RD 19] § 4.2.4.1.4 | Requirement:<br>As a minimum, the overall Mode 3/A probability of correct and valid code detection shall be better than 98% for large samples, without any geographical restrictions, of opportunity traffic. | 98 % |

### C - 2.1.19 Aircraft identity correctness

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R14** | The ratio of valid aircraft identities that are incorrect shall be equal to or less than **0.1 %**. | 0.1 % |
| [RD 2] § 6.3.3.2 | Requirement:<br>Validated false Mode A codes: < 0.1 %<br>Comment:<br>For SSR only and for Mode A only. | 0.1 % |
| [RD 4] SPR 10 § 3.4.2 & SPR 13 § 3.5.2 | Requirements:<br>The likelihood that the Aircraft Transmit Domain corrupts ADS-B information shall be no more than $10^{-5}$ per flight-hour<br>The likelihood that the ADS-B receive subsystem corrupts ADS-B information through the reception, processing or delivery of data (E2) shall be no more than $5.10^{-6}$ per ATSU hour.<br>Comment:<br>These requirements are aggregating all provided data items, not only the aircraft identity data item. There is a need to get traffic load to convert these figures in %; nevertheless they are assumed to be more demanding. | ? |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5N_C-R14** | The ratio of valid aircraft identities that are incorrect shall be equal to or less than **0.1 %**. | 0.1 % |
| [RD 18] § 7.2.3 | <u>Proposed requirement:</u><br>The probability of an incorrect identification data output from ground system is ≤ $1x10^{-3}$ per target report. | 0.1 % |
| [RD 42] SPR 22 & SPR 33 | <u>Requirements:</u><br>The likelihood of the Aircraft ADS-B function system integrity failure shall be $10^{-5}$ or less per flight-hour<br>The likelihood of an ADS-B Ground Domain system integrity failure shall be 2 x $10^{-5}$ or less per hour.<br><u>Comment:</u><br>These requirements are aggregating all provided data items, not only the aircraft identity data item. There is a need to get traffic load to convert the aircraft domain figure in % of target reports; nevertheless they are assumed to be more demanding. | - |
| [RD 46] § 3.3.7 | <u>Requirement:</u><br>The Probability of False Mode A code detection shall be less than or equal to 0.1%.<br>The Probability of False ACID detection shall be less than or equal to 0.1%. | 0.1 % |

### C - 2.1.20 Rate of climb/descent error recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R15 | The RMS error of the rate of climb/descent should be equal to or less than **250 ft/mn** for stable flights and should be equal or less than **500 ft/mn** for climbing/descending flights. | 250 ft/mn (stable)<br>500 ft/mn (climbing/descending) |
| SSTF #12-15 | The objective of this requirement is to specify the error on the rate of climb/descent. There is currently no equivalent requirement in any standard from which this requirement can be traced from. The initial value proposed at SSTF #12 has been reviewed at SSTF #15and has been found feasible. | |
| SSTF #17 | At SSTF #17 it was agreed to limit the assessment to climbing and descending rates that are below 8000 ft/mn. | |
| SSTF #19 | At SSTF #19 on the basis of the measurements presented by DSNA/DTI it was agreed to differentiate between stable flights and climbing/descending flights on the same basis as for the accuracy of the pressure altitude data item. It was also agreed to calculate the RMS error rather than the average error which is a more relevant parameter to report on the accuracy of the pressure rate. | 250 ft/mn (stable)<br>500 ft/mn (climbing/descending) |

### C - 2.1.21 Track velocity errors recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R16 & 5N_C-R17 | The RMS error of the track velocity and track velocity angle should be, respectively, equal to or less than **4 m/s and 10 °** for portions of trajectories in straight line and equal to or less than **8 m/s and 25 °** for portions of trajectories in turn. | 4/8 m/s<br>10/25 ° |
| SSTF #17 | The objective of this requirement is to specify the error on the track velocity when this data item is provided by the surveillance system. The same value as for 3 NM separation (based on actual system performance) have been used although the speed accuracy should be worse in the case of 5 NM separation because of the longer update interval but on the other side it should be better because in this airspace the aircraft are less manoeuvring and there is also a higher level of sensor overlapping coverage in that airspace. | 4/8 m/s<br>10/25 ° |

### C - 2.1.22 Uncorrelated false target report mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R18 | The density of uncorrelated false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals (450 updates periods of 8 s equal 1 hour) shall be less than or equal to 10. | 10 |
| [RD 2] § 6.3.2.2 & 6.3.2.3 | <u>Requirement:</u><br>Overall false target report ratio: < 0.1 %<br>Overall multiple SSR target report ratio: < 0.3 %<br><u>Comment:</u><br>Derived from SSR only requirements and aggregating all sources of false plots (false and multiple). Although the requirement is not expressed in a similar way, it seems less demanding. | 0.4 % |
| [RD 4] SPR 10 § 3.4.2 & SPR 13 § 3.5.2 | <u>Requirements:</u><br>The likelihood that the Aircraft Transmit Domain corrupts ADS-B information shall be no more than $10^{-5}$ per flight-hour.<br>The likelihood that the ADS-B receive subsystem corrupts ADS-B information through the reception, processing or delivery of data (E2) shall be no more than 5. $10^{-6}$ per ATSU hour.<br><u>Comments:</u><br>Although it is not possible to convert the above figure in accordance with the specified indicator, that requirement is deemed more demanding. | - |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R18 | The density of uncorrelated false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals (450 updates periods of 8 s equal 1 hour) shall be less than or equal to 10. | 10 |
| [RD 40] § 6.4 Approach #3 En route airspace | Requirements:<br><br>The number of false target reports per area of 900 $NM^2$ and per time interval of 30 minutes shall be less than or equal to 5.<br><br>Comments:<br><br>This requirement has been defined on the basis of user requirements and on the basis of assessments made on few datasets. It requires further analysis to confirm its applicability and relevance. For consistency the requirement has been expressed per hour.<br><br>At SSTF #19 it was agreed to convert the duration in a number of update interval to normalise the requirement irrespective of the selected update interval. The number of update interval being equal to 1 hour divided by the maximum allowed update interval. | 5 false target reports per 900 $NM^2$ and per 30 min |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R18 | The density of uncorrelated false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals (450 updates periods of 8 s equal 1 hour) shall be less than or equal to 10. | 10 |
| [RD 42] SPR 14, SPR 22 & SPR 33 | Requirements:<br><br>The probability that a horizontal position error exceeds the integrity containment bounds for more than 10 seconds without reflecting the fact at B1 shall be no greater than 0.001.<br><br>The likelihood of the aircraft ADS-B function system integrity failure shall be $10^{-5}$ or less per flight hour.<br><br>The likelihood of an ADS-B Ground Domain system integrity failure shall be 2 x $10^{-5}$ or less per hour.<br><br>Comment:<br><br>The first requirement is provided per flight hour (to be clarified/confirmed) and for a containment radius of 1 NM (close to the 2100 m maximum error). The second requirement is not specific to horizontal position data item, so the probability of integrity failure of horizontal position mad by the ground system should be smaller. Nevertheless, assuming that 900 $NM^2$ is the size of a sector and the high density traffic characteristics defined in [RD 42] (6 flight hours per sector and per hour) this requirement is more demanding (less than 0.00606 false target report per hour and per sector). | 0.00606 |
| SSTF #19 | At SSTF #19, it was agreed to specify the duration not as an absolute value but as a number of update intervals so as to normalise the requirement irrespective of the selected update interval. Therefore a value of 450 update intervals was agreed corresponding to one hour when update interval is 8 s. | |

### C - 2.1.23 Falsely confirmed track mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R19 | The number of falsely confirmed tracks close to true tracks (less than 7 NM) shall be less than or equal to 2 per hour and not simultaneous. | 2 |
| [RD 40] § 6.4 Approach #4 TMA airspace | Requirements:<br><br>The number of false tracks close to true tracks (less than 7 NM) shall be less than or equal to 2 per hour.<br><br>Comments:<br><br>This requirement has been defined on the basis of user requirements and on the basis of assessments made on few datasets. It requires further analysis to confirm the figures.<br><br>Before SSTF #17 it has been proposed to add the condition that the two false tracks must not appear simultaneously. | 2 false tracks per hour closer than 7 NM from true tracks |

### C - 2.1.24 Ground system continuity recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **$2.5\ 10^{-5}$** per hour of operation. | $2.5\ 10^{-5}$ |
| SSTF #12 | It was agreed during SSTF meeting #12. | $2.5\ 10^{-5}$ |
| [RD 2] § 5.3.2 | Requirement:<br><br>The radar surveillance data availability requirements are:<br>• full data availability shall be not less than 0.995, excluding periods of scheduled maintenance;<br>• essential data availability shall be not less than 0.99999;<br>• PSR data availability for major terminal areas shall be not less than 0.995.<br><br>Full data are:<br>• aircraft horizontal position and history;<br>• aircraft identification;<br>• aircraft vertical position;<br>• specific indication of Mode A special codes (i.e. 7500,7600,7700);<br>• ground speed;<br>• status of the Track whether it is primary, secondary, combined or extrapolated.<br><br>Essential data are:<br>• aircraft horizontal position and history;<br>• aircraft identification or Mode A code;<br>• aircraft vertical position.<br><br>Comment:<br><br>It is not possible to convert availability figure to probability of failure. However the requirement on essential data seems more demanding. | ? |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 4] § 3.5.2<br>SPR 14 & SPR 15 | <u>Ground Performance Requirement:</u><br><br>Availability and continuity requirements for ground equipment are left to local authorities. Factors that are recommended to be considered for developing these requirements include traffic density, traffic patterns, and criticality of services being provided.<br>SPR 14: The likelihood that ADS-B Receive subsystem does not provide updated ADS-B surveillance reports for more than one aircraft from which ADS-B messages are being received shall be no more than 5. $10^{-6}$ per ATSU hour.<br>SPR 15: The likelihood that the ADS-B receive subsystem does not provide updated ADS-B surveillance reports for one aircraft from which ADS-B messages are being received shall be no more than $10^{-4}$ per ATSU hour.<br><u>Comment:</u><br><br>For reliability of ADS-B ground only.<br><br>See below extract of B.4.4.2 Reliability requirements<br><br>Within the context of the ADS-B-NRA application it has been decided to only consider continuity requirements for the ground system. This was done because the scope of the OSED is limited to when aircraft have already entered non-radar airspace. This means that the operation has already commenced, and therefore was “available” at the start of the operation. What is specified in this OPA (and in the SPR requirements in section 3) is the continuity – the likelihood the system will be working normally for the entire flight of any one aircraft through the sector of NRA airspace. | 5. $10^{-6}$ for at least 2 aircraft |
| [RD 36] § 8.4.5 | <u>Safety Objectives ADS-B-NRA:</u><br><br>Safety objective of sudden and unexpected loss of position information for <u>multiple</u> aircraft previously identified in the sector detected by ATCO is 2.9 $10^{-4}$ per ATSU hour (severity 3) for En-Route (i.e. 5 NM horizontal separation).<br><br><u>Comment:</u><br><br>This is a safety objective not a performance requirement. | 2.9 $10^{-4}$ |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 37] § 5.3 | <u>Safety objective WAM:</u><br><br>Safety objective of detected loss of horizontal position for more than one aircraft is 6. $10^{-4}$ per ATSU hour (severity 3) for En-Route (i.e. 5 NM horizontal separation). | 6. $10^{-4}$ |
| [RD 38] § 4.6 and 7.2 | <u>Safety objectives ARTAS software:</u><br><br>Safety objective of total loss of aircraft lateral position information (ARTAS system tracks) within an ARTAS DOI is less than 1. $10^{-5}$ per ATSU hour (with fallback system) and less than 1. $10^{-6}$ per ATSU hour (without fallback system).<br><br><u>Comment:</u><br><br>This is a safety objective not a performance requirement.<br><br><u>Measured hazard rate on operational ARTAS software:</u><br><br>Hazard: total loss of aircraft lateral position information (ARTAS system tracks) within an ARTAS DOI.<br><br>Raw measurement: 2.7 $10^{-5}$ per ATSU hour (based on 185.000 hours of operation).<br><br>Theoretical rate (@ 50% confidence): 3.1 $10^{-5}$ per ATSU hour.<br><br>Theoretical rate (@ 90% confidence): 5. $10^{-5}$ per ATSU hour. | 1. $10^{-5}$<br><br>2.7 $10^{-5}$ |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 39] § 2.2 | Safety objectives Mode S system:<br><br>Maximum tolerability of System derived loss of aircraft horizontal position is 3.3 $10^{-9}$ per flight hour.<br><br>Assuming high traffic density it gives a figure of 3.3 $10^{-6}$ per ATSU hour.<br><br>Assuming low/medium traffic density it gives a figure of 3.3 $10^{-7}$ per ATSU hour.<br><br>Comment:<br><br>This is a safety objective not a performance requirement. | 3.3 $10^{-7}$ |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 19] § 14.2.2.2 | Requirement:<br><br>The availability calculation excludes all planned downtimes.<br><br>The figures for Availability quoted in this Specification are for Operational Availability ($A_o$) and shall be calculated using the following equation:<br><br>$A_o = MTBF / (MTBF + MTTR + MRT)$<br><br>MTBF = Mean Time Between Failures in hours.<br><br>MTTR = Mean Time To Repair in hours.<br><br>MRT = Mean Response Time in hours (i.e. the average time from notification of failure for a technician to be ready to commence repair action).<br><br>The operational availability of coherent and full radar data from the Mode S ground station site shall be greater than 99.98%.<br><br>The system reliability requirement for each Mode S ground station as described in Figure 3 (excluding Local Display and Recording/Playback facility) shall be greater than 20,000 hrs MTBF.<br><br>MTTR at Organisational Level shall be 30 (thirty) minutes.<br><br>The following figures are given for Tender Evaluation purposes:<br><br>(a) The MRT shall be 3.5 hours;<br><br>(b) The maximum time to repair shall not exceed 8 (eight) hours for 95% of all repairs;<br><br>(c) The maximum response time shall not exceed 8 (eight) hours.<br><br>Comment:<br><br>For a single Mode S sensor taking into account that the probability of failure is equal to 1/MTBF. | 5. $10^{-5}$ |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 5N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 42] SPR 20 & SPR 34 | Requirements:<br>The continuity of the ADS-B Aircraft Domain shall be 0.9998 per flight hour.<br>The likelihood of a Ground ADS-B Receive function continuity failure shall be $10^{-5}$ or less per hour.<br>Comment:<br>The probability of failure of the complete system will happen if all the ADS-B Aircraft Domains fail or if the ADS-B ground domain fails. The combined probability equals to $(2.\ 10^{-4})^N + 10^{-5}$ where N is the number of aircraft managed by the system. This calculation does not take into account the other components of the ADS-B ground domain. So the continuity of the complete system depends on the continuity of the ground domain which is equal, in the worst case, to $10^{-5}$; the contribution of the aircraft domain is negligible as long as N is greater than 2. | $10^{-5}$ |
| [RD 46] § 2.8.2 | Requirement:<br>The availability figure defined will typically be met with MTBCF and MTTR figures of 10,000 hours and 1 hour respectively.<br>Comment:<br>Indicative figure. | $10^{-4}$ |

## C - 2.2 3N_C: 3 NM horizontal separation

### C - 2.2.1 Update interval mandatory requirements

| Ref | Performance requirement statement/ Comment | Requirement threshold 1000 ft VSM | Requirement threshold 2000 ft VSM |
|---|---|---|---|
| **3N_C-R1** | The applicable update interval for horizontal position, pressure altitude and aircraft identity data items shall be set to **5 s** or less. | 5 s | |
| [RD 2] § 5.2.4 | Requirement:<br>Surveillance information updates shall enable the display updates to be no more than 5 seconds (s) for major terminal areas. | 5 s | |
| [RD 4] SPR 23 § 3.5.2 | Requirement:<br>For 3 NM separation – The update interval for Surveillance Reports containing any new ADS-B Position data associated with any single aircraft shall be no longer than 5 s with a probability of 95%.<br>Comment:<br>For ADS-B only. | 5 s | |
| [RD 12] Exigence 18 | Requirement:<br>The duration separating two screen refreshes relating to the same aircraft shall not in principle exceed the following:<br>• 5 s for a target separation minimum M, if 2 NM < M ≤ 3 NM | 5 s | |

| Ref | Performance requirement statement/ Comment | Requirement threshold 1000 ft VSM | Requirement threshold 2000 ft VSM |
|---|---|---|---|
| **3N_C-R1** | The applicable update interval for horizontal position, pressure altitude and aircraft identity data items shall be set to **5 s** or less. | 5 s | |
| [RD 18] § 6.3.3 | Proposed requirement:<br>The maximum data age of pressure altitude measured at the output of the ground system is:<br>• 1000ft separation = 5s<br>• 2000ft separation = 8s | 5 s | |
| [RD 42] SPR 53 | Requirement:<br>For 3 NM separation – The probability of providing a Surveillance Report containing newly received ADS-B Position data of sufficient quality associated with any aircraft in TMA airspace within 5 seconds shall be 97%.<br>Comment:<br>For ADS-B only. | 5 s | |
| [RD 46] § 3.3.1 | Requirement:<br>The defined *Update Interval* ***shall*** not exceed the following:<br>• 5 seconds for the TMA application<br>Comment:<br>For WAM only. | 8 s | |

### C - 2.2.2 Update interval recommended requirements

| Ref | Performance requirement statement/ Comment | Requirement threshold |
| --- | --- | --- |
| 3N_C-R1 | The applicable update interval for horizontal position, pressure altitude and aircraft identity data items should be set to **4 s** or less. | 4 s |
| SSTF #12 | It was agreed during SSTF meeting #12 that to take into account the future traffic increase in Europe it is needed to align the update interval for future system to the update interval currently applied in high-medium density airspace. | 4 s |

### C - 2.2.3 Horizontal position and pressure altitude probability of update mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R2** | The probability of update of the horizontal position and the pressure altitude in accordance with the applicable update interval shall be equal to or higher than **97 %** per flight. | 97 % (per flight) |
| [RD 2] § 6.3.2.1 | Requirement:<br>Target Position Detection<br>Overall probability of detection: > 97 %<br>Comment:<br>For 1 SSR only.<br>For 2 independent SSR's the requirement should be 99.91 %.<br>There is no requirement per flight; therefore it is not possible to compare them with the requirement above. | 97 % or 99.91 % (globally) |
| [RD 4] SPR 23 § 3.5.2 | Requirement:<br>For 3 NM separation – The update interval for Surveillance Reports containing any new ADS-B Position data associated with any single aircraft shall be no longer than 5 s with a probability of 95%. | 95 % (per flight) |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R2** | The probability of update of the horizontal position and the pressure altitude in accordance with the applicable update interval shall be equal to or higher than **97 %** per flight. | 97 % (per flight) |
| [RD 12] Exigence 18 | <u>Requirement:</u><br>The duration separating two screen refreshes relating to the same aircraft shall not in principle exceed the following:<br>• 5 s for a target separation minimum M, if 5 NM < M ≤ 3 NM<br>Any exceeding of these limits shall be considered individual cases and shall accordingly be the subject of a detailed analysis included in the Radar Separation Minimum Dossier (RSMD).<br>Such analysis will make it possible to ascertain the cause of the occurrence, the potential operational implications, its classification in the seriousness table, a theoretical estimation of its frequency, the possible proposal of mitigating measures and its acceptability vis-à-vis regulations.<br><u>Comment:</u><br>According to the above, any missed target report should be very rare as it will require a specific analysis. Although it is not expressed as a probability of update, it is deemed that this requirement is more demanding. | ? |
| [RD 42] SPR 53 | <u>Requirement:</u><br>For 3 NM separation – The probability of providing a Surveillance Report containing newly received ADS-B Position data of sufficient quality associated with any aircraft in TMA airspace within 5 seconds shall be 97%. | 97 % (per flight) |
| [RD 46] § 3.3.3 | <u>Requirement:</u><br>The *Probability of position detection* within the defined *Update Interval* ***shall*** be greater than or equal to **97%** for any target. | 97% (per flight) |

### C - 2.2.4 Horizontal position and pressure altitude probability of update recommended requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C_R2 | The probability of update of the horizontal position and the pressure altitude in accordance with the applicable update interval (see **Req. 01**) should be equal to or higher than **99 %** globally and equal to or higher than **97 %** per flight. | 99 % (globally)<br>97 % (per flight) |
| SSTF #12 | It was agreed during SSTF meeting #12 that to take into account the future traffic increase in Europe it is needed to align the probability of update of positional information for future system to the probability of update of positional information currently achieved in high-medium density airspace. | 99 % |
| SSTF #21 | It is proposed to supplement with the mandatory requirement of 97 % per flight with a global requirement of 99 %. | 99 % (global)<br>97 % (per flight) |

### C - 2.2.5 Ratio of missed 3D position involved in long gaps mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R3** | The ratio of missed 3D position (either horizontal position or pressure altitude missing) involved in long gaps (3 times the maximum update interval + 10% = 16.5 s) shall be equal to or less than **0.1 %**. | 0.1 % |
| SSTF #12-15 | The objective of this requirement is to limit the size of trajectory gaps without full 3D position information. The inclusion of the requirement was agreed at SSTF meeting #12 and the gap size was agreed during STTF meeting #15. | 0.1 % |
| [RD 46] § 3.3.4 | <u>Requirement:</u><br>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%.<br><u>Comment:</u><br>Assumed to be equivalent when WAM system provides synchronous outputs. | 0.1% |

### C - 2.2.6 Horizontal position error mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **300 m** RMS globall and equal to or less than **330 m** RMS per flight. | 300 m (global)<br>330 m (per flight) |
| [RD 2] § 5.2.3 | Requirement:<br><br>The positional accuracy of the surveillance radar data available, at the control position, shall have an error distribution with a **root mean square (RMS)** value equal to or less than **300 metres (m)** for major terminal areas. | 300 m |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **300 m** RMS globall and equal to or less than **330 m** RMS per flight. | 300 m (global)<br><br>330 m (per flight) |
| [RD 4] SPR 5<br>§ 3.4.2.1 | Requirement:<br><br>For ADS-B Airborne, the 95% accuracy of the horizontal position shall be less than **0.3 NM**.<br><br>Quality indicators that are transmitted in ADS-B messages shall account for any uncompensated latency on-board the aircraft.<br><br>***NOTE1:*** *Quality Indicators, particularly accuracy, as used in this document include all contributing factors for the uncertainty of position data with respect to the time of applicability for that data. These factors include the uncertainty of the position measurement and any uncompensated latency prior to transmission of the data.*<br><br>Comment:<br><br>Equivalent requirements for ADS-B only (556 m converted in RMS, assuming Rayleigh distribution, gives 321 m), but does not take into account position error due to latency of the information on the ground. There are separated requirements for specifying information latency (Airborne part: less than 1.5 second for 95%, ground part: less than 0.5 second for 95%).<br><br>In [RD 4] Appendix B.1.3 it is further stated: *"Finally, any uncompensated on-board latency or timing uncertainties that are not known to the ground will have the effect of degrading the position accuracy (predominantly in the along-track direction) of the ADS-B information received by the ground."*<br><br>Therefore it is unclear whether or not the error due to uncompensated latency is included or not in the requirement.<br><br>This requirement is also to be combined with the data integrity requirements for the airborne (SPR 10 $1.10^{-5}$ per flight hour) and the ground part (SPR 13 $5.10^{-6}$ per hour of operation). | 321 m (global)<br><br>321 m (per flight) |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **300 m** RMS globall and equal to or less than **330 m** RMS per flight. | 300 m (global)<br>330 m (per flight) |
| [RD 12] Exigence 12 | <u>Requirement:</u><br>The overall RMS shall not exceed the following thresholds:<br>• **300 m** for a target separation minimum of 3 NM<br><u>Comment:</u><br>It should be noted that the requirement shall also be met when the measurement is made on the basis of turning aircraft trajectories only. | 300 m (global) |
| [RD 13] § 6.4 Tables 15 & 16 | <u>Proposed requirement:</u><br>Position error standard deviation shall be less than 370 m.<br><u>Comment:</u><br>Even though it is not possible to convert this value to RMS it is deemed relatively close. | ? m |
| [RD 14] § 10.13 Table 3 & § 10.15 Table 4 | <u>Proposed requirement:</u><br>Proposed values for 95% containment value is 556 m (0.3 NM) with a standard deviation of 185 m (0.1 NM).<br><u>Comment:</u><br>Even though it is not possible to convert these values to RMS it is deemed relatively close. | ? m |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **300 m** RMS globall and equal to or less than **330 m** RMS per flight. | 300 m (global)<br><br>330 m (per flight) |
| [RD 19] § 4.2.6.2 & 4.2.6.3 | Requirements:<br><br>(i) All SSR Random errors shall be less than 30 m RMS (1 sigma)<br><br>(ii) All Mode S Random errors shall be less than 15 m RMS (1 sigma)<br><br>All azimuth error standard deviations shall be less than 0.068° (one sigma)<br><br>Comment:<br><br>For a single Mode S sensor and without taking into account information latency (maximum 2 s).<br><br>Assuming no bias and that the azimuth error is Gaussian and is the main component of the position error and taking into account maximum operational range for 3 NM separation is 80 NM. | 176 m (global) |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R4** | Horizontal position error, **including measurement error and error due to information latency**, shall be equal to or less than **300 m** RMS globall and equal to or less than **330 m** RMS per flight. | 300 m (global)<br><br>330 m (per flight) |
| [RD 42] SPR 12 | Requirement:<br><br>For 3 NM separation – The 95% accuracy of the measured horizontal position shall be less than 171 metres ($NAC_P$ = 8).<br><br>Comment:<br><br>More demanding requirement for ADS-B only (171 m @95% converted in RMS, assuming Rayleigh distribution, gives 99 m), but does not take into account position error due to information latency. There are separated requirements for specifying horizontal position latency (Airborne part: less than 0.6 second (uncompensated) for 95% SPR 24, ground part: less than 0.5 second for 95% SPR 35). It is also stated that these latencies are partially compensated (airborne) or fully compensated (ground), such compensation will introduce a budget error that is not possible to quantify without further assumptions. | 99 m (global)<br><br>99 m (per flight) |
| [RD 46] § 3.3.8 & 3.3.11 | Requirement:<br><br>The Horizontal position errors ***shall*** not exceed:<br><br>• 150 m RMS for the TMA application<br><br>**NOTE1:** The horizontal position error is calculated for the time of applicability provided by the target report.<br><br>In *Periodic Predicted Mode*, when the *Predicted Position* at time of output is transmitted, the maximum *Processing delay* ***shall*** be 0.5 second.<br><br>Comment:<br><br>Horizontal position error due to processing delay has to be added. | 150 m (global) |

### C - 2.2.7 Horizontal position error recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R4 | Horizontal position error, **including measurement error and error due to information latency**, should be equal to or less than **210 m** RMS global and equal to or less than **230 m** RMS per flight. | 210 m (global)<br>230 m (per flight) |
| SSTF #12-19 | It was agreed during SSTF meeting #12 that to take into account the future traffic increase in Europe it is needed to align the horizontal position error for future system to the horizontal position error currently achieved in high-medium density airspace.<br>At SSTF #19 it was agreed to keep the same ratio between the mandatory and the recommended performance requirements for 5 and 3 NM horizontal separation, therefore 200 m agreed at SSTF #12 has been amended as 210 m. | 210 m (global) |
| SSTF #21 | At SSTF #21 it was agreed to supplement the global requirement on RMS horizontal position error with a requirement per flight with an additional margin to take account of the limited number of samples when performing an assessment per flight. | 230 m (per flight) |

### C - 2.2.8 Horizontal position outlier criteria

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **§ 5.1.5** | The criteria on horizontal position error for declaring a target report as outlier, **including measurement error and error due to information latency**, shall be equal to **1690 m**. | 1690 m |
| [RD 41]<br>§ 1.2.2.1.2.1 | <u>Requirement:</u><br><br>Maximum horizontal position error shall be less than half of the chosen separation minimum minus a specified safety buffer.<br><br>Note 1: The maximum horizontal position uncertainty is assumed to occur at the end of the update interval.<br><br><u>Comment:</u><br><br>The value of 1690 m has been derived from the 2780 m value assuming a maximum aircraft speed of 400 knots (D - 4.3.2), an update interval of 5 s and an aircraft size of 60 m. This is further illustrated on Figure 31 below. | 2780 m |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|

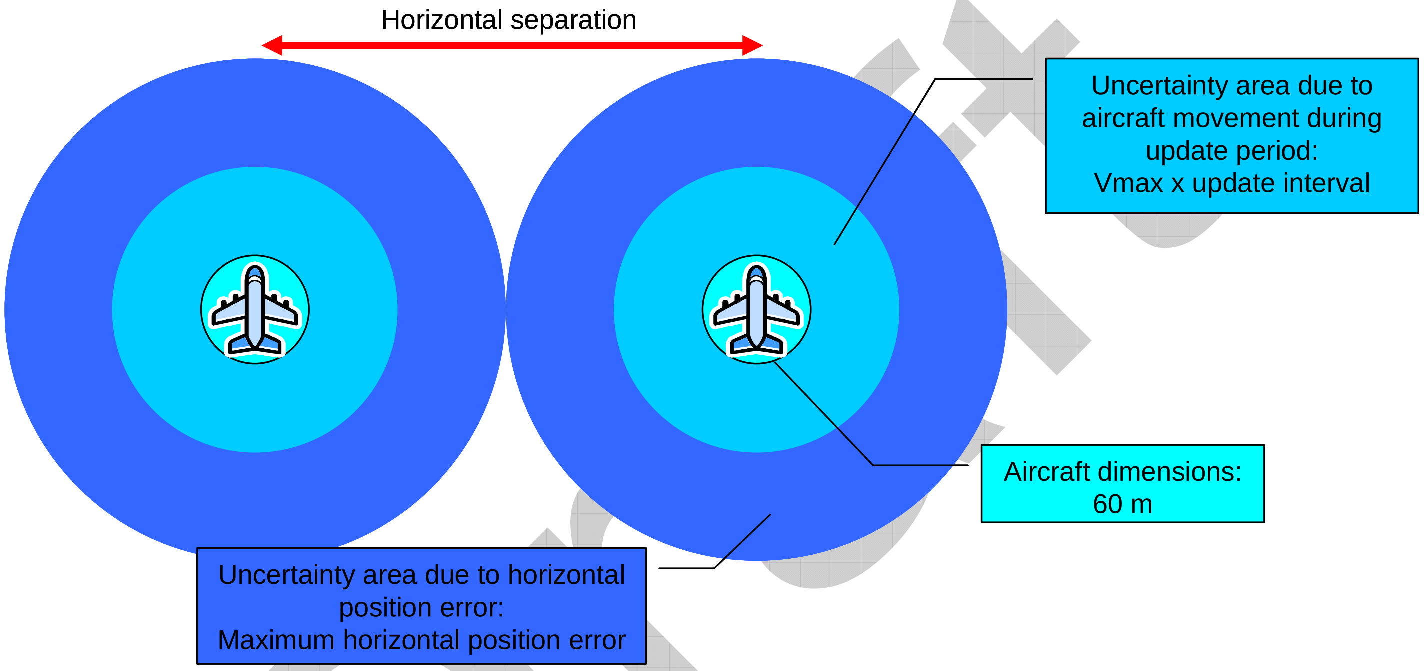


Figure 31: Maximum horizontal position

Provided that the position error remains in the dark blue area  the probability to be in collision during the period of display is null, even in the worst case of the two aircraft heading on. This simple approach does not address the evolution of the aircraft trajectory during the next updates.

### C - 2.2.9 Ratio of correlated horizontal position error recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R5 | There should be no more than **0.03 %** of position reports included in a series of correlated horizontal position errors in the same direction, larger than **556 m** and during more than **3 update intervals**. | 0.03 %<br>556 m<br>3 updates |
| [RD 12] Exigence 5 | Requirement:<br>The ratio of plots with a correlated deviation (i.e. the plots with an across deviation greater than **M/10** immediately preceded or followed (i.e. on the preceding or subsequent antenna revolutions) by two plots with an across deviation in the same direction greater than **M/20**) in the area of interest of the control unit served by the image evaluated shall not exceed **0.03%**.<br>Comment:<br>**M** is the applicable separation minima (i.e. 3 NM)<br>Statement derived from SSR only requirements. The amount of error to declare correlated errors is smaller but is limited to across error. | 0.03 %<br>556-278-278 m<br>278-278-556 m<br>3 updates |

### C - 2.2.10 Horizontal position relative time of applicability recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R6 | The relative time of applicability of horizontal position of close aircraft (separated by less than 10 NM horizontally) should be equal to or less than **0.3 s** RMS. | 0.3 s |
| [RD 12] Exigence 16 | Requirement:<br>The RMS of the time deviations separating the position update of the aircraft in proximity shall not exceed the following thresholds:<br>• 0.3 s for a target separation minimum M, if 2 NM < M ≤ 3 NM<br>Comment:<br>The requirement is put on the relative time of display between aircraft separated by less than 10 NM. | 0.3 s |

### C - 2.2.11 Correct pressure altitude probability of update mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R7** | The probability of update of correct and valid pressure altitude in accordance with the applicable update interval shall be equal to or higher than **96 %.** | 96 % |
| [RD 2] § 6.3.2.4 | <u>Requirement:</u><br>Overall Mode C probability of code detection: > 96 %<br><u>Comment:</u><br>For 1 SSR only. | 96 % |
| [RD 4] SPR 19 § 3.5.2 | <u>Requirement:</u><br>For 5 NM separation – The update interval for Surveillance Reports containing any new ADS-B Position data associated with any single aircraft shall be no longer than 5 s with a probability of 95%.<br><u>Comment:</u><br>For ADS-B only, it is considered that ADS-B target reports always contain horizontal position and pressure altitude so the ratio should be 100 % minus the cases of pressure altitude integrity error. | 100- % |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R7** | The probability of update of correct and valid pressure altitude in accordance with the applicable update interval shall be equal to or higher than **96 %**. | 96 % |
| [RD 42] SPR 49 | Requirement:<br><br>For 5 NM separation – The probability of providing a Surveillance Report containing newly received ADS-B Position data of sufficient quality associated with any aircraft in En Route airspace within 5 seconds shall be 97%.<br><br>Comment:<br><br>For ADS-B only. It is assumed that “ADS-B Position data” encompasses all the data items listed in SPR 27which include aircraft horizontal position data and pressure altitude so the ratio should be 100 % minus the cases of pressure altitude integrity error. | 100- % |
| [RD 46] § 3.3.3 & 3.3.6 | Requirement:<br><br>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%.** | 96% |

### C - 2.2.12 Forwarded pressure altitude average data age mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R8** | The average data age of the forwarded pressure altitude reported in all target reports shall be equal to or less than **2.5 s**. | 2.5 s |
| SSTF #12-15 | The objective of this requirement is to limit the latency of pressure altitude (forwarded data item) inside the surveillance system. There is currently no equivalent requirement in any standard from which this requirement can be traced. This value has been proposed during STTF meeting #12 and is based on current surveillance system experience. At SSTF meeting #15 it was reported that some systems are not able to meet this requirement. | 2.5 s |
| [RD 4] SPR 12 § 3.4.2.2 – SPR 16 § 3.5.2 | Requirement:<br>For barometric altitude, aircraft identification, mode A code, SPI and Emergency indicators, the Airborne Transmit Domain shall have a latency no greater than specified in current implementations for SSR.<br>The 95% latency for ADS-B Surveillance Reports (measured between points D and E2) shall be no greater than 0.5s.<br>Comment:<br>Airborne and transmission latencies are assumed to be negligible, therefore the global performance is better than the above specification. | 0.5 + s |
| [RD 41] SPR 35 § 3.4.2 | Requirement:<br>The 95% latency for ADS-B surveillance reports (measured between points D and E2 – output of the “Ground ADS-B Receive” function) **shall** be no greater than 0.5 seconds, excluding communication latency to the ATC processing system.<br>Comment:<br>Airborne latency is assumed to be the same as for SSR (as for NRA) and is therefore negligible, therefore the global performance is better than the above specification. | 0.5 + s |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R8** | The average data age of the forwarded pressure altitude reported in all target reports shall be equal to or less than **2.5 s**. | 2.5 s |
| [RD 46] § 3.3.11 | Requirement:<br>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.<br>Comment:<br>It is assumed that the WAM system under nominal condition will meet the requirement. | Max 9 s |

### C - 2.2.13 Forwarded pressure altitude maximum data age mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **5.1.5** | The maximum data age of the forwarded pressure altitude reported in all target reports shall be equal to or less than **16 s**. | 16 s |
| SSTF #21 | Assuming that a large proportion (to be quantified) of the aircraft vertical movements are performed at a rate of climb/descent less than or equal to 3000 ft/mn, 16 s corresponds to the delay for a climbing descending aircraft to leave its initial flight level but to not have yet reached the next (above or below) flight level. In accordance with ICAO Document 4444 [RD 1] an aircraft is at a given flight level if its pressure altitude is within +/- 200 ft from that flight level (VSM = 1000 ft). 16 seconds is derived from 1000 ft minus 200 ft divided by the considered normal vertical speed 3000 ft/mn (or 50 ft/s). | 16 s |
| | At SSTF #21 it was agreed that this delays must be applicable for 100% of the cases, however it is also recognised that cases of higher data age may happen in rare cases. These cases should be analysed to avoid/minimise their re-occurence. | |
| [RD 46] § 3.3.11 | Requirement:<br>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. | Max 6 s |

### C - 2.2.14 Forwarded pressure altitude correctness

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R9** | The ratio of valid forwarded pressure altitudes that are incorrect shall be equal to or less than **0.1 %.** | 0.1 % |
| [RD 1]§ 8.5.4.1 | Statement:<br><br>If the ATC displayed Mode C differs of more than 200 ft (1000 ft vertical separation) / 300 ft (2000 ft vertical separation) the controller shall verify the correctness of Mode C with the pilot. | |
| [RD 2] § 6.3.3.2 | Requirement:<br><br>Validated false Mode C codes: < 0.1 %<br><br>Comment:<br><br>For SSR only, in SASS-C the threshold to declare incorrect Mode C is set to 300 ft. | 0.1 % |
| [RD 4] SPR 10 § 3.4.2 & SPR 13 § 3.5.2 | Requirements:<br><br>The likelihood that the Aircraft Transmit Domain corrupts ADS-B information shall be no more than $10^{-5}$ per flight-hour<br><br>The likelihood that the ADS-B receive subsystem corrupts ADS-B information through the reception, processing or delivery of data (E2) shall be no more than 5 x $10^{-6}$ per ATSU hour.<br><br>Comments:<br><br>These requirements are aggregating all provided data items, not only the pressure altitude data item. There is a need to get traffic load to convert these figures in %; nevertheless they are assumed to be more demanding. | ? |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R9** | The ratio of valid forwarded pressure altitudes that are incorrect shall be equal to or less than **0.1 %.** | 0.1 % |
| [RD 12] Exigences 19-1 & 19-2 | Requirements:<br><br>The ratio of Mode C codes displayed with a deviation equal to or greater than 300 ft shall not exceed 0.1% of the sub-population of aircraft stable in level flight.<br><br>The ratio of Mode C codes displayed with a deviation equal to or greater than 300 ft shall not exceed 1.5% of the sub-population of aircraft which are climbing/descending. | 0.1% for stable flights (< 300 ft/mn)<br><br>1.5 % for vertically moving flights (> 200 ft/mn) |
| [RD 18] § 6.2.3 | Requirements:<br><br>The probability of false pressure altitude output from the ground surveillance system is ≤ $1.10^{-3}$ per target report.<br><br>Comments:<br><br>Criteria for correctness are in line with [RD 1] § 8.5.4.1: 200 ft for 1000 ft VSM and 300 ft for 2000 ft VSM. | 0.1% |
| [RD 42] SPR 22 & SPR 33 | Requirements:<br><br>The likelihood of the Aircraft ADS-B function system integrity failure shall be $10^{-5}$ or less per flight-hour<br><br>The likelihood of an ADS-B Ground Domain system integrity failure shall be $2 \times 10^{-5}$ or less per hour.<br><br>Comment:<br><br>These requirements are aggregating all provided data items, not only the pressure altitude data item. There is a need to get traffic load to convert the aircraft domain figure in % of target reports; nevertheless they are assumed to be more demanding. | - |
| [RD 46] § 3.3.7 | Requirement:<br><br>The Probability of False pressure altitude ***shall*** be less than or equal to **0.1%.** | 0.1 % |

### C - 2.2.15 Pressure altitude unsigned error mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R10** | The pressure altitude unsigned error shall be less than or equal to 200/300 ft in **99.9%** of the cases for stable flights and less than or equal to 300 ft in **98.5%** of the cases for climbing / descending flights. | 99.9 %<br>98.5 % |
| [RD 12] Exigences 19-1 and 19-2 | It limits the error on pressure altitude, at its time of display, in the same way as the horizontal position error. | 99.9 %<br>98.5 % |
| SSTF #17 | At SSTF #17 it was agreed to put a maximum limit to the vertical speed of 8000 ft/mn and to not address pressure altitude data items corresponding to portion of trajectories exceeding 8000 ft/mn as climbing of descending rate. | |
| | Usually the pressure altitude that is provided to the users is the last valid measured altitude (see § 5.2.5 [RD 2]) because an extrapolated altitude is not enough reliable. However new systems could provide reliable calculated pressure altitude and a new requirement is now defined to cover this type of implementation. | |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R10** | The pressure altitude unsigned error shall be less than or equal to 200/300 ft in **99.9%** of the cases for stable flights and less than or equal to 300 ft in **98.5%** of the cases for climbing / descending flights. | 99.9 %<br>98.5 % |
| [RD 1] § 8.5.5.1.1-2 | For stable flights inside RVSM, respectively non-RVSM, airspace the threshold has been set to 200 ft, respectively 300 ft, because of the requirements specified in ICAO document 4444 [RD 1] § 8.5.5.1.1-2 where it is stated:<br>*"8.5.5.1.1 The tolerance value used to determine that pressure-altitude-derived level information displayed to the controller is accurate shall be ±60 m (±200 ft) in RVSM airspace. In other airspace, it shall be ±90 m (±300 ft), except that the appropriate ATS authority may specify a smaller criterion, but not less than ±60 m (±200 ft), if this is found to be more practical. Geometric height information shall not be used for separation.*<br>*8.5.5.1.2 Verification of pressure-altitude-derived level information displayed to the controller shall be effected at least once by each suitably equipped ATC unit on initial contact with the aircraft concerned or, if this is not feasible, as soon as possible thereafter. The verification shall be effected by simultaneous comparison with altimeter-derived level information received from the same aircraft by radiotelephony. The pilot of the aircraft whose pressure-altitude-derived level information is within the approved tolerance value need not be advised of such verification. Geometric height information shall not be used to determine if altitude differences exist."*<br>It is assumed that when an aircraft is transferred from one ATC centre to another it stays at a stable flight level. | |
| [RD 1] § 8.5.5.2.3-4 | For climbing/descending flights, and irrespective of the airspace, the threshold has been set to 300 ft because of the requirements specified in ICAO document 4444 [RD 1] § 8.5.5.2.3-4 where it is stated:<br>*"8.5.5.2.3 Aircraft vacating a level. An aircraft cleared to leave a level is considered to have commenced its manoeuvre and vacated the previously occupied level when the pressure-altitude-derived level information indicates a change of more than 90 m (300 ft) in the anticipated direction from its previously assigned level.*<br>*8.5.5.2.4 Aircraft passing a level in climb or descent. An aircraft in climb or descent is considered to have crossed a level when the pressure-altitude-derived level information indicates that it has passed this level in the required direction by more than 90 m (300 ft)."* | |

### C - 2.2.16 Change in emergency indicator/SPI report delay mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R11** | The time between changing the emergency indicator / SPI report on board the aircraft and availability of the new value at the output of the surveillance system shall be equal to or less than **7.5 s** in 95 % of the cases. | 7.5 s |
| SSTF #14 | Calculations have been made on the basis of single radar and multi-radar tracker configurations and the figure of 7.5 s has been agreed for this requirement. | 7.5 s |
| SSTF#21 | At SSTF #21 it was agreed that this delays must be applicable for 100% of the cases, however it is also recognised that cases of higher delay may happen in rare cases. These cases should be analysed to avoid/minimise their re-occurence. | 7.5 s |
| [RD 4] SPR 26 § 3.5.2 | Requirement:<br>For 3 NM separation – The time to alert for a change in Surveillance Emergency/SPI Reports measured at point E2 shall be no longer than 5 s for with a probability of 100%.<br>Note:<br>The point E2 is at the input of the ATC Processing System before the ATC Display System. | 5 s |

### C - 2.2.17 Change in aircraft identity delay mandatory requirements

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R12** | The time between changing the aircraft identity on board the aircraft and availability of the new value at the output of the surveillance system shall be equal to or less than **15 s** in 95 % of the cases. | 15 s |
| SSTF #12-15 | The objective of this requirement is to limit the latency of a change of aircraft identity (forwarded data item) inside the surveillance system. There is currently no equivalent requirement in any standard (except SPR 25 in [RD 4]) from which this requirement can be traced. The inclusion of the requirement was agreed at SSTF meeting #12 and the threshold value was agreed during STTF meeting #15. | 15 s |
| SSTF#21 | At SSTF #21 it was agreed that this delays must be applicable for 100% of the cases, however it is also recognised that cases of higher delay may happen in rare cases. These cases should be analysed to avoid/minimise their re-occurence. | 15 s |
| [RD 4] SPR 25 § 3.5.2 | The update interval for Surveillance Reports containing only ADS-B Identity data associated with any single aircraft shall be less than 100s with a probability of 95%.<br><br><u>Comment:</u><br><br>This requirement is not clear and not further explained in document [RD 4]. | 100 s |
| [RD 41] § 1.2.2.1.1.3 | <u>Requirement:</u><br><br>Any change of Identity shall be reported at the output of the surveillance system in less than 20s. | 20 s |

### C - 2.2.18 Correct aircraft identity probability of update mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R13** | The probability of update of correct and valid aircraft identity (Mode A or aircraft identification) shall equal or greater than 98% globally. | 98 % |
| SSTF #19 | At SSTF #19 it has been agreed that this type of requirement was lacking and the value of 98 % was agreed. | 98 % |
| [RD 2] § 6.3.2.4 | <u>Requirement:</u><br>Overall Mode A probability of code detection: > 98 %<br><u>Comment:</u><br>For 1 SSR only and for Mode A only. | 98 % |
| [RD 42] SPR 49 | <u>Requirement:</u><br>For 5 NM separation – The probability of providing a Surveillance Report containing newly received ADS-B Position data of sufficient quality associated with any aircraft in En Route airspace within 8 seconds shall be 97%.<br><u>Comment:</u><br>For ADS-B only. It is assumed that “ADS-B Position data” encompasses all the data items listed in SPR 27 which include aircraft identity. As the requirement is on the proportion of target reports with horizontal position therefore the achieved ADS-B performance should be 100 % minus the cases of aircraft identity (Mode A or Aircraft Identification) integrity error. | 100- % |
| [RD 46] § 2.8.2 | <u>Requirement:</u><br>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%**. | 98 % |
| [RD 19] § 4.2.4.1.4 | <u>Requirement:</u><br>As a minimum, the overall Mode 3/A probability of correct and valid code detection shall be better than 98% for large samples, without any geographical restrictions, of opportunity traffic. | 98 % |

### C - 2.2.19 Aircraft identity correctness

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R14** | The ratio of valid aircraft identities that are incorrect shall be equal to or less than **0.1%.** | 0.1 % |
| [RD 2] § 6.3.3.2 | Requirement:<br>Validated false Mode A codes: < 0.1 %<br>Comment:<br>For SSR only and for Mode A only. | 0.1 % |
| [RD 4] SPR 10 § 3.4.2 & SPR 13 § 3.5.2 | Requirements:<br>The likelihood that the Aircraft Transmit Domain corrupts ADS-B information shall be no more than $10^{-5}$ per flight-hour<br>The likelihood that the ADS-B receive subsystem corrupts ADS-B information through the reception, processing or delivery of data (E2) shall be no more than 5. $10^{-6}$ per ATSU hour.<br>Comments:<br>These requirements are aggregating all provided data items, not only the aircraft identity data item. There is a need to get traffic load to convert these figures in %; nevertheless they are assumed to be more demanding. | ? |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| **3N_C-R14** | The ratio of valid aircraft identities that are incorrect shall be equal to or less than **0.1%**. | 0.1 % |
| [RD 18] § 7.2.3 | Proposed requirement:<br>The probability of an incorrect identification data output from ground system is ≤ $1x10^{-3}$ per target report. | 0.1 % |
| [RD 42] SPR 22 & SPR 33 | Requirements:<br>The likelihood of the Aircraft ADS-B function system integrity failure shall be $10^{-5}$ or less per flight-hour<br>The likelihood of an ADS-B Ground Domain system integrity failure shall be 2 x $10^{-5}$ or less per hour.<br>Comment:<br>These requirements are aggregating all provided data items, not only the aircraft identity data item. There is a need to get traffic load to convert the aircraft domain figure in % of target reports; nevertheless they are assumed to be more demanding. | - |
| [RD 46] § 3.3.7 | Requirement:<br>The Probability of False Mode A code detection shall be less than or equal to 0.1%.<br>The Probability of False ACID detection shall be less than or equal to 0.1%. | 0.1 % |

### C - 2.2.20 Rate of climb/descent error recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R15 | The RMS error of the rate of climb/descent should be equal to or less than **250 ft/mn** for stable flights and should be equal or less than **500 ft/mn** for climbing/descending flights. | 250 ft/mn (stable)<br>500 ft/mn (climbing/descending) |
| SSTF #15 | The objective of this requirement is to specify the error on the rate of climb/descent. There is currently no equivalent requirement in any standard from which this requirement can be trace from. The inclusion of the requirement based on the average error was agreed at SSTF meeting #12 and the threshold (300 ft/mn) value was agreed during STTF meeting #15. | |
| SSTF #17 | At SSTF #17 it was agreed to limit the assessment to climbing and descending rates that are below 8000 ft/mn. | |
| SSTF #19 | At SSTF #19 on the basis of the measurements presented by DSNA/DTI it was agreed to differentiate between stable flights and climbing/descending flights on the same basis as for the accuracy of the pressure altitude data item. It was also agreed to calculate the RMS error rather than the average error which is a more relevant parameter to report on the accuracy of the pressure rate. | 250 ft/mn (stable)<br>500 ft/mn (climbing/descending) |

### C - 2.2.21 Track velocity errors recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R16 & 3N_C-R17 | The RMS error of the track velocity and angle should be, respectively, equal to or less than **4 m/s and 10 °** for portions of trajectories in straight line and equal to or less than **8 m/s and 25 °** for portions of trajectories in turn. | 4/8 m/s<br>10/25 ° |
| SSTF #17 | The objective of this requirement is to specify the error on the track velocity when this data item is provided by the surveillance system. These figures have been derived from the performance achieved by systems in operation providing 3 NM horizontal separation. | 4/8 m/s<br>10/25 ° |

### C - 2.2.22 Uncorrelated false target report mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R18 | The density of uncorrelated false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals shall be less than or equal to 2. | 2 |
| [RD 2] § 6.3.2.2 & 6.3.2.3 | <u>Requirement:</u><br>Overall false target report ratio: < 0.1 %<br>Overall multiple SSR target report ratio: < 0.3 %<br><u>Comment:</u><br>Derived from SSR only requirements and aggregating all sources of false plots (false and multiple). | 0.4 % |
| [RD 4] SPR 10 § 3.4.2 & SPR 13 § 3.5.2 | <u>Requirements:</u><br>The likelihood that the Aircraft Transmit Domain corrupts ADS-B information shall be no more than $10^{-5}$ per flight-hour<br>The likelihood that the ADS-B receive subsystem corrupts ADS-B information through the reception, processing or delivery of data (E2) shall be no more than 5. $10^{-6}$ per ATSU hour.<br><u>Comments:</u><br>Although it is not possible to convert the above figure in accordance with the specified indicator, that requirement is deemed more demanding. | 0.05 |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R18 | The density of uncorrelated false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals shall be less than or equal to 2. | 2 |
| [RD 40] § 6.4 Approach #3 En route airspace | Requirements:<br>The number of false target reports per area of 100 $NM^2$ and per 30 minutes shall be less than or equal to 1.<br>Comments:<br>This requirement has been defined on the basis of user requirements and on the basis of assessments made on few datasets. It requires further analysis to confirm its applicability and relevance. For consistency the requirement has been converted per hour.<br>At SSTF #19 it was agreed to convert the duration in a number of update interval to normalise the requirement irrespective of the selected update interval. The number of update interval being equal to 1 hour divided by the maximum allowed update interval. | 1 false target reports per 100 $NM^2$ and per 30 min |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R18 | The density of uncorrelated false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals shall be less than or equal to 2. | 2 |
| [RD 42] SPR 14, SPR 22 & SPR 33 | Requirements:<br>The probability that a horizontal position error exceeds the integrity containment bounds for more than 10 seconds without reflecting the fact at B1 shall be no greater than 0.001 (per flight hour)<br>The likelihood of aircraft ADS-B function system integrity failure shall be 1 x $10^{-5}$ or less per flight hour.<br>The likelihood of an ADS-B Ground Domain system integrity failure shall be 2 x $10^{-5}$ or less per hour.<br>Comment:<br>The first requirement is provided per flight hour (to be clarified/confirmed) and for a containment radius of 0.6 NM (less than the 1700 m maximum error). The second and third requirements are not specific to horizontal position data item, so the probability of integrity failure of horizontal position made by the total system should be smaller. Nevertheless, assuming that 100 NM² is the size of a sector and the high density traffic characteristics defined in [RD 42] (6 flight hours per sector and per hour) this requirement is more demanding (less than 0.00606 false target report per hour and per sector). | 0.00606 |
| SSTF #19 | At SSTF #19, it was agreed to specify the duration not as an absolute value but as a number of update intervals so as to normalise the requirement irrespective of the selected update interval. Therefore a value of 720 update intervals was agreed corresponding to one hour when update interval is 5 s. | |

### C - 2.2.23 Falsely confirmed track mandatory requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R19 | The number of false tracks close to true tracks (less than 9 NM) shall be less than or equal to 1 per hour. | 1 |
| [RD 40] § 6.4 Approach #4 TMA airspace | Requirements:<br>The number of false tracks close to true tracks (less than 9 NM) shall be less than or equal to 1 per hour.<br>Comments:<br>This requirement has been defined on the basis of user requirements and on the basis of assessments made on few datasets. It requires further analysis to confirm the figures. | 1 false track per hour closer than 9 NM from true tracks |

### C - 2.2.24 Ground system continuity recommended requirement

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| SSTF #12 | It was agreed during SSTF meeting #12. | 2.5 $10^{-5}$ |
| [RD 2] § 5.3.2 | Requirement:<br>The radar surveillance data availability requirements are:<br>• full data availability shall be not less than 0.995, excluding periods of scheduled maintenance;<br>• essential data availability shall be not less than 0.99999;<br>• PSR data availability for major terminal areas shall be not less than 0.995.<br>Full data are :<br>• aircraft horizontal position and history;<br>• aircraft identification;<br>• aircraft vertical position;<br>• specific indication of Mode A special codes (i.e. 7500,7600,7700);<br>• ground speed;<br>• status of the Track whether it is primary, secondary, combined or extrapolated.<br>Essential data are:<br>• aircraft horizontal position and history;<br>• aircraft identification or Mode A code;<br>• aircraft vertical position.<br>Comment:<br>It is not possible to convert availability figure to probability of failure. However the requirement on essential data seems more demanding. | ? |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **$2.5\ 10^{-5}$** per hour of operation. | $2.5\ 10^{-5}$ |
| [RD 4] § 3.5.2<br>SPR 14 & SPR 15 | <u>Ground Performance Requirement:</u><br><br>Availability and continuity requirements for ground equipment are left to local authorities. Factors that are recommended to be considered for developing these requirements include traffic density, traffic patterns, and criticality of services being provided.<br>SPR 14: The likelihood that ADS-B Receive subsystem does not provide updated ADS-B surveillance reports for more than one aircraft from which ADS-B messages are being received shall be no more than $5.\ 10^{-6}$ per ATSU hour.<br>SPR 15: The likelihood that the ADS-B receive subsystem does not provide updated ADS-B surveillance reports for one aircraft from which ADS-B messages are being received shall be no more than $10^{-4}$ per ATSU-hour.<br><u>Comment:</u><br><br>For reliability of ADS-B ground only.<br><br>See below extract of B.4.4.2 Reliability requirements<br><br>Within the context of the ADS-B-NRA application it has been decided to only consider continuity requirements for the ground system. This was done because the scope of the OSED is limited to when aircraft have already entered non-radar airspace. This means that the operation has already commenced, and therefore was “available” at the start of the operation. What is specified in this OPA (and in the SPR requirements in section 3) is the continuity – the likelihood the system will be working normally for the entire flight of any one aircraft through the sector of NRA airspace. | $5.\ 10^{-6}$ for at least 2 aircraft |
| [RD 36] § 8.4.5 | <u>Safety Objective ADS-B-NRA:</u><br><br>Safety objective of sudden and unexpected loss of position information for <u>multiple</u> aircraft previously identified in the sector detected by ATCO is $2.9\ 10^{-5}$ per ATSU hour (severity 3) for TMA (i.e. 3 NM horizontal separation).<br><br><u>Comment:</u><br><br>This is a safety objective not a performance requirement. | $2.9\ 10^{-5}$ |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 37] § 5.3 | Safety objective WAM:<br><br>Safety objective of detected loss of horizontal position for more than one aircraft is 2.8 $10^{-5}$ per ATSU hour (severity 2) for TMA (i.e. 3 NM horizontal separation). | 2.8 $10^{-5}$ |
| [RD 38] § 4.6 and 7.2 | Safety objective ARTAS software:<br><br>Safety objective of total loss of aircraft lateral position information (ARTAS system tracks) within an ARTAS DOI is less than 1. $10^{-5}$ per ATSU hour (with fallback system) and less than 1. $10^{-6}$ per ATSU hour (without fallback system).<br><br>Comment:<br><br>This is a safety objective not a performance requirement.<br><br>Measured hazard rate on operational ARTAS software:<br><br>Hazard: total loss of aircraft lateral position information (ARTAS system tracks) within an ARTAS DOI.<br><br>Raw measurement: 2.7 $10^{-5}$ per ATSU hour (based on 185.000 hours of operation).<br><br>Theoretical rate (@ 50% confidence): 3.1 $10^{-5}$ per ATSU hour.<br><br>Theoretical rate (@ 90% confidence): 5. $10^{-5}$ per ATSU hour. | 1. $10^{-5}$<br><br>2.7 $10^{-5}$ |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 39] § 2.2 | Safety objectives Mode S system:<br><br>Maximum tolerability of System derived loss of aircraft horizontal position is 3.3 $10^{-9}$ per flight hour.<br><br>Assuming high traffic density it gives a figure of 3.3 $10^{-6}$ per ATSU hour.<br><br>Assuming low/medium traffic density it gives a figure of 3.3 $10^{-7}$ per ATSU hour.<br><br>Comment:<br><br>This is a safety objective not a performance requirement. | 3.3 $10^{-7}$ |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 19] § 14.2.2.2 | <u>Requirement:</u><br>The availability calculation excludes all planned downtimes.<br>The figures for Availability quoted in this Specification are for Operational Availability ($A_o$) and shall be calculated using the following equation:<br>$A_o = MTBF / (MTBF + MTTR + MRT)$<br>MTBF = Mean Time Between Failures in hours.<br>MTTR = Mean Time To Repair in hours.<br>MRT = Mean Response Time in hours (i.e. the average time from notification of failure for a technician to be ready to commence repair action).<br>The operational availability of coherent and full radar data from the Mode S ground station site shall be greater than 99.98%.<br>The system reliability requirement for each Mode S ground station as described in Figure 3 (excluding Local Display and Recording/Playback facility) shall be greater than 20,000 hrs MTBF.<br>MTTR at Organisational Level shall be 30 (thirty) minutes.<br>The following figures are given for Tender Evaluation purposes:<br>(a) The MRT shall be 3.5 hours;<br>(b) The maximum time to repair shall not exceed 8 (eight) hours for 95% of all repairs;<br>(c) The maximum response time shall not exceed 8 (eight) hours.<br><u>Comment:</u><br>For a single Mode S sensor taking into account that the probability of failure is equal to 1/MTBF. | 5. $10^{-5}$ |

| Ref | Performance requirement statement / Comment | Requirement threshold |
|---|---|---|
| 3N_C-R20 | The probability of critical failure of the ground surveillance system should be equal to or less than **2.5 $10^{-5}$** per hour of operation. | 2.5 $10^{-5}$ |
| [RD 42] SPR 20 & SPR 34 | Requirements:<br><br>The continuity of the ADS-B Aircraft Domain shall be 0.9998 per flight hour.<br><br>The likelihood of a Ground ADS-B Receive function continuity failure shall be $10^{-5}$ or less per hour.<br><br>Comment:<br><br>The probability of failure of the complete system will happen if all the ADS-B Aircraft Domains fail or if the ADS-B ground domain fails. The combined probability equals to $(2.\ 10^{-4})^N + 10^{-5}$ where N is the number of aircraft managed by the system. This calculation does not take into account the other components of the ADS-B ground domain. So the continuity of the complete system depends on the continuity of the ground domain which is equal, in the worst case, to $10^{-5}$; the contribution of the aircraft domain is negligible as long as N is greater than 2. | $10^{-5}$ |
| [RD 46] § 2.8.2 | Requirement:<br><br>The availability figure defined will typically be met with MTBCF and MTTR figures of 10,000 hours and 1 hour respectively.<br><br>Comment:<br><br>Indicative figure. | $10^{-4}$ |

# ANNEX - D DEFINITIONS

## D - 1 Data item definitions

### D - 1.1 Position data items

**Geodetic Position** – This is the position of the aircraft projection on the earth's ellipsoid, as defined in WGS84. It is expressed as latitude and longitude. This data item can be forwarded and/or calculated depending on surveillance system architecture.

**Horizontal Position** – This is the 2D projected position which is used to display the aircraft position onto the ATCO HMI. This data item is calculated by the ground surveillance system.

**Pressure altitude** – This is the altitude in Flight Levels (FL) of the aircraft derived from an airborne pressure measurement in accordance with the ICAO International Standard Atmosphere (defined in ICAO document 7488 [RD 43]). In principle, this data item can be forwarded and/or calculated depending on surveillance system architecture. One FL is equal to 100 feet, pressure altitude when measured on board the aircraft is expressed with a resolution of 25 ft (1/4 FL) or with a resolution of 100 ft (1 FL).

**QFE corrected Pressure Altitude** – This is the height of the aircraft in feet above a local aerodrome. This height is derived from the Pressure altitude reported by the aircraft in accordance with the pressure datum corresponding to the pressure measured on the ground of the aerodrome. This data item is calculated by the ground surveillance system.

**QNH corrected Pressure Altitude** – This is the altitude of the aircraft in feet above mean sea level for a given area. This altitude is derived from the Pressure altitude reported by the aircraft in accordance with the pressure datum corresponding to mean sea level for the corresponding area. This data item is calculated by the ground surveillance system.

**Vertical Geometric Altitude** – This is the vertical distance between the aircraft and the position of its projection on the earth's ellipsoid, as defined in WGS84. This data item can be forwarded and/or calculated depending on surveillance system architecture.

### D - 1.2 Aircraft Identity data items

**Aircraft identification** – This is the data item 7 in the ICAO flight plan or the Tail number / Registration if there is no associated flight plan. This data item is forwarded by the surveillance system.

**Mode A Code** – This is the code (4 octal digits) that has been allocated to the aircraft by the ATC. This data item is forwarded by the surveillance system.

### D - 1.3 Supplemental indicator data items

**Emergency indicator –** This data item reports the type of emergency; it can be conveyed via special Mode A codes (i.e. 7500 unlawful interference, 7600 radio-communication failure, 7700 state of emergency). This data item is forwarded by the surveillance system.

**SPI – Special Position Identification** – This is special information that is sent by the aircraft when requested to by the ANSP. This data item is forwarded by the surveillance system.

### D - 1.4 Velocity data items

The projection system(s) used to calculate those data items need to be clarified.

**Ground Speed** – This is the speed (amplitude) of the aircraft over the ground. This data item is calculated on-board the aircraft. If available, this data item may be forwarded by the surveillance system.

**Indicated Airspeed (IAS)** – This is the speed of the aircraft as shown on its pitot static airspeed indicator calibrated to reflect standard atmosphere adiabatic compressible flow at sea level uncorrected for airspeed system errors. This definition is extracted from the EASA document [RD 44]. This data item is calculated on-board the aircraft. If available, this data item may be forwarded by the surveillance system.

**Inertial vertical velocity** – This is the vertical velocity of the aircraft as measured by an inertial device on board the aircraft. This data item is calculated on-board the aircraft. If available, this data item may be forwarded by the surveillance system.

**Magnetic heading** – This is the direction over the ground to which the aircraft axis is pointed. The reference is the Magnetic North at the aircraft position. This data item is calculated on-board the aircraft. If available, this data item may be forwarded by the surveillance system.

**Pressure altitude rate** – This is the variation over time of the aircraft pressure altitude. This data item is calculated on-board the aircraft. If available, this data item may be forwarded by the surveillance system.

**Track Angle Rate** – This is the variation over time of the aircraft True track angle. This data item can be forwarded and/or calculated depending on surveillance system architecture.

**True Airspeed (TAS)** – This is the speed (amplitude) of the aircraft in the air. It can only be calculated on board the aircraft on the basis of the Indicated Airspeed. This data item is forwarded by the surveillance system.

**True Track Angle (or Course)** – This is the direction over the ground of the aircraft track. This data item is calculated on-board the aircraft. If available, this data item may be forwarded by the surveillance system.

**Track velocity vector** – This is speed vector of the aircraft track as calculated by the surveillance ground system, it may take into account down-linked aircraft parameters such as the ground speed and the true track angle. The naming of this data item is consistent with the naming adopted in ASTERIX category 062 ([RD 47]) and has been chosen to avoid confusion with similar data items that can be down-linked by the aircraft.

**Rate of climb/descent** – This is the variation over time of the aircraft pressure altitude as calculated by the ground surveillance system, it may take into account down-linked aircraft parameters such as pressure altitude rate. It may also be reduced to a trend with discrete values (climbing, descending, straight level flight or unknown). The naming of this data item is consistent with the naming adopted in ASTERIX category 062 ([RD 47]) and has been chosen to avoid confusion with similar data items that can be down-linked by the aircraft.

### D - 1.5 Intent data items

**FMS Selected altitude** – This is the altitude input by the pilot on the FMS. This data item is forwarded by the surveillance system.

**MCP/FCU Selected altitude** – This is the altitude input by the pilot on the MCP/FCU. This data item is forwarded by the surveillance system.

### D - 1.6 Target report surveillance data status data items

**Coasted status** – This indicates whether the horizontal position data item is based on a measured horizontal position that is older (coasted) or not (non-coasted) than the surveillance system actual update interval. This data item is calculated by the ground surveillance system.

**Flight status** – This indicates whether the aircraft is airborne or on the ground or unknown (either on the ground or airborne). This data item is defined on board the aircraft, in general based on a weight on wheel mechanism. This data item is forwarded by the surveillance system.

**Surveillance technique source (cooperative, non-cooperative, combined)** – This reflects whether the data contained in the target report is based on information provided by a cooperative surveillance source only or by a non-cooperative surveillance source or both. This data item is calculated by the ground surveillance system.

### D - 1.7 Time data items

**Time of applicability** – This reflects the time for which the system considers the provided calculated data item is valid. This data item is determined by the ground surveillance system.

**Data age** – This indicates the age of a particular data item, i.e. the elapsed time since it was measured or extracted from the aircraft by the ground sensor. This data item is calculated by the ground surveillance system.

### D - 1.8 Other definitions

**ICAO International Standard Atmosphere** – This is an atmospheric model of how the pressure, temperature, density, and viscosity of the Earth's atmosphere change over a wide range of altitudes. It consists of tables of values at various altitudes, plus some formulas by which those values were derived. The International Organization for Standardization (ISO), publishes the ISA as an international standard, ISO 2533:1975. ICAO published an extension (the altitude coverage is extended up to 80 kilometres (262,500 feet)) of the same atmospheric model under their own standards-making authority.

## D - 2 Performance characteristic definitions

It is to be noted that a performance characteristic can be defined at data item level or at system level.

### D - 2.1 Accuracy definition

**Accuracy** is applicable to a data item that is provided by the system (e.g. measured and/or calculated). It is the degree of conformity of the provided value of a data item with its actual value at the time when the data item is considered.

In ICAO Annex 15 [RD 25], **accuracy** is defined as the degree of conformance between the estimated or measured value and the true value.

It is also agreed that the accuracy specification will also cover the case where information not related to a true aircraft is reported. This will need to be specified independently as there will be no actual value. It is also agreed that, to be credible, the false information must at least contain horizontal position and aircraft identity.

### D - 2.2 Integrity definition

**Integrity** is applicable to a data item that is transferred by the system (provided externally by another system and forwarded to another system, e.g. Mode A code, Mode C code). It is the degree of undetected (at system level) non-conformity of the input value of the data item with its output value. In that case the system is only a communication medium so it should not modify the value of the data item.

In ICAO Annex 15 [RD 25], **integrity** is defined as the degree of assurance that a data item and its value has not been lost or altered since the data origination or authorised amendment.

### D - 2.3 Availability definition

**Availability**: The probability that a system will perform its required function at the initiation of the intended operation.

The **availability** is composed of two independent and distinct availabilities: the planned availability ($A_P$) and the operational availability ($A_O$).

The planned availability ($A_P$) is derived from the planned outage rate ($F_P$), which is a local requirement depending on local constraints.

$$A_P = 1 – F_P$$

The operational availability calculation excludes all planned downtimes.

The Operational Availability ($A_O$) and shall be calculated using the following equation:

$$A_O = MTBCF / (MTBCF + MTTR + MRT)$$

Where:

- MTBCF = Mean Time Between Critical Failures in hours.
- MTTR = Mean Time To Repair in hours.
- MRT = Mean Response Time in hours (i.e. the average time from notification of failure for a technician to be ready to commence repair action).

The availability of the system/service is $A = A_P * A_O$

For a surveillance system the critical failure to be considered for MTBCF is the loss of horizontal positions of all aircraft during at least 10 seconds at the output of the Surveillance system.

### D - 2.4 Continuity definition

**Continuity**: Continuity is the probability that a system will perform its required function without unscheduled interruption, assuming that the system is available at the initiation of the intended operation. (Continuity is expressed per unit time). The continuity can be related to the Mean Time Between Critical Failures (MTBCF).

Continuity = 1 / MTBCF

The definition of what is a surveillance system critical failure is provided in the previous paragraph of this annex.

### D - 2.5 Reliability definition

**Reliability**: The probability that a system or service will be available throughout a specified geographic volume for a specified amount of time without degradation or failure to the service or system.

### D - 2.6 Time related definitions

The latency or data age is the difference between time of output of a data item and the time of applicability of the data item.

The latency represents the system capability to provide a calculated value of a data item that is consistent with its time of output and to timely provide a forwarded data item.

It is assumed that any information is time stamped in accordance with a common time reference (i.e. UTC in general). This time stamp represents the instant when the information is declared valid. If information is not provided with time stamping it is assumed that, by default, it is time stamped by the receiving system/sub-system with its time of arrival.

The update interval is the difference in time between two consecutive deliveries of the same data item.

The diagram below shows the different times in the case of a data item that is forwarded by the ground surveillance system.

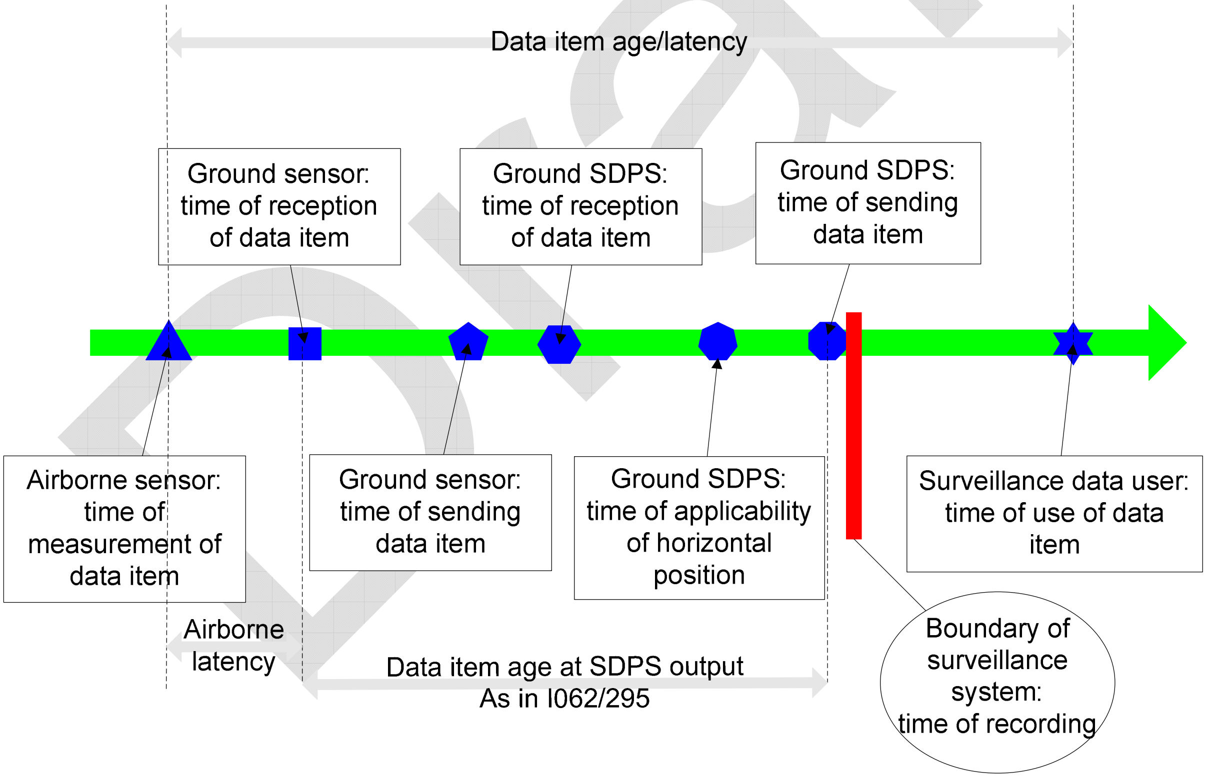


**Figure 32: The different stages of surveillance system data processing (forwarded data item)**

Taking into account a ground surveillance system composed of:

- Mode S sensor
- Sensor data distribution system (network)
- Surveillance data processing system (ARTAS tracker)
- Surveillance data distribution system (network)
- ATC centre display system

Applying the generic diagram above on the same surveillance system further illustrates the definitions in the case of pressure altitude data item

- Time of airborne measurement (T1) of aircraft pressure altitude by the aircraft altimeter.
- Time of arrival of a Mode S reply (DF5) from the aircraft containing the pressure altitude, e.g. Mode C code.
- From this Mode S reply the Mode S sensor decodes the Mode C code and copies it in a Mode S target report that is dated (Time of arrival at sensor level T2) in accordance with the time of arrival of the reply.
- The Mode S target report is transmitted to the tracker through the sensor network.
- This Mode C is copied in the next update of the track dated Time of applicability (T3) that is output by the tracker. This track is processed by the ATC centre system and the aircraft vertical position is transferred through the surveillance network and displayed at the CWP at Time of output of surveillance system (T4), then the ATCO uses this information to undertake vertical separation with another aircraft.

In this case the pressure altitude data age is equal to $T_4 – T_1$.

In the case where the measurement of a data item is performed on board the aircraft, the date of the measurement is not forwarded to the ground surveillance system, nevertheless:

- In the case of an SSR/Mode S target report, the delay between T2 and T1 is normally below a specified threshold.
- In an ADS-B report, all data items are dated "on the basis[4]" of the time of arrival of the last transmitted data item. In any case the exact time of measurement is not known.

[4] The position may be extrapolated; in that case the date will correspond to the one of the extrapolation, which is itself based on the previous received position dated with its time of arrival.

The diagram below shows the different times in the case of a data item that is elaborated by the ground surveillance system.

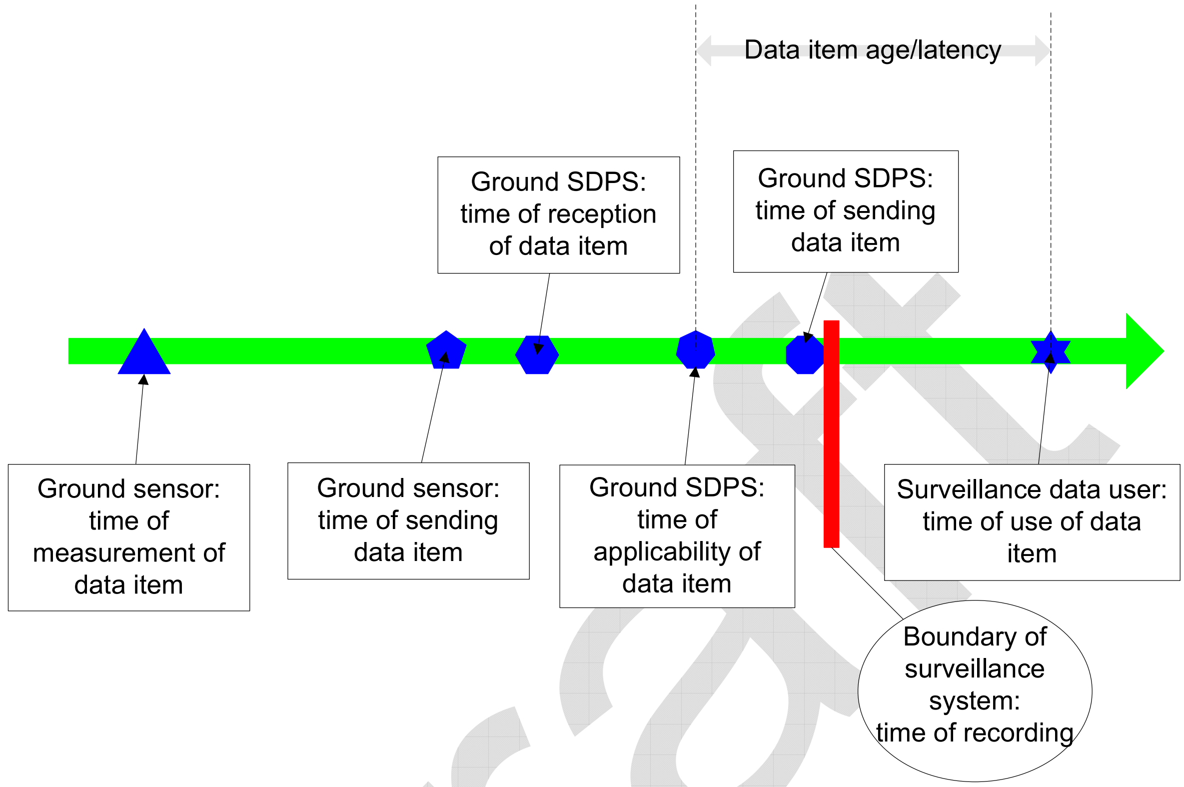


**Figure 33: The different stages of surveillance system data processing (calculated data item)**

Applying the generic diagram above on this specific surveillance system further illustrates the definitions in the case of the horizontal position data item:

- Time of arrival of a Mode S reply from an aircraft.
- From this Mode S reply the Mode S sensor elaborate the horizontal position (azimuth and range) of a Mode S target report that is dated (Time of arrival at sensor level T1) in accordance with the time of arrival of the reply.
- The Mode S target report is transmitted to the tracker through the sensor network.
- From the Mode S target report the tracker extrapolate a horizontal position for the Time of applicability ($T_2$). The track data items are transferred through the surveillance network and the horizontal position is displayed at the CWP at the Time of output of the surveillance system ($T_3$), and then the ATCO uses this information to undertake horizontal separation with another aircraft.

In this case the data age of the horizontal position at the output of the surveillance system is equal to $T_3 – T_2$.

## D - 2.7 Responsibility domain and interest domain definitions

The responsibility domain of an ATC centre/organism is a geographical volume with vertical and horizontal boundaries within which the centre/organism has the responsibility of the air traffic control and in which it provides air traffic services (e.g. surveillance separation).

The interest domain of an ATC centre/organism includes its responsibility domain plus some horizontal and vertical margins needed to survey traffic in the vicinity of the responsibility domain and traffic that is about to be transferred to the centre/organism. The centre/organism may provide air traffic services (e.g. surveillance separation) in this domain.

The above definitions are derived and translated from document [RD 12]

### D - 2.8 Capacity, Total Load, Throughput and Density definitions

The three following definitions are extracted from document [RD 4].

**Capacity**: It relates to the maximum numbers of aircraft in the system for which all the service surveillance performance parameters have to be provided. Capacity will depend upon the particular environment characteristics (i.e. traffic densities, area of coverage required).

**Total load**: Maximum number of aircraft in coverage.

**Density**: Maximum number of targets within a confined area.

The two following definitions are extracted from document [RD 5].

**Throughput**: The rate of item provided for a service over a time interval.

**Capacity**: The number of service provisions able to be delivered to the end user in a period of time.

## D - 3 Other definitions

### D - 3.1 False target report definition

A false target report is either an horizontal outlier target report or a target report (including at least horizontal position and aircraft identity data items) that does not correspond to a true aircraft at the reported position and at the reported time.

### D - 3.2 Falsely confirmed track

A falsely confirmed track is a suite of at least 3 false target reports used to form a track.

### D - 3.3 Outlier target report definition

An outlier target report is a target report corresponding to a true aircraft but showing a horizontal position error larger than a defined value.

### D - 3.4 Track disappearance delay

It is the delay between the last target report corresponding to a given aircraft and the “theoretical” exit of this aircraft out of the operational volume (volume where the service is provided/supported) of the surveillance system.

### D - 3.5 Track initiation delay

It is the delay between the first target report (horizontal position at least) corresponding to a new aircraft and the “theoretical” entry of this aircraft in the operational volume (volume where the service is provided/supported) of the surveillance system.

# D - 4 Environment definitions

## D - 4.1 Airspace classes

The scope of this document is limited to the classes/sections of airspace where the provision of air traffic services or functions apply and in particular for those in which the surveillance is used to separate aircraft.

Concerning the separation service it is further stated in [RD 1] that:

*Vertical or horizontal separation shall be provided:*

*a) between all flights in Class A and B airspaces;*

*b) between IFR flights in Class C, D and E airspaces;*

*c) between IFR flights and VFR flights in Class C airspace;*

*d) between IFR flights and special VFR flights; and*

*e) between special VFR flights, when so prescribed by the appropriate ATS authority;*

Furthermore in [RD 28] it is specified that in Class A airspace only IFR are permitted whereas IFR and VFR are permitted in Class B, C, D, E, F and G airspaces.

In class F and G airspaces separation service is not provided.

Therefore separation service is only provided between IFR flights in Class A, B, C, D and E airspaces, between VFR flights in class B airspace and between IFR flights and VFR flights in Class B and C.

This is illustrated in Figure 34 below (special VFR flights are not shown).

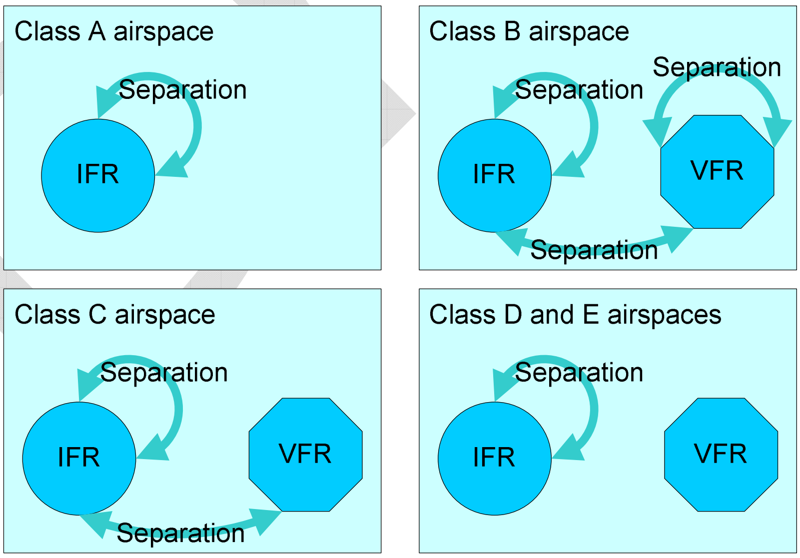


**Figure 34: Provision of separation service in Class of airspaces**

## D - 4.2 Airspace Design and Complexity

The airspace structure is one of the factors that influences the determination, by a local authority, of the separation minima to be applied by ATCOs [RD 16]. Different airspace characteristics and environments must be taken into account and some of these include:

- Use of parallel routes or opposite routes
- Frequency of use of separation minima
- Traffic demand, peaks, averages and general patterns.
- Aircraft types or population
- The existence and location of special use airspace
- Meteorological conditions

## D - 4.3 Traffic Characteristics

### D - 4.3.1 5 NM horizontal separation traffic characteristics

Aircraft maximum horizontal speed is equal to 600 knots.

### D - 4.3.2 3 NM horizontal separation traffic characteristics

Aircraft maximum horizontal speed is equal to 400 knots.

## D - 4.4 Aircraft equipage requirements

**Assumption 1: All aircraft flying IFR in the considered airspace are equipped with an SSR transponder functioning as specified in the draft SPI IR [RD 32] (Article 4 and Annex IV).**

Note: Aircraft flying VFR in the considered airspace may be equipped with an SSR transponder functioning as specified in the draft SPI IR [RD 32] or with a less capable SSR transponder (e.g. Mode A/C only).

# ANNEX - E AIR TRAFFIC SERVICES

The definitions related to ATS below are extracted from ICAO PANS-ATM [RD 1].

***Air traffic service****. A generic term meaning variously, flight information service, alerting service, air traffic advisory service, air traffic control service (area control service, approach control service or aerodrome control service).*

***Approach control service****. Air traffic control service for arriving or departing controlled flights.*

***Area control service.*** *Air traffic control service for controlled flights in control areas.*

***Aerodrome control service.*** *Air traffic control service for aerodrome traffic.*

***Flight information service****. A service provided for the purpose of giving advice and information useful for the safe and efficient conduct of flights.*

***Alerting service.*** *A service provided to notify appropriate organizations regarding aircraft in need of search and rescue aid, and assist such organizations as required.*

***Air traffic advisory service****. A service provided within advisory airspace to ensure separation, in so far as practical, between aircraft which are operating on IFR flight plans.*

***Air traffic control service****. A service provided for the purpose of:*

*a) preventing collisions:*

*1) between aircraft, and*

*2) on the manoeuvring area between aircraft and obstructions; and*

*b) expediting and maintaining an orderly flow of air traffic*

***ATS surveillance service****. A term used to indicate a service provided directly by means of an ATS surveillance system.*

The previous definitions are further detailed and illustrated on the following diagram.

The Area Control Services are fully located under the ATC services whereas the Approach Control Services are only partly under ATC services, the part that is described in § 8.9 of the ICAO PANS-ATM ([RD 1]) is specific.

The 3 and 5 NM separation services are located in the light blue boxes i.e. the Area Control Services and the Approach Control Services which are also part of the Air Traffic Control (ATC) Services.

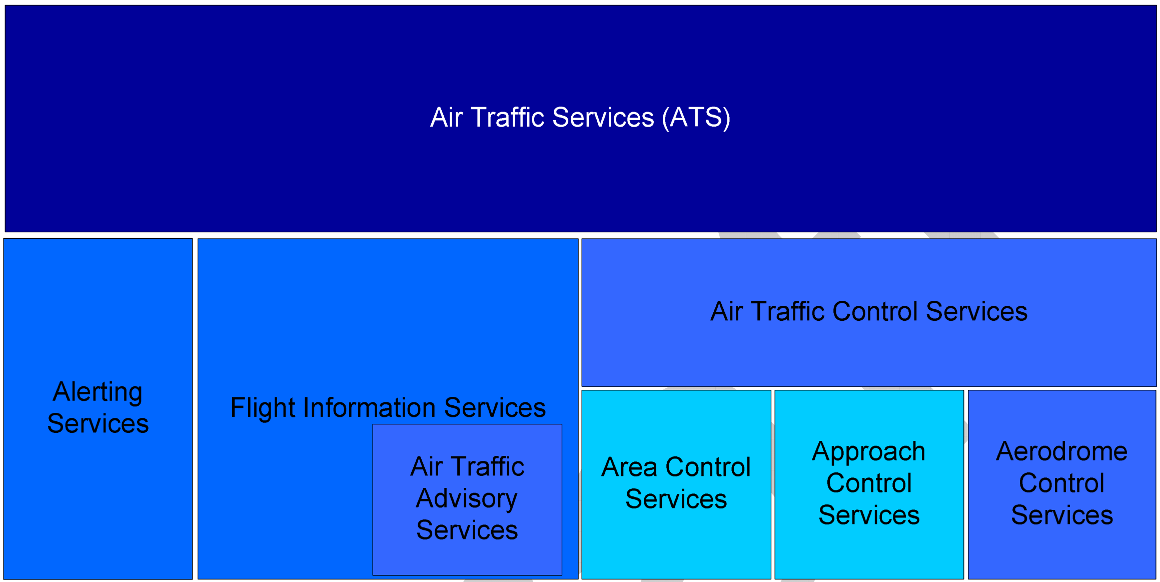


**Figure 35: Hierarchy of Air Traffic Services**

ICAO PANS-ATM ([RD 1]) identifies a number of functions based on surveillance data and that are integrated in an ATC system, these functions are:

- Short Term Conflict Alert (STCA) which assists the controller in preventing collision between aircraft by generating, in a timely manner, an alert of a potential or actual infringement of separation minima (see [RD 1] § 15.7.2).
- Minimum Safe Altitude Warning (MSAW) which assists the controller in the prevention of controlled flight into terrain accidents by generating, in a timely manner, a warning of the possible infringement of a minimum safe altitude (see [RD 1] § 15.7.4).

# ANNEX - F CONFORMITY ASSESSMENT OF SPECIFIC DESIGNS

This annex assesses the conformity to this specification of specific surveillance system designs: pure mono-sensor designs (Mode A/C SSR , Mode S SSR, ADS-B and WAM sensors) and designs including a tracker, either mono or multi-sensor tracker.

In case of a mono-sensor system design the specified requirements must be achieved by the sensor itself and alone.

The following tables compare for each mono-sensor systems its specified performance with the performance requirements stated in this specification. Different justifications are provided for each requirement and for the different types of sensor.

The following conventions are applied:

- OK means that the specific surveillance system design meets the corresponding performance requirement.
- OK means that the specific surveillance system design meets the corresponding performance requirement under specific conditions.
- Not OK means that the specific surveillance system design does not meet the corresponding performance requirement.

# F - 1 SSR Mono radar system design based on [RD 2]

## F - 1.1 5N_C

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 5N_C-R1 | Update interval | **Less than or equal to 8 seconds** | OK | Provided that SSR rotation period is less than 8 s |
| Horizontal position | 5N_C-R2 | Probability of update | **Greater than or equal to 97 % (per flight)** | ? | 97 % global |
| Horizontal position or pressure altitude | 5N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | Probability of 3 consecutive missed target report (assuming not correlated) is 1,25 $10^{-4}$ ($0.05^3$). |
| Horizontal position | 5N_C-R4 | RMS error | **Less than or equal to 500 m global and 550 m per flight** | OK | Assuming azimuth error is predominant over range error (i.e. range > 30 NM), assuming azimuth error follows a Gaussian distribution with 0.08° standard deviation and assuming all aircraft are at the same range.<br>An RMS error of 500 m corresponds to a range of 190 NM.<br>It does not take into account error due to latency. Maximum latency (2 s) at maximum speed (600 knots) gives an error of 620 m.<br>Based on measurements made previously this impact is limited and can be compensated by a range reduction.<br>Azimuth bias (0,1°) must be taken into account for addressing radar vectoring.<br>550 m RMS per flight should be achieved as well. |
| Horizontal position | 5N_C-R5 | Ratio of target reports involved in series of at least 3 consecutive correlated errors larger than 926 m - 0.5 NM | Less than or equal to 0.03 % | OK | Taking into account the probability of azimuth error greater than 926 m at 190 NM and assuming errors are uncorrelated and Gaussian, the probability of having 3 consecutive errors larger than 926 m (1.88 $\sigma$) is $(0.0301)^3 = 2.7\ 10^{-5}$ |
| Horizontal position | 5N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 second RMS for relative data age | OK | OK by design because the radar scans monotonically the space. Aircraft at low altitude and on each side of the radar (one taking off and one landing) will increase the RMS but in that case these aircraft are not subject to horizontal separation so such cases will not be taken into account. |
| Pressure altitude | 5N_C-R7 | Probability of update | **More than or equal to 96 %** | OK | Same performance for SSR |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Forwarded pressure altitude | 5N_C-R8 | Average data age | **Less than or equal to 4 seconds** | OK | SSR specified maximum processing time is 2 s. |
| Forwarded pressure altitude | | Maximum data age | **Less than or equal to 16 seconds** | OK | Max 2 s specified |
| Forwarded pressure altitude | 5N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Same specified performance for SSR. |
| Pressure altitude | 5N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 5N_C-R11 | Delay | **Less than or equal to 12 seconds** | ? | 97 % (Hor Pos) x 98 % (Mode A) = 95% globally over the maximum range.<br>So it should be less than 10 seconds (8 seconds maximum update interval + 2 seconds maximum processing delay) in 95 % of the cases. |
| Change in Aircraft identity | 5N_C-R12 | Delay | **Less than or equal to 24 seconds** | ? | 97 % (Hor Pos) x 98 % (Mode A) = 95% globally over the maximum range.<br>So it should be less than 10 seconds (8 seconds maximum update interval + 2 seconds maximum processing delay) in 95 % of the cases. |
| Aircraft identity | 5N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | Correct and valid Mode A Pd = 98 % |
| Aircraft identity | 5N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Same specified performance for SSR. |
| Rate of climb/descent | 5N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |
| Track velocity | 5N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 5N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| False target reports | 5N_C-R18 | Density of uncorrelated false target reports | Less than 10 false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals | OK | If range is limited to 190 NM it gives a maximum of 1260 false target reports over 450 updates periods which correspond to 2,8 false target report per scan.<br>Specified maximum rate of false target report is 0,4% (0,1 % false + 0,3 % duplicated) from this rate and from previous figure a maximum number of 700 (2,8/.004) target reports per scan can be derived, which is a reasonable SSR capacity when limited to 190 NM. |
| False tracks | 5N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 2 non-simultaneous falsely confirmed tracks per hour that are closer than 13000 m - 7 NM from true tracks | ? | No corresponding specification. |
| System | 5N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | ? | No corresponding specification. |

### F - 1.2 3N_C

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 3N_C-R1 | Update interval | **Less than or equal to 5 seconds** | OK | Provided that SSR rotation period is less than 5 s. |
| Horizontal position | 3N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | ? | 97 % global |
| Horizontal position or pressure altitude | 3N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | Probability of 3 consecutive missed target report (assuming uncorrelated) is 1,25 $10^{-4}$ which gives a rate of 0,0375 %. |
| Horizontal position | 3N_C-R4 | RMS error | **Less than or equal to 300 m global and 330 m per flight** | OK | Assuming azimuth error is predominant over range error (i.e. range > 30 NM), assuming azimuth error follows a Gaussian distribution with 0.08° standard deviation and assuming all aircraft are at the same range.<br>An RMS error of 300 m corresponds to a range of 115 NM.<br>It does not take into account error due to latency. Maximum latency (2 s) at maximum speed (400 knots) gives an error of 412 m.<br>Based on measurements made previously this impact is limited and can be compensated by a range reduction.<br>Azimuth bias (0,1°) must be taken into account for addressing radar vectoring.<br>330 m RMS per flight should be achieved as well. |
| Horizontal position | 3N_C-R5 | Ratio of target reports involved in sets of 3 consecutive correlated errors larger than 555 m - 0.3 NM | Less than or equal to 0.03 % | OK | Taking into account the probability of azimuth error greater than 555 m at 115 NM and assuming errors are uncorrelated and Gaussian, the probability of having 3 consecutive errors larger than 555 m (1.87 $\sigma$) is $(0.0303)^3 = 2.8\ 10^{-5}$ |
| Horizontal position | 3N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 seconds RMS | OK | OK by design because the radar scans monotonically the space.<br>Aircraft at low altitude and on each side of the radar (one taking off and one landing) will increase the RMS but in that case these aircraft are not subject to horizontal separation so such cases will not be taken into account. |
| Pressure altitude | 3N_C-R7 | Probability of update | **More than or equal to 96 %** | OK | Same performance for SSR |
| Forwarded pressure altitude | 3N_C-R8 | Average data age | **Less than or equal to 2.5 seconds** | OK | SSR specified maximum processing time is 2s. |

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Forwarded pressure altitude | | Maximum data age | **Less than or equal to 16 seconds** | OK | Max 2 s specified |
| Forwarded pressure altitude | 3N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Same specified performance for SSR. |
| Pressure altitude | 3N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 3N_C-R11 | Delay | **Less than or equal to 7.5 seconds** | ? | 97 % (Hor Pos) x 98 % (Mode A) = 95% globally over the maximum range.<br>So it should be less than 7 seconds (5 seconds maximum update interval + 2 seconds maximum processing delay) in 95 % of the cases. |
| Change in Aircraft identity | 3N_C-R12 | Delay | **Less than or equal to 15 seconds** | ? | 97 % (Hor Pos) x 98 % (Mode A) = 95% globally over the maximum range.<br>So it should be less than 7 seconds (5 seconds maximum update interval + 2 seconds maximum processing delay) in 95 % of the cases. |
| Aircraft identity | 3N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | Mode A Pd = 98 % |
| Aircraft identity | 3N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Same specified performance for SSR. |
| Rate of climb/descent | 3N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |
| Track velocity | 3N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 3N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| False target reports | 3N_C-R18 | Density of uncorrelated false target reports | Less than or equal to 2 false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals | OK | If range is limited to 115 NM it gives a maximum of 830 false target reports over 720 updates periods which correspond to 1,15 false target report per scan.<br>Specified maximum rate of false target report is 0,4% (0,1 % false + 0,3 % duplicated) from this rate and from previous figure a maximum number of 288 (1,15/0.004) target reports per scan can be derived, which is a reasonable SSR capacity when limited to 115 NM. |
| False tracks | 3N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 1 falsely confirmed track per hour that are closer than 16700 m - 9 NM from true tracks | ? | No corresponding specification. |
| System | 3N_C-R20 | Continuity (probability of critical failure) | Less than or equal to $2.5\ 10^{-5}$ per hour of operation | ? | No corresponding specification. |

# F - 2 Mode S mono radar system design based on [RD 19]

## F - 2.1 5N_C

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 5N_C-R1 | Update interval | **Less than or equal to 8 seconds** | OK | Provided that rotation period is less than 8 s |
| Horizontal position | 5N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | ? | 97 % global |
| Horizontal position or pressure altitude | 5N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | OK. Probability of 3 consecutive and uncorrelated (assumption) missed target report is between 8. $10^{-6}$ and 1.25 $10^{-4}$. |
| Horizontal position | 5N_C-R4 | RMS error | **Less than or equal to 500 m global and 550 m per flight** | OK | Assuming azimuth error is predominant over range error (i.e. range > 30 NM), assuming azimuth error follows a Gaussian distribution with 0.068° standard deviation and assuming all aircraft are within the measurement volume (> 170 NM) ) it gives an RMS error of 375 m..<br>It does not take into account error due to latency. Maximum latency (2 s) at maximum speed (600 knots) gives an error of 620 m.<br>Based on measurements made previously this impact is limited and can be compensated by a range reduction.<br>Azimuth bias (0,022°) must be taken into account for addressing radar vectoring.<br>550 m RMS per flight should be achieved as well. |
| Horizontal position | 5N_C-R5 | Ratio of target reports involved in series of at least 3 consecutive correlated errors larger than 926 m - 0.5 NM | Less than or equal to 0.03 % | OK | Taking into account the probability of azimuth error greater than 926 m at 170 NM and assuming errors are uncorrelated and Gaussian, the probability of having 3 consecutive errors larger than 926 m (2.47 $\sigma$) is $(0.0068)^3$ = 3.2 $10^{-7}$. |
| Horizontal position | 5N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 second RMS for relative data age | OK | OK by design because the radar scans monotonically the space. Aircraft at low altitude and on each side of the radar (one taking off and one landing) will increase the RMS but in that case these aircraft are not subject to horizontal separation so such cases will not be taken into account. |
| Pressure altitude | 5N_C-R7 | Probability of update | **Greater than or equal to 96 %** | OK | 98% specified |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Forwarded pressure altitude | 5N_C-R8 | Average data age | **Less than or equal to 4 seconds** | OK | Specified maximum processing time is 2 s therefore performance is reached by single Mode S radar. |
| Forwarded pressure altitude | | Maximum data age | **Less than or equal to 16 seconds** | OK | Max 2 s specified |
| Forwarded pressure altitude | 5N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Same specified performance for Mode S. |
| Pressure altitude | 5N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 5N_C-R11 | Delay | **Less than or equal to 12 seconds** | ? | 99 % (Hor Pos) x 98 % (Mode A) = 97% globally over the measurement volume.<br>So it should be less than 10 seconds (8 seconds maximum update interval + 2 seconds maximum processing delay) in 97 % of the cases. |
| Change in Aircraft identity | 5N_C-R12 | Delay | **Less than or equal to 24 seconds** | ? | 99 % (Hor Pos) x 98 % (Mode A) = 97% globally over the measurement volume.<br>So it should be less than 10 seconds (8 seconds maximum update interval + 2 seconds maximum processing delay) in 97 % of the cases. |
| Aircraft identity | 5N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | Mode A Pd = 99% over the measurement volume for Mode S equipped aircraft (cf. SPI IR).<br>Mode A Pd = 98% over the measurement volume for Mode A/C equipped aircraft. |
| Aircraft identity | 5N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Same specified performance for Mode S. |
| Rate of climb/descent | 5N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |
| Track velocity | 5N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Track velocity angle | 5N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |
| False target reports | 5N_C-R18 | Density of uncorrelated false target reports | Less than 10 false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals | OK | If range is limited to 170 NM (measurement volume) it gives a maximum of 1000 false target reports over 450 updates.<br>Specified maximum rate of false target report is 0,1% and 1 duplicated target report per scan.<br>One can derive a maximum of 1222 target reports per scan which is above the Mode S radar capacity (900). |
| False tracks | 5N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 2 non-simultaneous falsely confirmed tracks per hour that are closer than 13000 m - 7 NM from true tracks | ? | No corresponding specification. |
| System | 5N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | Not OK | MTBF = 20000 h which gives a continuity of 5 $10^{-5}$ per hour of operation. |

## F - 2.2 3N_C

| **Data items** | **Req. #** | **Quality of service** | **Mandatory**/recommended **performance** | **Status** | **Justification and conditions** |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 3N_C-R1 | Update interval | **Less than or equal to 5 seconds** | OK | Provided that rotation period is less than 5 s |
| Horizontal position | 3N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | ? | 97 % global |
| Horizontal position or pressure altitude | 3N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | OK. Probability of 3 consecutive and uncorrelated (assumption) missed target report is between 8. $10^{-6}$ and 1.25 $10^{-4}$. |
| Horizontal position | 3N_C-R4 | RMS error | **Less than or equal to 300 m global and 330 m per flight** | OK | Assuming azimuth error is predominant over range error (i.e. range > 30 NM), assuming azimuth error follows a Gaussian distribution with 0.068° standard deviation and assuming all aircraft are at the same range.<br>An RMS error of 300 m corresponds to a range of 135 NM.<br>It does not take into account error due to latency. Maximum latency (2 s) at maximum speed (400 knots) gives an error of 412 m.<br>Based on measurements made previously this impact is limited and can be compensated by a range reduction.<br>Azimuth bias (0,022°) must be taken into account for addressing radar vectoring.<br>330 m RMS per flight should be achieved as well. |
| Horizontal position | 3N_C-R5 | Ratio of target reports involved in sets of 3 consecutive correlated errors larger than 555 m - 0.3 NM | Less than or equal to 0.03 % | OK | Taking into account only the azimuth error at the range of 135 NM and assuming errors are uncorrelated the probability of having 3 consecutive errors larger than 555 m (1.87 $\sigma$) is $(0.0303)^3$ = 2.8 $10^{-5}$ |
| Horizontal position | 3N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 seconds RMS | OK | OK by design because the radar scans monotonically the space. Aircraft at low altitude and on each side of the radar (one taking off and one landing) will increase the RMS but in that case these aircraft are not subject to horizontal separation so such cases will not be taken into account. |
| Pressure altitude | 3N_C-R7 | Probability of update | **Greater than or equal to 96 %** | OK | 98% specified |
| Forwarded pressure altitude | 3N_C-R8 | Average data age | **Less than or equal to 2.5 seconds** | OK | Specified maximum processing time is 2 s therefore performance is reached by single Mode S radar. |
| Forwarded pressure altitude | | Maximum data age | **Less than or equal to 16 seconds** | OK | Max 2 s specified |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Forwarded pressure altitude | 3N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Same specified performance for Mode S. |
| Pressure altitude | 3N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 3N_C-R11 | Delay | **Less than or equal to 7.5 seconds** | ? | 99 % (Hor Pos) x 98 % (Mode A) = 97% globally over the measurement volume.<br>So it should be less than 7 seconds (5 seconds maximum update interval + 2 seconds maximum processing delay) in 97 % of the cases. |
| Change in Aircraft identity | 3N_C-R12 | Delay | **Less than or equal to 15 seconds** | ? | 99 % (Hor Pos) x 98 % (Mode A) = 97% globally over the measurement volume.<br>So it should be less than 7 seconds (5 seconds maximum update interval + 2 seconds maximum processing delay) in 97 % of the cases. |
| Aircraft identity | 3N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | Mode A Pd = 99% over the measurement volume for Mode S equipped aircraft (cf. SPI IR).<br>Mode A Pd = 98% over the measurement volume for Mode A/C equipped aircraft. |
| Aircraft identity | 3N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Same specified performance for Mode S. |
| Rate of climb/descent | 3N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |
| Track velocity | 3N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 3N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| False target reports | 3N_C-R18 | Density of uncorrelated false target reports | Less than or equal to 2 false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals | OK | OK. If range is limited to 135 NM it gives a maximum of 1060 false target reports over 720 updates.<br>Specified maximum rate of false target report is 0,1% and 0,8 duplicated target report per scan.<br>One can derive a maximum 672 target reports per scan which is above the Mode S radar capacity (900 target report per scan at 256 NM)taking into account reduced range. |
| False tracks | 3N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 1 falsely confirmed track per hour that are closer than 16700 m - 9 NM from true tracks | ? | No corresponding specification. |
| System | 3N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | Not OK | MTBF = 20000 h which gives a continuity of 5 $10^{-4}$ per hour of operation. |

## F - 3 Single ADS-B ground station based on [RD 4] (ADS-B NRA)

### F - 3.1 5N_C

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 5N_C-R1 | Update interval | **Less than or equal to 8 seconds** | Not OK. | 95% per aircraft is specified for 10 s update interval. This due to the selection of 10 s as the update interval for en-route airspace. In practice 95% at 8 s would be reached per flight. |
| Horizontal position | 5N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | | |
| Horizontal position or pressure altitude | 5N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | Not OK | Assuming probability of update is uncorrelated from update interval to update interval, the probability to have at least 2 consecutive missed target reports (gap of 30 s) is equal to 2.5 $10^{-3}$. |
| Horizontal position | 5N_C-R4 | RMS error | **Less than or equal to 500 metres global and 550 m per flight** | Not OK | Assuming ADS-B position errors follow a Rayleigh distribution and are contained within 0,5 NM at 95 %, it gives an RMS value of 535 m.<br>In practice, the actual performance is far better than what is announced in the NAC value (the 95% containment value).<br>Does not take into account error due to latency. 1,5 s airborne latency at 95% and 0,5 s ground latency at 95 % at maximum speed (600 knots) gives an error of 620 m.<br>Will be OK per flight but not taking into account latencies. |
| Horizontal position | 5N_C-R5 | Ratio of target reports involved in series of at least 3 consecutive correlated errors larger than 926 m - 0.5 NM | Less than or equal to 0.03 % | OK | Assuming errors are uncorrelated and are always in the same direction (worst case), one can derive a probability of $(0.05)^3$ = 1.25 $10^{-4}$.<br>Correlated errors are bound by the requirements on the NIC (4) and the SIL (2) which specify that the probability of having an undetected error above 2 NM during more than 10 s is less than 1. $10^{-5}$ per flight hour. This specification is expected to be more stringent although it cannot be formally demonstrated. |
| Horizontal position | 5N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 second RMS for relative data age | ? | No corresponding specification, the inclusion of a monosensor tracker should guarantee the achievement of this performance. |
| Pressure altitude | 5N_C-R7 | Probability of update | **Greater than or equal to 96 %** | OK | Pressure altitude is present in every target report, probability of integrity error on Mode C code is very remote. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Forwarded pressure altitude | 5N_C-R8 | Average data age | **Less than or equal to 4 seconds** | OK | Airborne latency of pressure pressure is specified as equivalent as for SSR (assumed negligible) and ground latency is less than 0,5 s in 95 % of the cases, it should be OK without problems. |
| Forwarded pressure altitude | | Maximum data age | | ? | Airborne latency of pressure pressure is specified as equivalent as for SSR (assumed negligible) and ground latency is less than 0,5 s in 95 % of the case. |
| Forwarded pressure altitude | 5N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Integrity requirement of less than $10^{-5}$ corruption per flight hour means less than one corruption for 100000 flight hours. One flight hour represents 450 target reports (8 s update interval). So the ratio of incorrect data item will be less than 1 /(450 x 100000) = 2.22 $10^{-8}$ for any data item. Should be even less for pressure altitude. It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| Pressure altitude | 5N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights** **Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 5N_C-R11 | Delay | **Less than or equal to 12 seconds** | NOT OK | Less than 10 s in 95% of the cases. |
| Change in Aircraft identity | 5N_C-R12 | Delay | **Less than or equal to 24 seconds** | ? | No corresponding specification. |
| Aircraft identity | 5N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | Aircraft ID and Mode A are present in every target report, probability of integrity error on Mode A or Aircraft ID code is very remote. |
| Aircraft identity | 5N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Integrity requirement of less than $10^{-5}$ corruption per flight hour means less than one corruption for 100000 flight hours. One flight hour represents 450 target reports (8 s update interval). So the ratio of incorrect data item will be less than 1 /(450 x 100000) = 2.22 $10^{-8}$ for any data item. Should be even less for aircraft identity (Mode A or aircraft identification). It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Rate of climb/descent | 5N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |
| Track velocity | 5N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 5N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |
| False target reports | 5N_C-R18 | Density of uncorrelated false target reports | Less than 10 false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals | OK | Assuming 900 $NM^2$ is the size of a sector and assuming that a controller controls 6 flight hour per hour and taking into account the integrity requirement of less than $10^{-5}$ corruption per flight hour it gives 6. $10^{-5}$ false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals.<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| False tracks | 5N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 2 non-simultaneous falsely confirmed tracks per hour that are closer than 13000 m - 7 NM from true tracks | ? | No corresponding specification. |
| System | 5N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | ? | There is a specification for the airborne domain continuity but there is nothing for the ground, therefore it is not possible to calculate a global system (air+ground) continuity. |

## F - 3.2 3N_C

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 3N_C-R1 | Update interval | **Less than or equal to 5 seconds** | OK. | Same performance. |
| Horizontal position and pressure altitude | 3N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | Not OK | Specified performance 95% per flight. |
| Horizontal position or pressure altitude | 3N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | Assuming probability of update is uncorrelated from update interval to update interval, the probability to have at least 3 consecutive missed target reports (gap of 20 s) is equal to 1.25 $10^{-4}$. |
| Horizontal position | 3N_C-R4 | RMS error | **Less than or equal to 300 m global and 330 m per flight** | Not OK | Assuming ADS-B position errors follow a Rayleigh distribution and are contained within 0,3 NM at 95 %, it gives an RMS value of 320 m. In practice the actual performance is far better than what is announced in the NAC value (the 95% containment value).<br>Does not take into account error due to latency. 1,5 s airborne latency at 95% and 0,5 s ground latency at 95 % at maximum speed (400 knots) gives an error of 416 m.<br>Will be OK per flight but not taking into account latencies. |
| Horizontal position | 3N_C-R5 | Ratio of target reports involved in sets of 3 consecutive correlated errors larger than 555 m - 0.3 NM | Less than or equal to 0.03 % | OK | Assuming errors are uncorrelated and are always in the same direction (worst case), one can derive a probability of $(0.05)^3$ = 1.25 $10^{-4}$.<br>Correlated errors are bound by the requirements on the NIC (5) and the SIL (2) which specify that the probability of having an undetected error above 1 NM during more than 10 s is less than 1. $10^{-5}$ per flight hour. This specification is expected to be more stringent although it cannot be formally demonstrated. |
| Horizontal position | 3N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 seconds RMS | ? | No corresponding specification, the inclusion of a monosensor tracker should guarantee the achievement of this performance. |
| Pressure altitude | 3N_C-R7 | Probability of update | **Greater than or equal to 96 %** | OK | Pressure altitude is present in every target report, probability of integrity error on Mode C code is very remote. |
| Forwarded pressure altitude | 3N_C-R8 | Average data age | **Less than or equal to 2.5 seconds** | OK | Airborne latency of pressure pressure is specified as equivalent as for SSR (assumed negligible) and ground latency is less than 0,5 s in 95 % of the cases, it should be OK without problems. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Forwarded pressure altitude | | Maximum data age | | ? | Airborne latency of pressure pressure is specified as equivalent as for SSR (assumed negligible) and ground latency is less than 0,5 s in 95 % of the case. |
| Forwarded pressure altitude | 3N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Integrity requirement of less than $10^{-5}$ corruption per flight hour means less than one corruption for 100000 flight hours. One flight hour represents 720 target reports (5 s update interval). So the ratio of incorrect data item will be less than 1 /(720 x 100000) = 1.4 $10^{-8}$ for any data item. Should be even less for pressure altitude.<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| Pressure altitude | 3N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 3N_C-R11 | Delay | **Less than or equal to 7.5 seconds** | ? | Less than 5 s in 95% of the cases. |
| Change in Aircraft identity | 3N_C-R12 | Delay | **Less than or equal to 15 seconds** | ? | No corresponding specification |
| Aircraft identity | 3N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | Aircraft ID and Mode A are present in every target report, probability of integrity error on Mode A or Aircraft ID code is very remote. |
| Aircraft identity | 3N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Integrity requirement of less than $10^{-5}$ corruption per flight hour means less than one corruption for 100000 flight hours. One flight hour represents 720 target reports (5 s update interval). So the ratio of incorrect data item will be less than 1 /(720 x 100000) = 1.4 $10^{-8}$ for any data item.<br>Should be even less for aircraft identity (Mode A or aircraft identification).<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| Rate of climb/descent | 3N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Track velocity | 3N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 3N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |
| False target reports | 3N_C-R18 | Density of uncorrelated false target reports | Less than or equal to 2 false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals | OK | Assuming 100 $NM^2$ is the size of a sector and assuming that a controller controls 6 flight hour per hour and taking into account the integrity requirement of less than $10^{-5}$ corruption per flight hour it gives 6. $10^{-5}$ false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals.<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| False tracks | 3N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 1 falsely confirmed track per hour that are closer than 16700 m - 9 NM from true tracks | ? | No corresponding specification. |
| System | 3N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | ? | There is a specification for the airborne domain continuity but there is nothing for the ground, therefore it is not possible to calculate a global system (air+ground) continuity. |

## F - 4 Single ADS-B ground station based on [RD 42] (ADS-B RAD)

### F - 4.1 5N_C

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 5N_C-R1 | Update interval | **Less than or equal to 8 seconds** | OK | Same performance for en route (5 NM separation) |
| Horizontal position | 5N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | OK | 97% per flight is specified for en route (5 NM separation) |
| Horizontal position or pressure altitude | 5N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | Assuming probability of update is uncorrelated from update interval to update interval, the probability to have at least 3 consecutive missed target reports (gap larger than 24s) is equal to $(0.03)^3 = 2.7\ 10^{-5}$. |
| Horizontal position | 5N_C-R4 | RMS error | **Less than or equal to 500 m global and 550 m per flight** | OK | Assuming ADS-B position errors follow a Rayleigh distribution and are contained within 308 m at 95 %, it gives an RMS value of 178 m. Does not take into account error due to latency. 0,6 s (airborne) and 0,5 s (ground) latency at 95 %, at maximum speed (600 knots) gives an error of 340 m. |
| Horizontal position | 5N_C-R5 | Ratio of target reports involved in series of at least 3 consecutive correlated errors larger than 926 m - 0.5 NM | Less than or equal to 0.03 % | OK | Assuming ADS-B errors follow a Rayleigh distribution, the probability of having an error greater than 926 m is equal to $1.3\ 10^{-10}$.Then assuming errors are uncorrelated and are always in the same direction (worst case), the probability of having 3 consecutive errors greater than 926 m is very remote.<br>Correlated errors are bound by the requirements on the NIC (5) and the SIL (3) which specify that the probability of having an undetected error above 1 NM during more than 10 s is less than $1.\ 10^{-7}$ per flight hour. This specification is expected to be more stringent although it cannot be formally demonstrated. |
| Horizontal position | 5N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 second RMS for relative data age | ? | No corresponding specification, the inclusion of a monosensor tracker should guarantee the achievement of this performance. |
| Pressure altitude | 5N_C-R7 | Probability of update | **Greater than or equal to 96 %** | OK | Pressure altitude is present in every target report, probability of integrity error on Mode C code is very remote. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Forwarded pressure altitude | 5N_C-R8 | Average data age | **Less than or equal to 4 seconds** | OK | Airborne latency of pressure pressure is assumed as equivalent as for SSR (assumed negligible) and ground latency is less than 0,5 s in 95 % of the cases, it should be OK without problems. |
| Forwarded pressure altitude | | Maximum data age | **Less than or equal to 12 seconds** | ? | Airborne latency of pressure pressure is specified as equivalent as for SSR (assumed negligible) and ground latency is less than 0,5 s in 95 % of the case. |
| Forwarded pressure altitude | 5N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Integrity requirement of less than 2. $10^{-5}$ corruption per flight hour means less than one corruption for 50000 flight hours. One flight hour represents 450 target reports (8 s update interval). So the ratio of incorrect data item will be less than 1 /(450 x 50000) = 4.44 $10^{-8}$ for any data item. Should be even less for pressure altitude.<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| Pressure altitude | 5N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 5N_C-R11 | Delay | **Less than or equal to 12 seconds** | ? | Less than 8 s in 95% of the cases. |
| Change in Aircraft identity | 5N_C-R12 | Delay | **Less than or equal to 24 seconds** | ? | Less than 8 s in 95% of the cases for Mode A code, should be even less for the Aircraft Identification. |
| Aircraft identity | 5N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | 100 % as aircraft identity is provided in each target report. |
| Aircraft identity | 5N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Integrity requirement of less than 2. $10^{-5}$ corruption per flight hour means less than one corruption for 50000 flight hours. One flight hour represents 450 target reports (8 s update interval). So the ratio of incorrect data item will be less than 1 /(450 x 50000) = 4.44 $10^{-8}$ for any data item.<br>Should be even less for aircraft identity (Mode A or aircraft identification).<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Rate of climb/descent | 5N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |
| Track velocity | 5N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 5N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |
| False target reports | 5N_C-R18 | Density of uncorrelated false target reports | Less than 10 false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals | OK | Assuming 900 $NM^2$ is the size of a sector and assuming that a controller controls 6 flight hour per hour and taking into account the integrity requirement of less than 2. $10^{-5}$ corruption per flight hour it gives 1.2 $10^{-4}$ false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals.<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| False tracks | 5N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 2 non-simultaneous falsely confirmed tracks per hour that are closer than 13000 m - 7 NM from true tracks | ? | No corresponding specification. |
| System | 5N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | OK | Assuming the ground domain continuity is preponderant in the system (air+ground) continuity. The ground domain continuity is specified 1. $10^{-5}$. |

## F - 4.2 3N_C

| Data items | Req. # | Quality of service | **Mandatory**/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 3N_C-R1 | Update interval | **Less than or equal to 5 seconds** | OK. | Same performance for TMA (3 NM separation) |
| Horizontal position | 3N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | OK | 97% per flight is specified for TMA (3 NM separation) |
| Horizontal position or pressure altitude | 3N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | Assuming probability of update is uncorrelated from update interval to update interval, the probability to have at least 3 consecutive missed target reports (gap larger than 15 s) is equal to $(0.03)^3 = 2.7\ 10^{-5}$. |
| Horizontal position | 3N_C-R4 | RMS error | **Less than or equal to 300 m global and 330 m per flight** | OK | Assuming ADS-B errors follow a Rayleigh distribution 171 m at 95 % gives an RMS value of 99 m.<br>Does not take into account error due to latency. 0,6 s (airborne) and 0,5 s (ground) latency at 95 % at maximum speed (400 knots) gives an error of 227 m. |
| Horizontal position | 3N_C-R5 | Ratio of target reports involved in sets of 3 consecutive correlated errors larger than 555 m - 0.3 NM | Less than or equal to 0.03 % | OK | Assuming ADS-B errors follow a Rayleigh distribution, the probability of having an error greater than 555 m is smaller than $10^{-13}$.Then assuming errors are uncorrelated and are always in the same direction (worst case), the probability of having 3 consecutive errors greater than 555 m is extremely remote.<br>Correlated errors are bound by the requirements on the NIC (6) and the SIL (3) which specify that the probability of having an undetected error above 0.6 NM during more than 10 s is less than $1.\ 10^{-7}$ per flight hour. This specification is expected to be more stringent although it cannot be formally demonstrated. |
| Horizontal position | 3N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 seconds RMS | ? | No corresponding specification, the inclusion of a monosensor tracker should guarantee the achievement of this performance. |
| Pressure altitude | 3N_C-R7 | Probability of update | **Greater than or equal to 96 %** | OK | Pressure altitude is present in every target report, probability of integrity error on Mode C code is very remote. |
| Forwarded pressure altitude | 3N_C-R8 | Average data age | **Less than or equal to 2.5 seconds** | OK | Airborne latency of pressure pressure is assumed as equivalent as for SSR (assumed negligible) and ground latency is less than 0,5 s in 95 % of the cases, it should be OK without problems. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Forwarded pressure altitude | | Maximum data age | **Less than or equal to 12 seconds** | ? | Airborne latency of pressure pressure is specified as equivalent as for SSR (assumed negligible) and ground latency is less than 0,5 s in 95 % of the case. |
| Forwarded pressure altitude | 3N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Integrity requirement of less than 2. $10^{-5}$ corruption per flight hour means less than one corruption for 50000 flight hours. One flight hour represents 720 target reports (5 s update interval). So the ratio of incorrect data item will be less than 1 /(720 x 50000) = 2.8 $10^{-8}$ for any data item. Should be even less for pressure altitude.<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| Pressure altitude | 3N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 3N_C-R11 | Delay | **Less than or equal to 7.5 seconds** | ? | Less than 5 s in 95% of the cases. |
| Change in Aircraft identity | 3N_C-R12 | Delay | **Less than or equal to 15 seconds** | ? | Less than 5 s in 95% of the cases for Mode A code, should be even less for the Aircraft Identification. |
| Aircraft identity | 3N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | 100 % as aircraft identity is provided in each target report. |
| Aircraft identity | 3N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Integrity requirement of less than 2. $10^{-5}$ corruption per flight hour means less than one corruption for 50000 flight hours. One flight hour represents 720 target reports (5 s update interval). So the ratio of incorrect data item will be less than 1 /(720 x 50000) = 2.8 $10^{-8}$ for any data item.<br>Should be even less for aircraft identity (Mode A or aircraft identification).<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| Rate of climb/descent | 3N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Track velocity | 3N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 3N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |
| False target reports | 3N_C-R18 | Density of uncorrelated false target reports | Less than or equal to 2 false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals | OK | Assuming 100 $NM^2$ is the size of a sector and assuming that a controller controls 6 flight hour per hour and taking into account the integrity requirement of less than 2. $10^{-5}$ corruption per flight hour it gives 1.2 $10^{-4}$ false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals.<br>It is also assumed that the contribution of the airborne part is preponderant over the ground contribution (5. $10^{-6}$ per hour). |
| False tracks | 3N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 1 falsely confirmed track per hour that are closer than 16700 m - 9 NM from true tracks | ? | No corresponding specification. |
| System | 3N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | OK | Assuming the ground domain continuity is preponderant in the system (air+ground) continuity. The ground domain continuity is specified 1. $10^{-5}$. |

## F - 5 Wide Area Multilateration system based on [RD 46]

### F - 5.1 5N_C

| Data items | Req. # | Quality of service | **Mandatory**/recommended **performance** | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 5N_C-R1 | Update interval | **Less than or equal to 8 seconds** | OK | Same performance for en route (i.e. 5 NM separation) |
| Horizontal position | 5N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | OK | 97% (probability of position detection for any aircraft) |
| Horizontal position or pressure altitude | 5N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | It should be OK for synchronous output. |
| Horizontal position | 5N_C-R4 | RMS error | **Less than or equal to 500 m global and 550 m per flight** | OK | 350 m RMS for en route (i.e. 5 NM separation) but does not take into account latency of maximum 0.5 s which gives at maximum speed (600 knots) 154 m. |
| Horizontal position | 5N_C-R5 | Ratio of target reports involved in series of at least 3 consecutive correlated errors larger than 926 m - 0.5 NM | Less than or equal to 0.03 % | ? | A model of the WAM horizontal error distribution is needed to progress further in this area. |
| Horizontal position | 5N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 second RMS for relative data age | ? | No corresponding specification, the inclusion of a monosensor tracker should guarantee the achievement of this performance. |
| Pressure altitude | 5N_C-R7 | Probability of update | **Greater than or equal to 96 %** | OK | 96% (probability of Mode C code detection for any aircraft) |
| Forwarded pressure altitude | 5N_C-R8 | Average data age | **Less than or equal to 4 seconds** | OK | Ground latency is less than 0,5 s maximum, it should be OK without problems. |
| Forwarded pressure altitude | | Maximum data age | **Less than or equal to 12 seconds** | OK | Ground latency is less than 0,5 s maximum |
| Forwarded pressure altitude | 5N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Probability of false Mode C code is less than 0.1%.. |

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Pressure altitude | 5N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 5N_C-R11 | Delay | **Less than or equal to 12 seconds** | ? | Less than 8 s in 95 % of the cases (§ 3.3.2) |
| Change in Aircraft identity | 5N_C-R12 | Delay | **Less than or equal to 24 seconds** | Not OK | Less than 24 s in 95 % of the cases (§ 3.3.2) |
| Aircraft identity | 5N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | Mode A Pd = 98 % |
| Aircraft identity | 5N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Less than 0.1% of false Mode A code or false ACID |
| Rate of climb/descent | 5N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |
| Track velocity | 5N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 5N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |
| False target reports | 5N_C-R18 | Density of uncorrelated false target reports | Less than 10 false target reports per area of 900 $NM^2$ and over a duration of 450 update intervals | OK | The Probability of false detection shall be less than or equal to 0.1% (§ 3.3.5).<br>Assuming the same coverage as an SSR and a similar capacity, as the rate of false target reports for WAM is 4 times less than an SSR it should also meet the requirement. |
| False tracks | 5N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 2 non-simultaneous falsely confirmed tracks per hour that are closer than 13000 m - 7 NM from true tracks | ? | No corresponding specification. |
| System | 5N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | Not OK | Indicative MTBCF = 10000 hours. |

### F - 5.2 3N_C

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Horizontal position, pressure altitude and aircraft identity | 3N_C-R1 | Update interval | **Less than or equal to 5 seconds** | OK | Same performance for TMA (i.e. 3 NM separation) |
| Horizontal position | 3N_C-R2 | Probability of update | **Greater than or equal to 97 % per flight** | OK | 97% (probability of position detection for any aircraft) |
| Horizontal position or pressure altitude | 3N_C-R3 | Ratio of missed 3D position involved in long gaps (larger than 3 maximum update intervals + 10%) | **Less than or equal to 0.1 %** | OK | It should be OK for synchronous output. |
| Horizontal position | 3N_C-R4 | RMS error | **Less than or equal to 300 m global and 330 m per flight** | OK | 150 m RMS for TMA (i.e. 3 NM separation) but does not take into account latency of maximum 0.5 s which gives at maximum speed (400 knots) 103 m. |
| Horizontal position | 3N_C-R5 | Ratio of target reports involved in sets of 3 consecutive correlated errors larger than 555 m - 0.3 NM | Less than or equal to 0.03 % | ? | A model of the WAM horizontal error distribution is needed to progress further in this area. |
| Horizontal position | 3N_C-R6 | Relative time of applicability for aircraft in close proximity (less than 18520 m - 10 NM) | Less than or equal to 0.3 seconds RMS | ? | No corresponding specification, the inclusion of a monosensor tracker should guarantee the achievement of this performance. |
| Pressure altitude | 3N_C-R7 | Probability of update | **Greater than or equal to 96 %** | OK | 96% (probability of Mode C code detection for any aircraft) |
| Forwarded pressure altitude | 3N_C-R8 | Average data age | **Less than or equal to 2.5 seconds** | OK | Ground latency is less than 0,5 s maximum, it should be OK without problems. |
| Forwarded pressure altitude | | Maximum data age | **Less than or equal to 12 seconds** | OK | Ground latency is less than 0,5 s maximum |
| Forwarded pressure altitude | 3N_C-R9 | Ratio of incorrect pressure altitude | **Less than or equal to 0.1 %** | OK | Probability of false Mode C code is less than 0.1%.. |
| Pressure altitude | 3N_C-R10 | Unsigned error | **Less than or equal to 200/300 ft in 99.9% of the cases for stable flights**<br>**Less than or equal to 300 ft in 98.5% of the cases for climbing / descending flights** | NA | Verification performed on the basis of 5N_C-R7 and 8. |
| Change in emergency indicator/SPI report | 3N_C-R11 | Delay | **Less than or equal to 7.5 seconds** | ? | Less than 5 s in 95 % of the cases (§ 3.3.2) |

| Data items | Req. # | Quality of service | Mandatory/recommended performance | Status | Justification and conditions |
|---|---|---|---|---|---|
| Change in Aircraft identity | 3N_C-R12 | Delay | **Less than or equal to 15 seconds** | Not OK | Less than 15 s in 95 % of the cases (§ 3.3.2) |
| Aircraft identity | 3N_C-R13 | Probability of update | **Greater than or equal to 98 % global** | OK | Mode A Pd = 98 % |
| Aircraft identity | 3N_C-R14 | Ratio of incorrect aircraft identity | **Less than or equal to 0.1 %** | OK | Less than 0.1% of false Mode A code or false ACID |
| Rate of climb/descent | 3N_C-R15 | RMS error | Less than or equal to 250 ft/mn for stable flights and less than or equal to 500 ft/mn for climbing/descending flights | NA | Assumed no tracker included. |
| Track velocity | 3N_C-R16 | RMS error | Less than or equal to 4 m/s for straight line and less than or equal to 8 m/s for turn | NA | Assumed no tracker included. |
| Track velocity angle | 3N_C-R17 | RMS error | Less than or equal to 10° for straight line and less than or equal to 25° for turn | NA | Assumed no tracker included. |
| False target reports | 3N_C-R18 | Density of uncorrelated false target reports | Less than or equal to 2 false target reports per area of 100 $NM^2$ and over a duration of 720 update intervals | OK | The Probability of false detection shall be less than or equal to 0.1% (§ 3.3.5).<br>Assuming the same coverage as an SSR and a similar capacity, as the rate of false target reports for WAM is 4 times less than an SSR it should also meet the requirement. |
| False tracks | 3N_C-R19 | Number per hour of falsely confirmed track close to true tracks | Less than or equal to 1 falsely confirmed track per hour that are closer than 16700 m - 9 NM from true tracks | ? | No corresponding specification. |
| System | 3N_C-R20 | Continuity (probability of critical failure) | Less than or equal to 2.5 $10^{-5}$ per hour of operation | Not OK | Indicative MTBCF = 10000 hours. |

## F - 6 System design including tracker

Without making assumptions on the mono-sensor tracker characteristics and on the traffic it is impossible to quantitatively predict the performance of a mono-sensor tracker in a generic way. However some qualitative statements can be provided:

- a mono-sensor tracker will aim at removing outlier positions (horizontal or vertical) and at eliminating uncorrelated false target reports, however it may generate additional outlier positions when it provides coasted position updates
- a mono-sensor tracker will provide additional data items (e.g. track velocity and rate of climb/descent)
- a mono-sensor tracker will aim at improving horizontal position accuracy in the uniform motion phases of the aircraft trajectories, however horizontal position accuracy may be degraded in the portion of trajectories showing high acceleration
- the inclusion of an additional processing stage may delay the provision of data items provided by the aircraft (e.g. SPI or new Mode A code)
- the continuity of the total system will depend on continuity of the sensor and the continuity of the mono-sensor tracker.
- mono-sensor tracker, working in a periodic mode, will geographically synchronise the target reports so that geographically close target reports are calculated and delivered at close times.

Without making assumptions on the multi-sensor tracker characteristics, on the associated infrastructure (surveillance data network) and on the traffic it is impossible to quantitatively predict the performance of a multi-sensor system in a generic way. However some qualitative statements can be provided in areas where information from different sensors are available:

- a multi-sensor tracker will aim at removing outlier positions (horizontal or vertical) and at eliminating uncorrelated false target reports, however it may generate additional outlier positions when it provides coasted position updates
- a multi-sensor tracker will provide additional data items (e.g. track velocity and rate of climb/descent)
- by receiving data items from several sensors, multi-sensor tracker will improve the probability of update of data items compared to the probability of update of individual sensors
- a multi-sensor tracker will aim at improving horizontal position accuracy thanks to an higher update rate of that information from the different sensors.
- integrity of data items will be improved by comparing the values of the same data item provided by the different sensors
- the inclusion of additional processing and network stages may delay the provision of data items provided by the aircraft (e.g. SPI or new Mode A code)
- the continuity of the sensor stage will be improved (components in parallel), total system continuity will depend on the multi-sensor tracker continuity
- multi-sensor tracker, working in a periodic mode, will geographically synchronise the target reports so that target reports in close proximity are calculated and delivered at close times.

# ANNEX - G DETAILED DESCRIPTION OF THE OPERATIONAL PERFORMANCE ASSESSMENT SCENARIOS

## G - 1 Crossing track scenario 5 NM separation detailed description

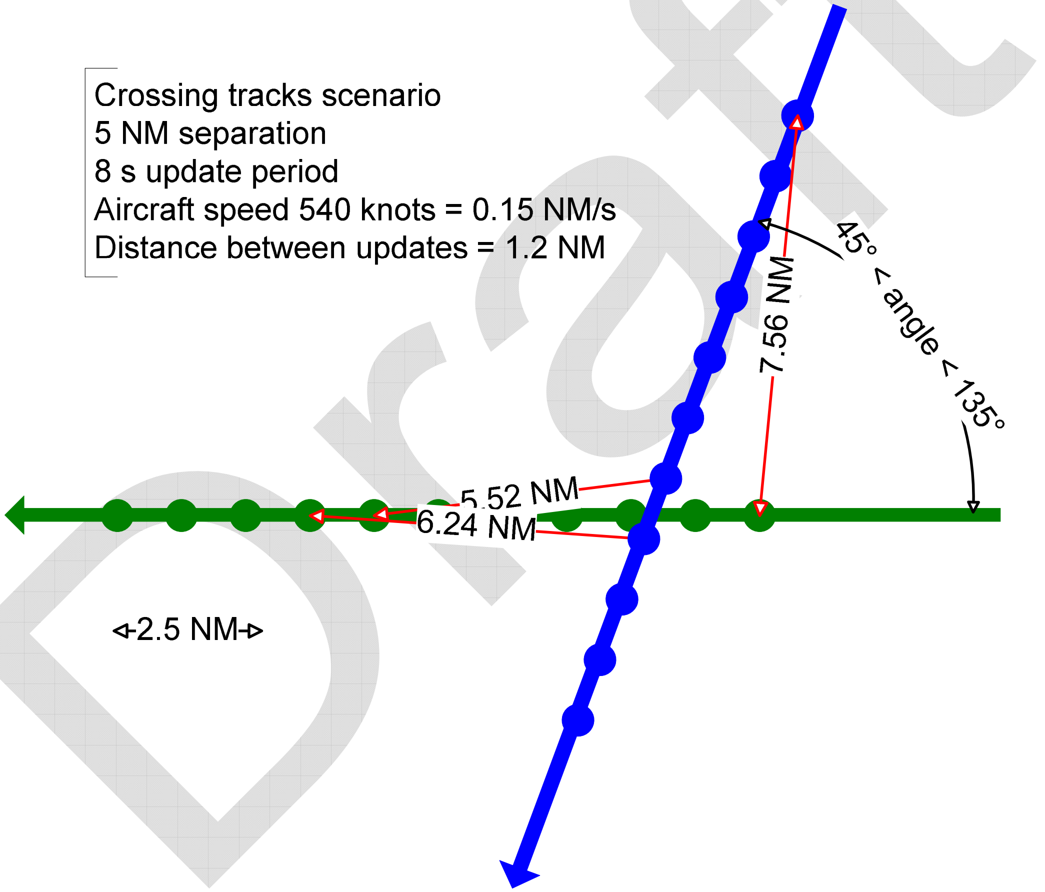


**Figure 36: Crossing track scenario 5 NM separation**

## G - 2 Crossing track scenario 3 NM separation detailed description

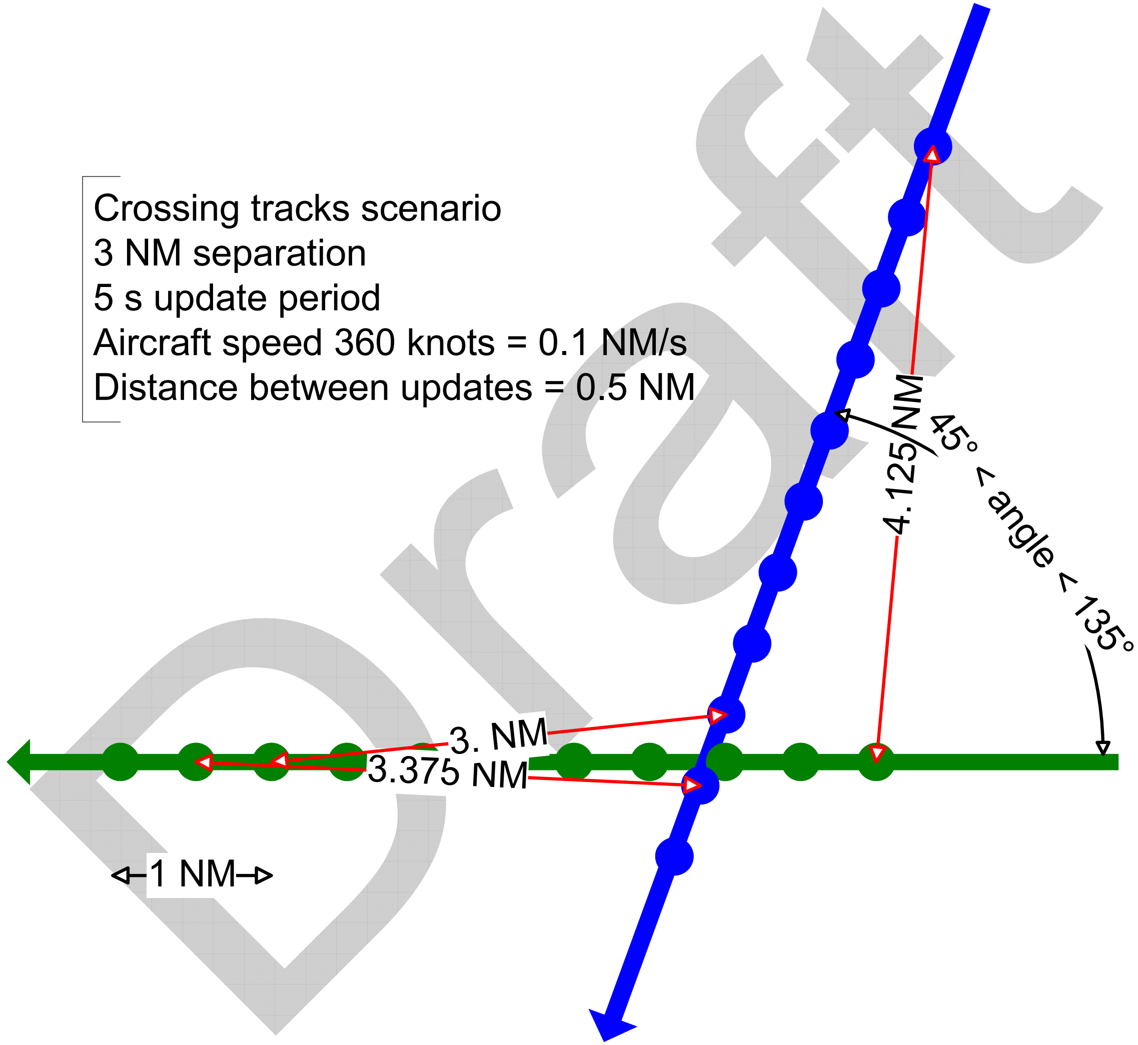


**Figure 37: Crossing track scenario 3 NM separation**

## G - 3 Same track crossing scenario 5 NM separation detailed description

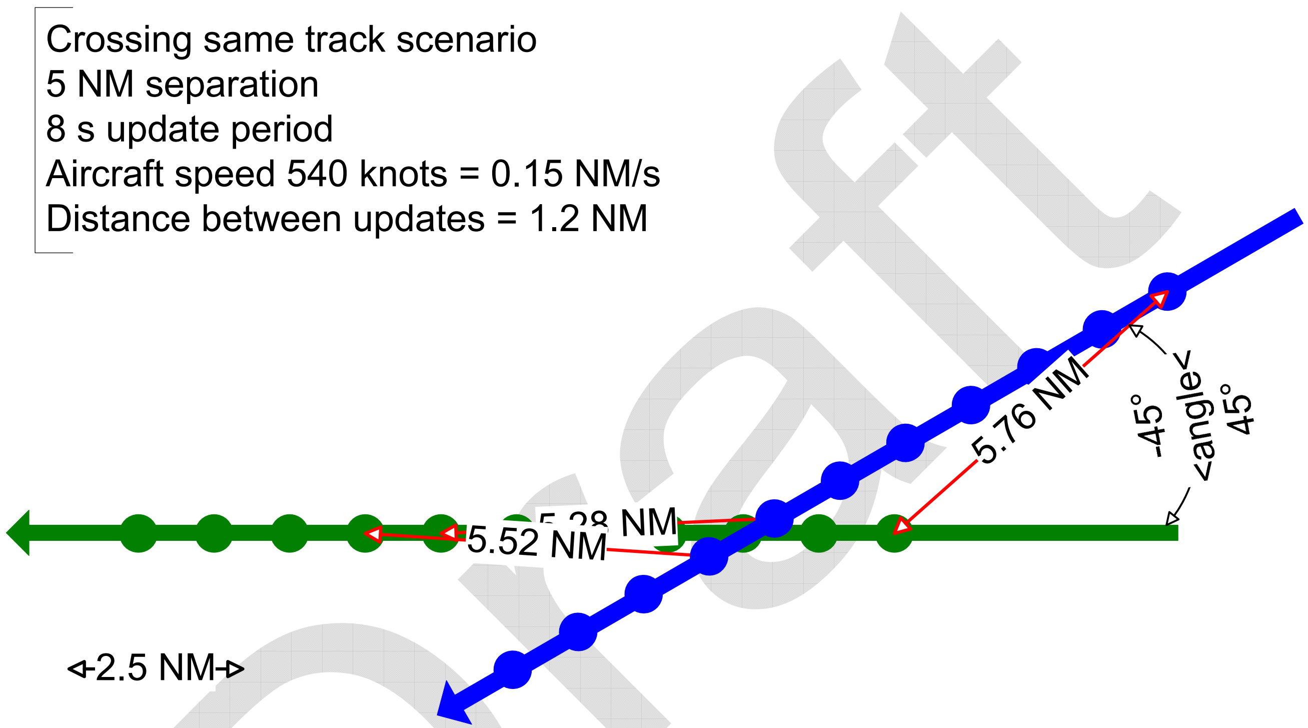


**Figure 38: Same track crossing scenario 5 NM separation**

## G - 4 Same track crossing scenario 3 NM separation detailed description

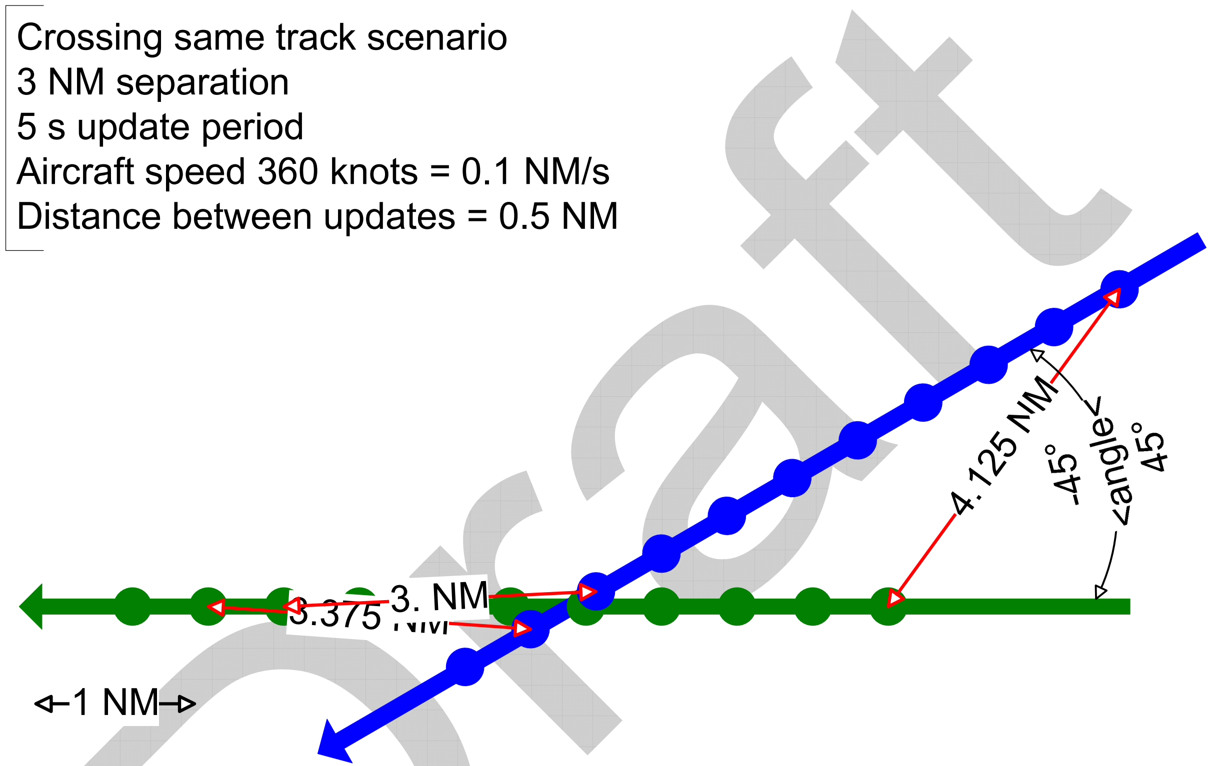


**Figure 39: Same track crossing scenario 3 NM separation**

## G - 5 Reciprocal track crossing scenario 5 NM separation detailed description

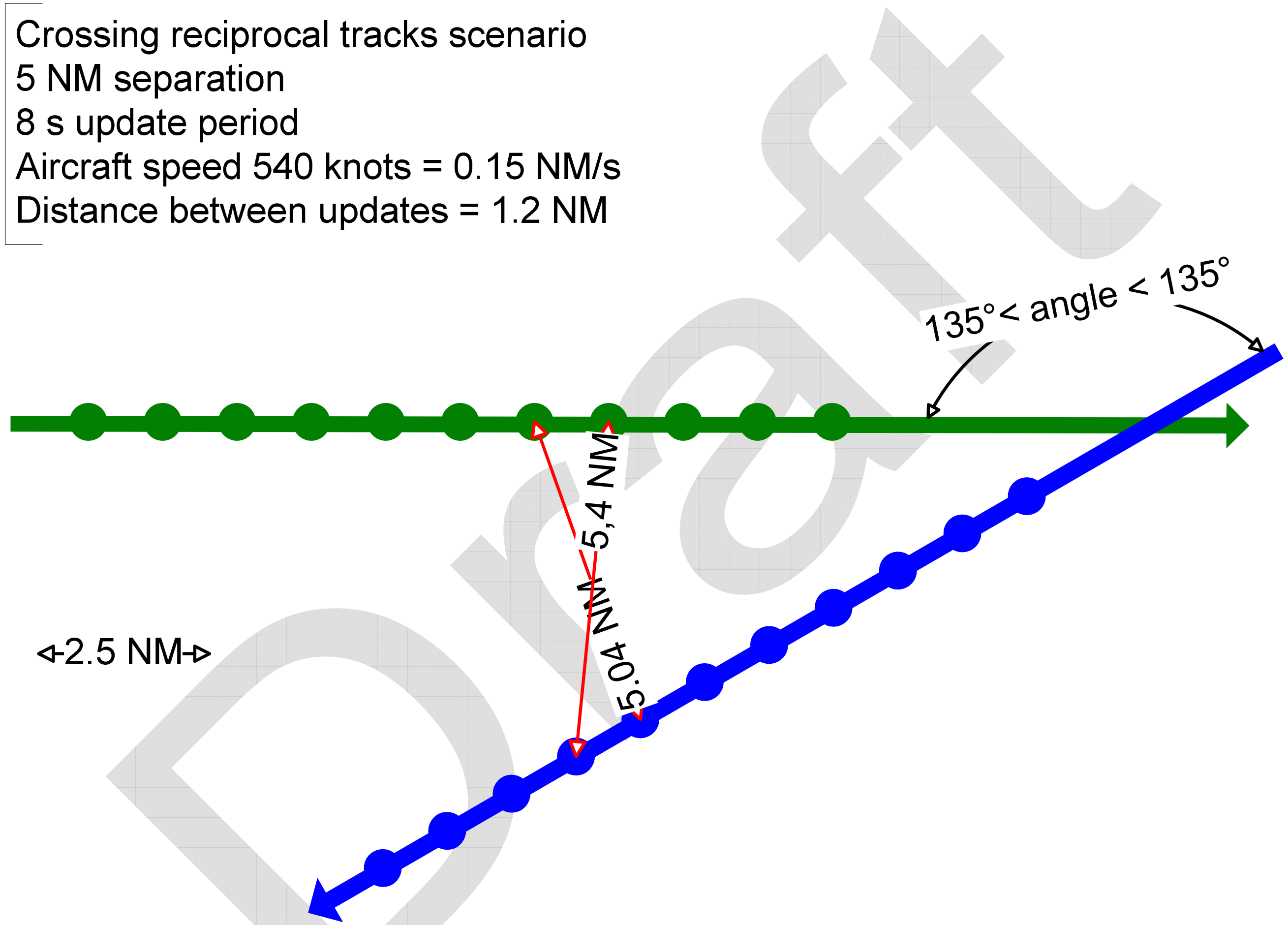


**Figure 40: Reciprocal track crossing scenario 5 NM separation**

## G - 6 Reciprocal track crossing scenario 3 NM separation detailed description

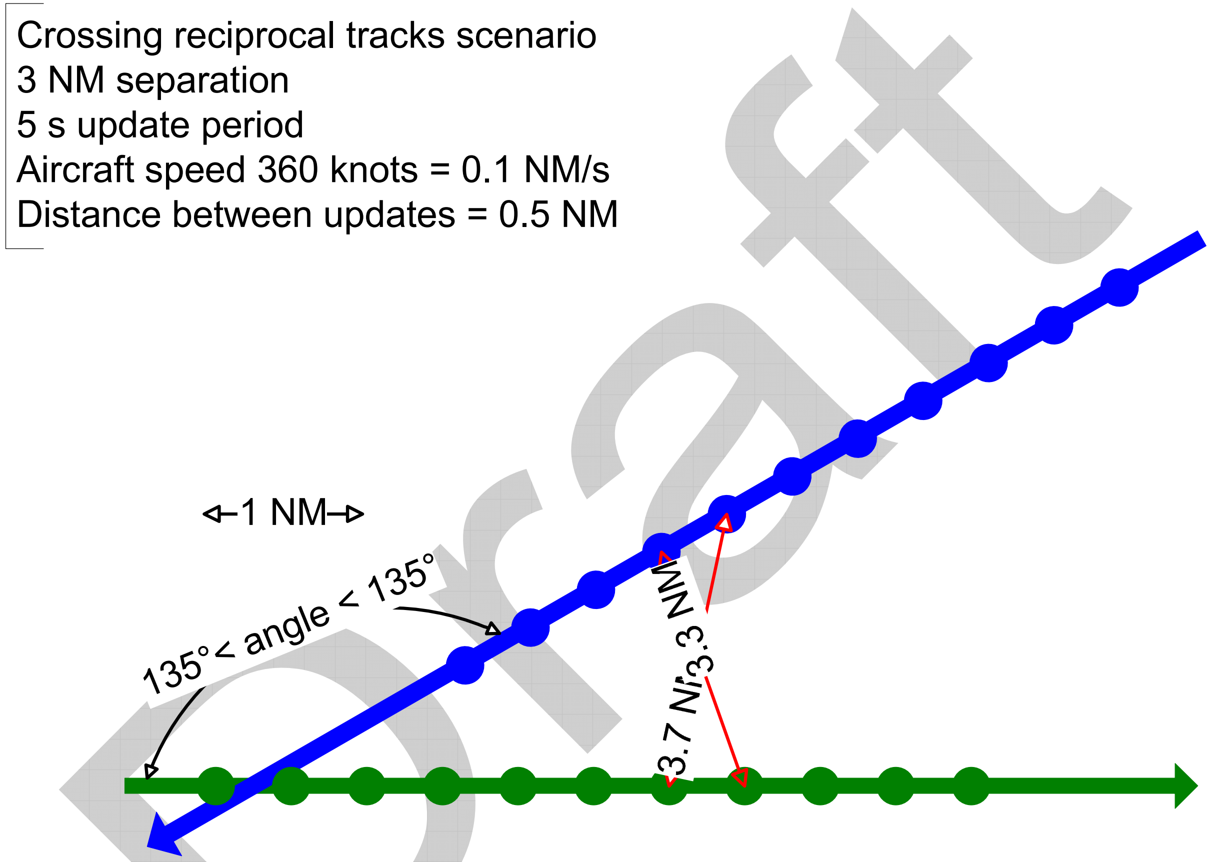


**Figure 41: Reciprocal track crossing scenario 3 NM separation**

## G - 7 Vertical crossing track scenario 5 NM separation detailed descriptions

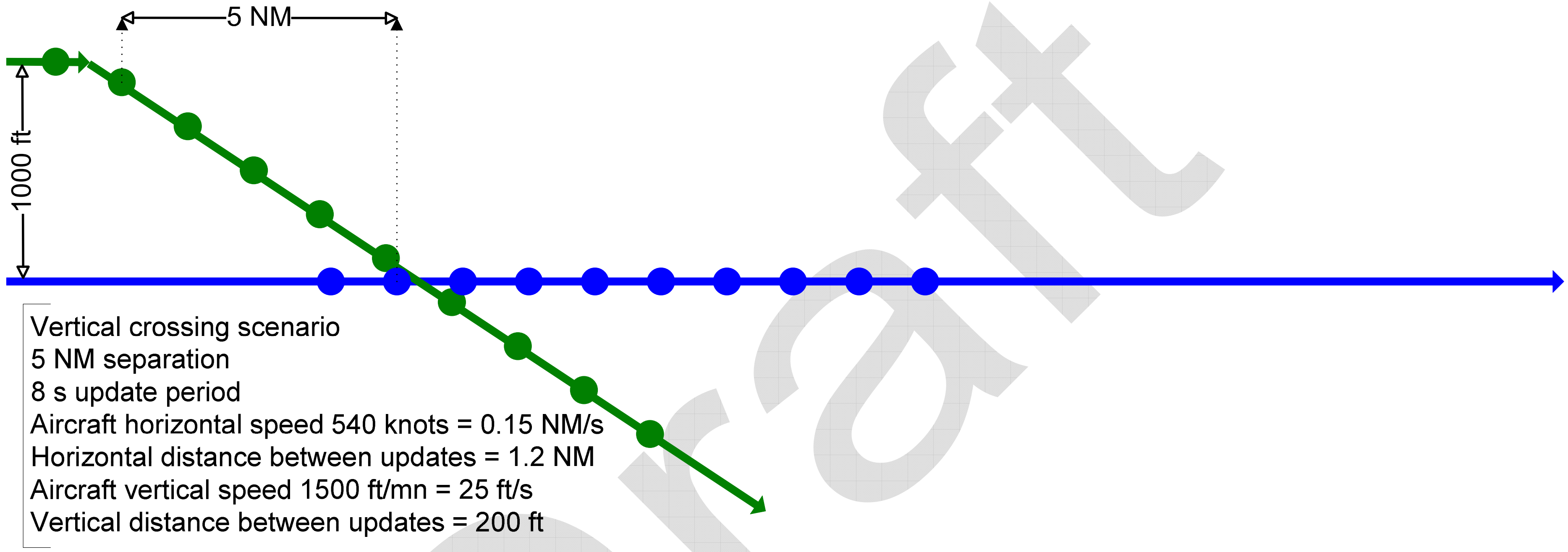


**Figure 42: Vertical crossing track scenario 5 NM separation at 1500 ft/mn**

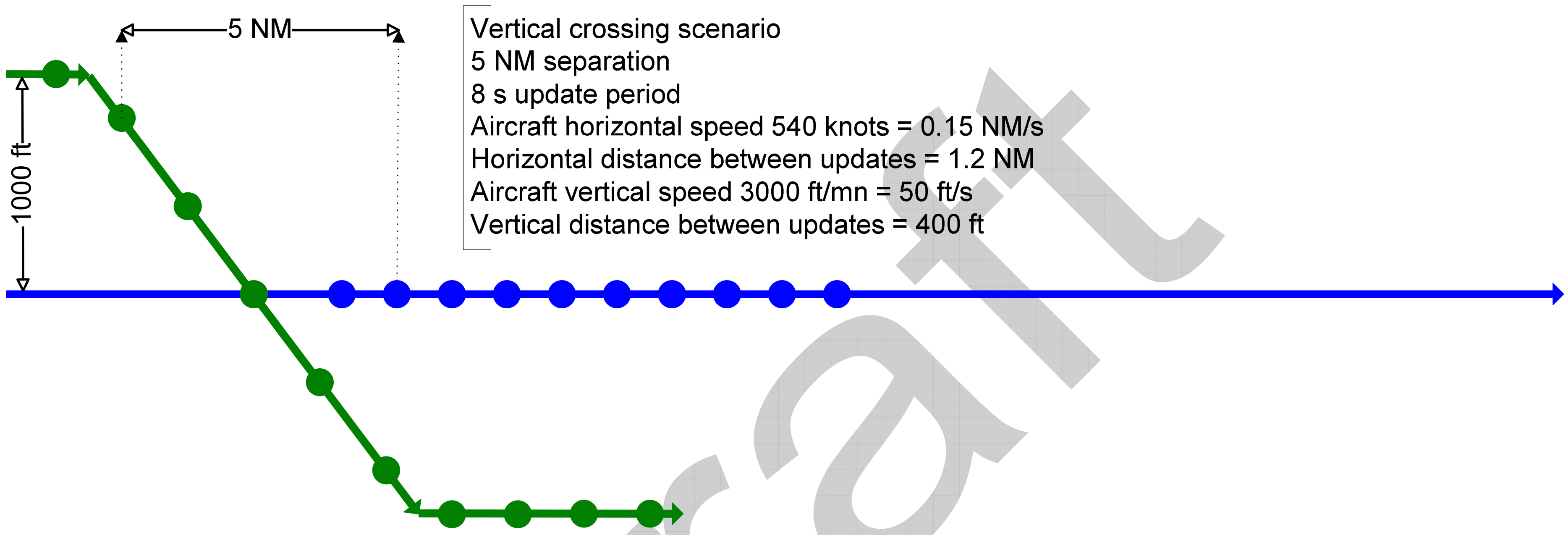


**Figure 43: Vertical crossing track scenario 5 NM separation at 3000 ft/mn**

## G - 8 Vertical crossing track scenario 3 NM separation detailed descriptions

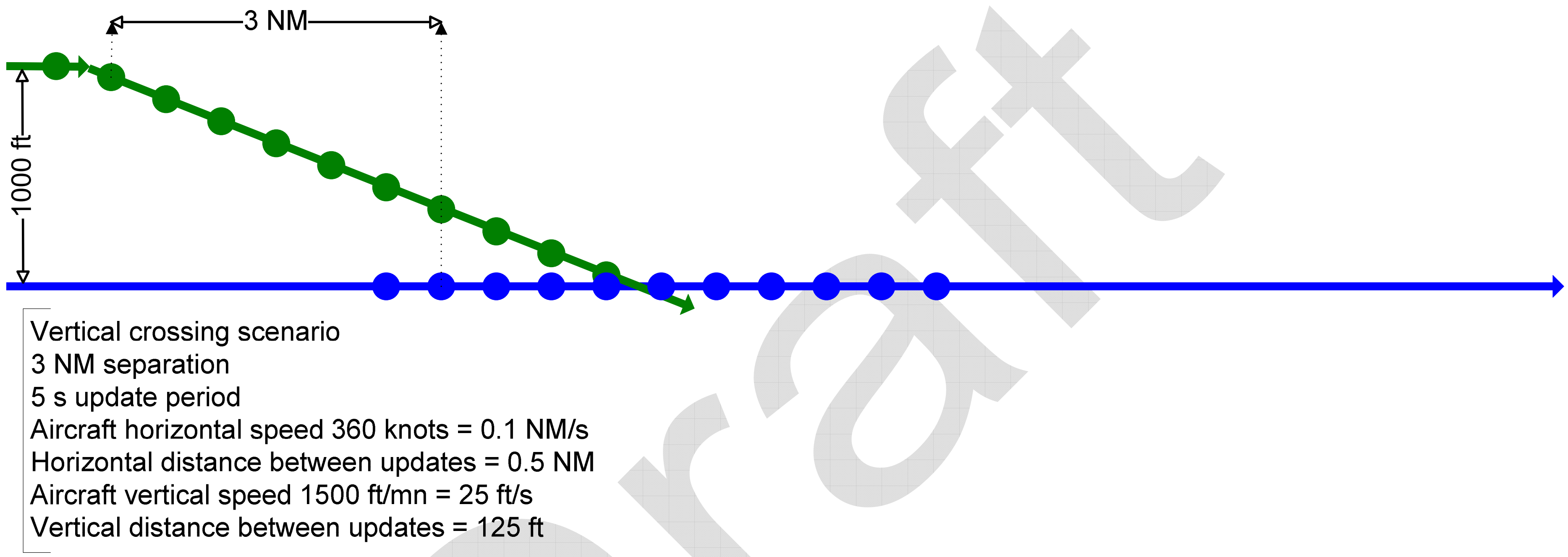


**Figure 44: Vertical crossing track scenario 3 NM separation at 1500 ft/mn**

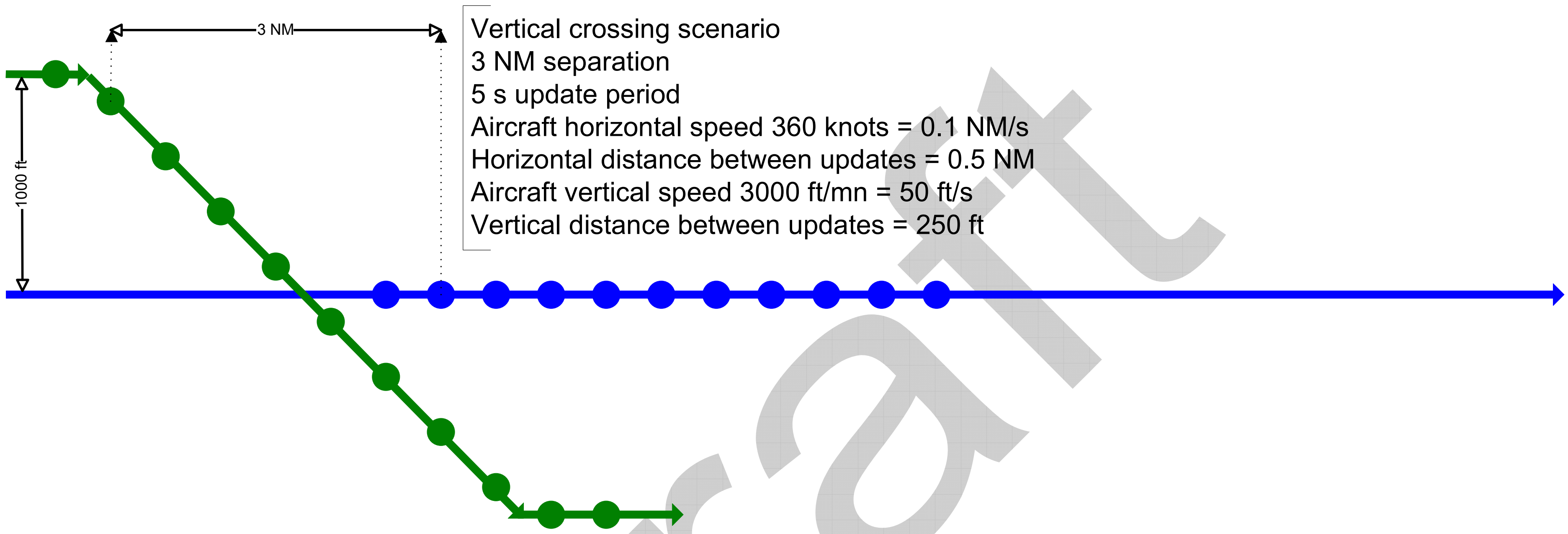


**Figure 45: Vertical crossing track scenario 3 NM separation at 3000 ft/mn**

# ANNEX - H AN APPROACH TO JUSTIFY REQUIREMENTS BASED ON THE MODEL DESCRIBED IN [RD 48] AND IN [RD 14]

## H - 1 Introduction

The objective of this annex is to provide a top-down approach justifying a sub-set of the requirements included in this specification, in particular the requirements on the core of the horizontal position error provided that they are supplemented by requirements on the tail of the horizontal position error. The requirement on the tail of horizontal position error cannot be defined in a generic way and should be derived from the surveillance safety assessment taking into account the internal design of the surveillance system and its environment.

Further technical details can be found in documents [RD 48] and [RD 14].

## H - 2 Generalities

This model is based on the calculation of risk of collision between two aircraft being horizontally separated in accordance with a separation minima (i.e. 5 or 3 NM).

The equation relating collision risk to the input parameters is as follows.

| | |
|---|---|
| $R(S) = F \times P_v \times P_h(S)$ | **Equation 9** |

It relates

- collision risk per flight hour due to imperfections in the surveillance system, R(S),
- the frequency of use of surveillance per flight hour, F,
- the probability of vertical overlap during an encounter $P_v$, and
- the probability of horizontal overlap $P_h(S)$ as a function of the separation standard S

Note that $P_h(S)$ is a function of the separation standard S and as a consequence, so is the risk R(S). Note also that this risk equation implicitly implies that other risk-mitigating factors are ignored. In particular, the effect of ACAS and any pilot-initiated collision avoidance measures are neglected.

To judge the acceptability of an estimated risk R(S), it must be compared with a measure of acceptability of risk, a Target Level Of Safety (TLS), quoted in fatal accidents per flight hour.

The surveillance system, together with a separation standard S, is safe if and only if

| | |
|---|---|
| $R(S) \le \alpha \times TLS$ | **Equation 10** |

where both R(S) and the TLS are measured in collisions per flight hour and $\alpha$ is the proportion of the TLS that is assigned to this cause of accidents, namely failures in the surveillance system.

The contributing factors to the governing equation F, $P_v$ and $P_h(S)$ are further discussed below.

It is usual at this stage to define a critical probability of horizontal overlap $P_c$ which, given a specific TLS, is the probability of horizontal overlap that exactly meets this TLS. This critical probability $P_c$ is given by

| | |
|---|---|
| $P_c = \dfrac{\alpha \times TLS}{F \times P_v}$ | **Equation 11** |

This equation tells us what the required the critical probability of horizontal overlap is given particular values for the apportioned TLS, the frequency of surveillance use and the probability of vertical overlap and all the other input parameters.

This probability of horizontal overlap is then determined by the model for a certain set of input parameters and the assessment is complete. The model also contains the functionality to be run "backwards" to determine the required horizontal position accuracy performance characteristics given the rest of the surveillance system parameters.

This model is not static it takes into account 3 consecutive detections (i.e. over 2 update intervals) and requires as inputs:

- TLS for the horizontal plane, TLS = 5. $10^{-9}$ fatal accidents per flight hour
- Proportion of risk budget assigned to surveillance α = 10%
- Fatal accidents per collision 2
- Common aircraft speed in knots (as defined in Annex D - 4.3)
- Height and diameter of aircraflt cylinder (i.e. cylinder representing the aircraft)
- Probability of single missing target report update (as specified in Table 4 and Table 6)
- Probability of target report missing given that preceding one is missing
- Update interval in seconds (as specified in Table 4 and Table 6)
- Frequency of use of surveillance system per flight hour (F) in that case the aircraft are assumed to not be vertically separated (i.e. being within less than $V_i$ = 500 ft)
- The weighting assigned to 3 different scenarii separation
- The shape of the tail of the horizontal position error distribution by imposing the probability density curve to fit 2 points ($Q_1 = P(D_1)$) and ($Q_2 = P(D_2)$))

This model relies on the assumption that the probability density function F of the horizontal position error X follows a double-double exponential:

| | |
|---|---|
| $P(X) = (1-a) \times e^{-X/p} + a \times e^{-X/q}$ | **Equation 12** |

Parameter p (in Equation 12) characterises the core horizontal position error and is set to match the corresponding requirement for the RMS of the horizontal position error.

The parameters a and q (in Equation 12) characterise the tail error and are derived from the shape of the tail of the horizontal position error distribution defined in the model.

The following common parameter values have been used for both 5 and 3 NM separation:

- Diameter of aircraft cylinder 61.1 m
- Height of aircraft cylinder (H) 17 m (55 ft)
- Common aircraft speed (V) 450 knots
- Probability of single missing update ($P_s$) 3%
- Probability of target report missing given that preceding one is missing ($P_m$) 25%

The 3 scenarii that are modelled are the following:

- Crossing tracks scenario (angle = 90°)
- Reciprocal tracks scenario (angle = 180°)
- Parallel tracks scenario followed by a crossing tracks scenario (angle = 60°)

These 3 scenarii have a relative weight:

- Crossing tracks scenario 0.949999
- Reciprocal traks scenario 0.000001
- Parallel tracks scenario followed by a crossing tracks scenario 0.05

The probability of vertical overlap for the crossing tracks scenario is defined below, assuming that the horizontal crossing is combined with a vertical crossing.

The probability of vertical overlap in the case of crossing traffic depends on the height of the aircraft and the vertical region they are counted within. In the case where the value of F (the frequency of use of surveillance) is generated for aircraft within 500 ft and the aircraft height H = 55ft the calculation becomes

| | |
|---|---|
| $P_v = \dfrac{2 \times H}{2 \times V_i} = \dfrac{2 \times 55}{2 \times 500} = 0.11$ | **Equation 13** |

For the 2 other scenarii, the aircraft are assumed to be at the same flight level therefore $P_v = 0.4$.

The model determines the horizontal overlap probability $P_h(S)$ using as a basis methods similar to those used in [RD 14] for a reference-standard radar, but expanded from those to include the dynamic effects of particular operational scenarios.

Several other parameters need to be defined for $P_h(S)$ to be generated. These are

- The update period of the surveillance system (in seconds), this is the final update on the controllers screen. For some systems such as mono-radar this may be the same of the update period of the radar head itself, for other technologies this is likely to be a processed or latest result.
- The horizontal position error distribution of the surveillance system. This is expressed as a double-double exponential governed by 4 parameters (see Equation 12). These are related to the percentiles along the tail distribution and a representation of the distribution size at those percentiles.
- The speed of the aircraft.
- The probability that a target report will be received within the update interval.
- The probability that having missed a target report from one aircraft, the following target report from that aircraft shall will also be missed. This is a common mode failure probability and is likely to be higher than the initial probability of the event.
- The probability that having missed a target report from one aircraft, the target report from the other aircraft (in conflict) is missed.
- The different scenarios encountered within the airspace region under investigation.

The calculation of $P_h(S)$ is performed in an Excel spreadsheet in accordance with the above equations and taking into account the different parameters above. Then R(S) is calculated in accordance with Equation 9 and is compared with α x TLS.

## H - 3 Model parameters and model results for 5 NM separation

For the 5 NM separation application the following specific model parameters have been set:

- Update interval 8 seconds
- Common aircraft speed 600 knots
- Frequency of use of surveillance system 0.5 times per flight hour
- $Q_1 = 0.001$ (probability of an error larger than $D_1$ during one flight hour) $D_1 = 1.8$ NM
- $Q_2 = 0.0005$ (probability of an error larger than $D_2$ during one flight hour) $D_2 = 2.1$ NM

The following figures depict the results of the model for the 5 NM separation application and in particular the sensitivity of the following parameters:

- Common aircraft speed,
- Probability of update,
- Update period,
- Horizontal separation minimum,
- Probability of target report missing given that preceding one is missing.

The red circle indicates the point on the curve corresponding to the selected parameters, this point correspond to a risk of 1.86 $10^{-12}$ per flight hour. Therefore there is margin a factor of more than 100 with the maximum acceptable risk (5. $10^{-10}$).

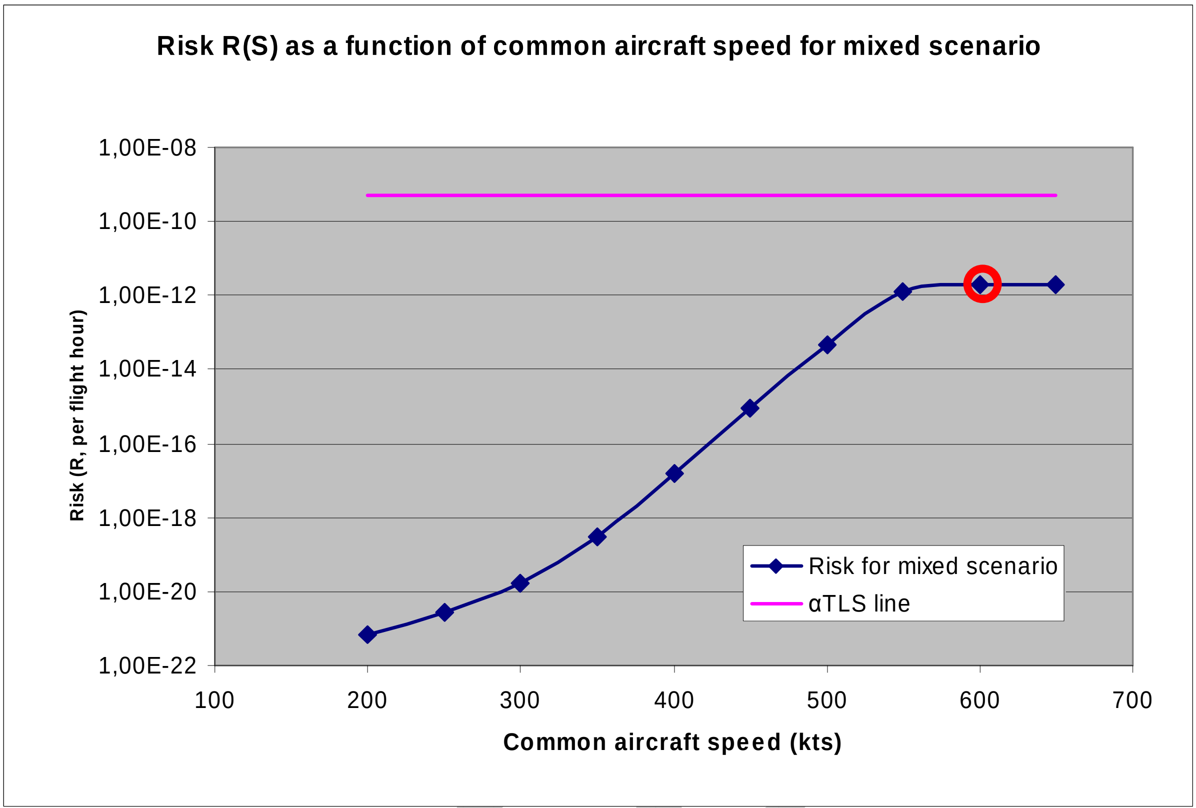


**Figure 46: Risk R(S) as a function of common aircraft speed**

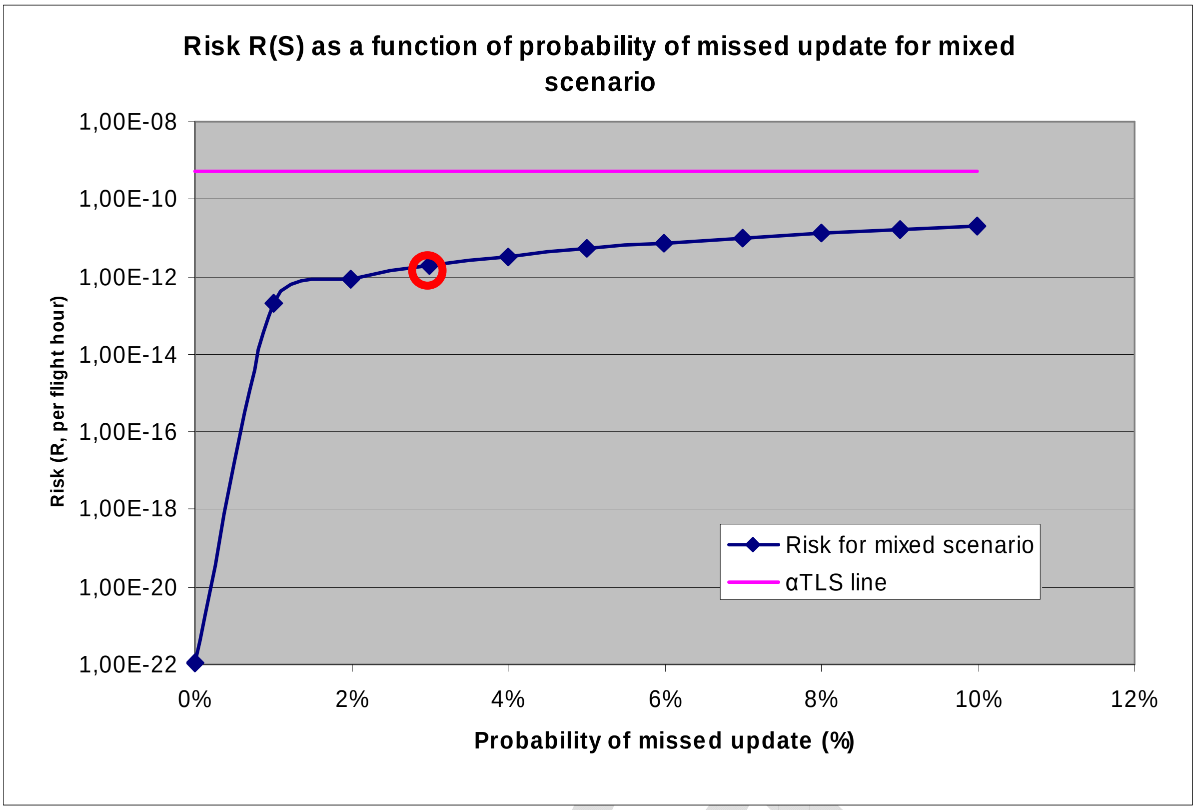


**Figure 47: Risk R(S) as a function of probability of missed update[5]**

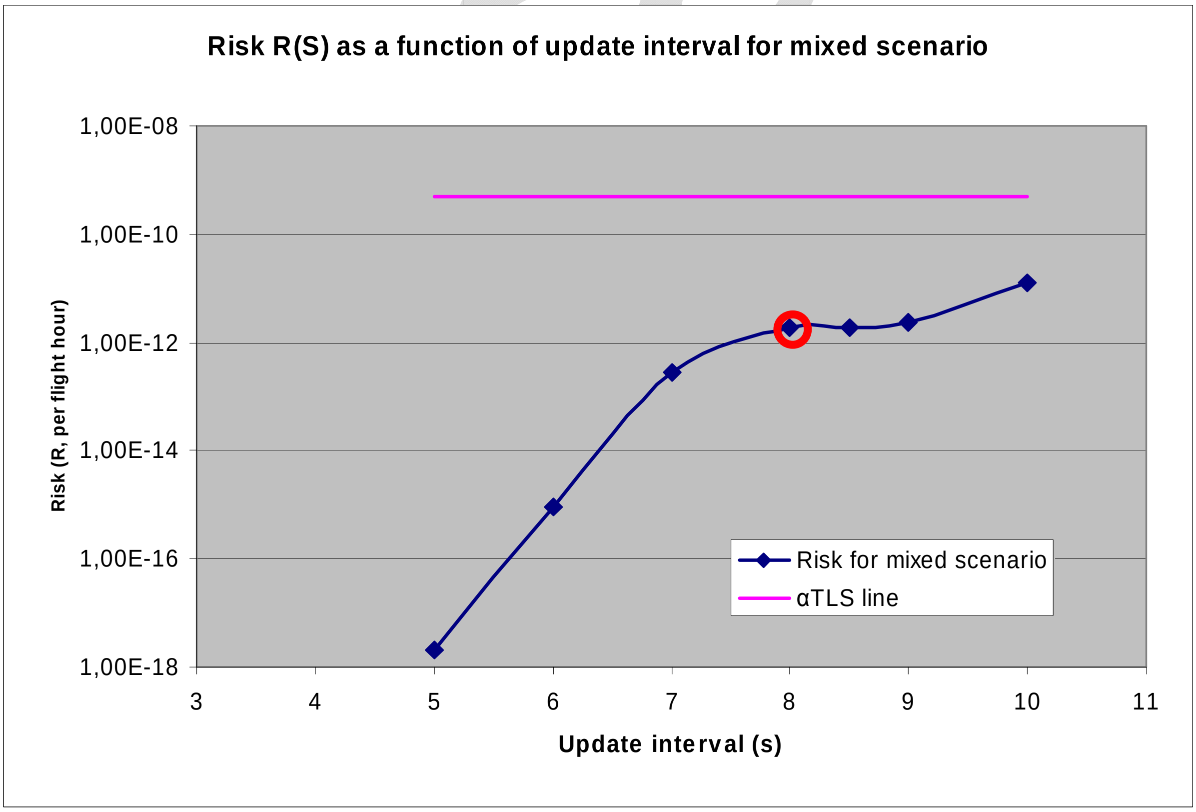


**Figure 48: Risk R(S) as a function of update interval**

[5] the probability of missed update is equal to 1 minus the probability of update

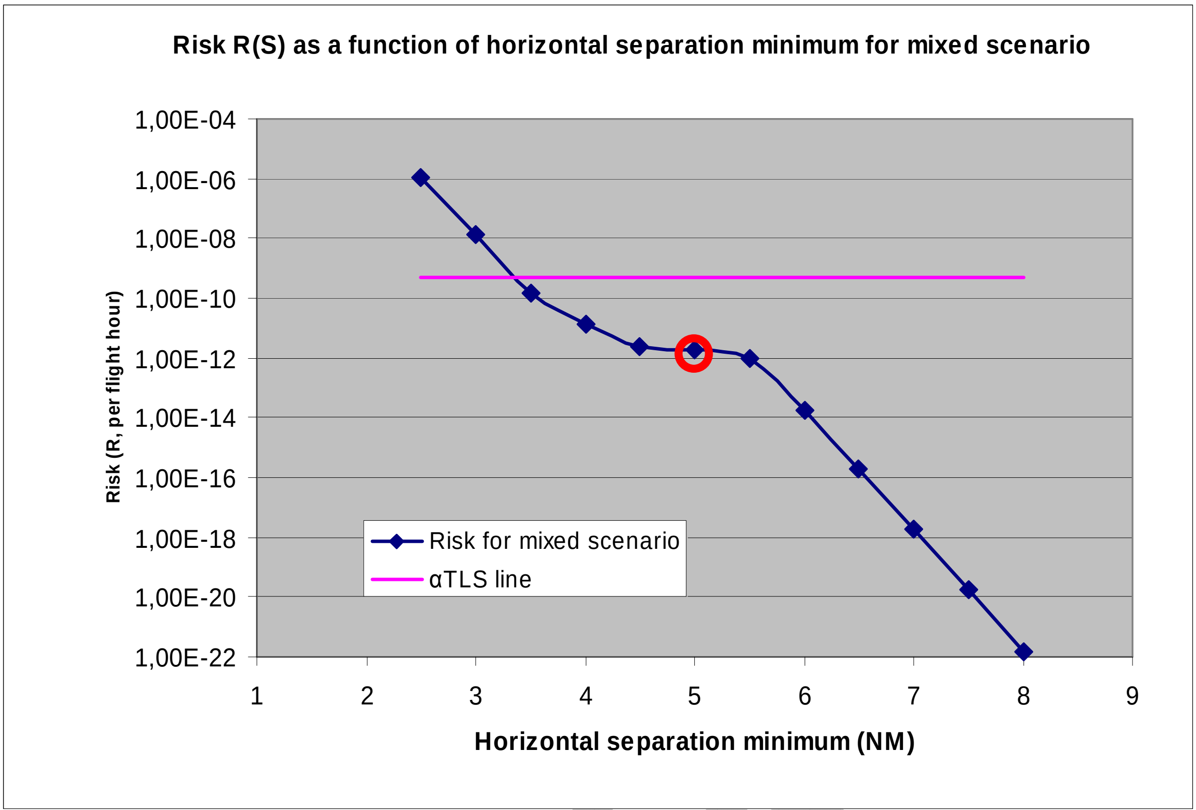


**Figure 49: Risk R(S) as a function of horizontal separation minimum**

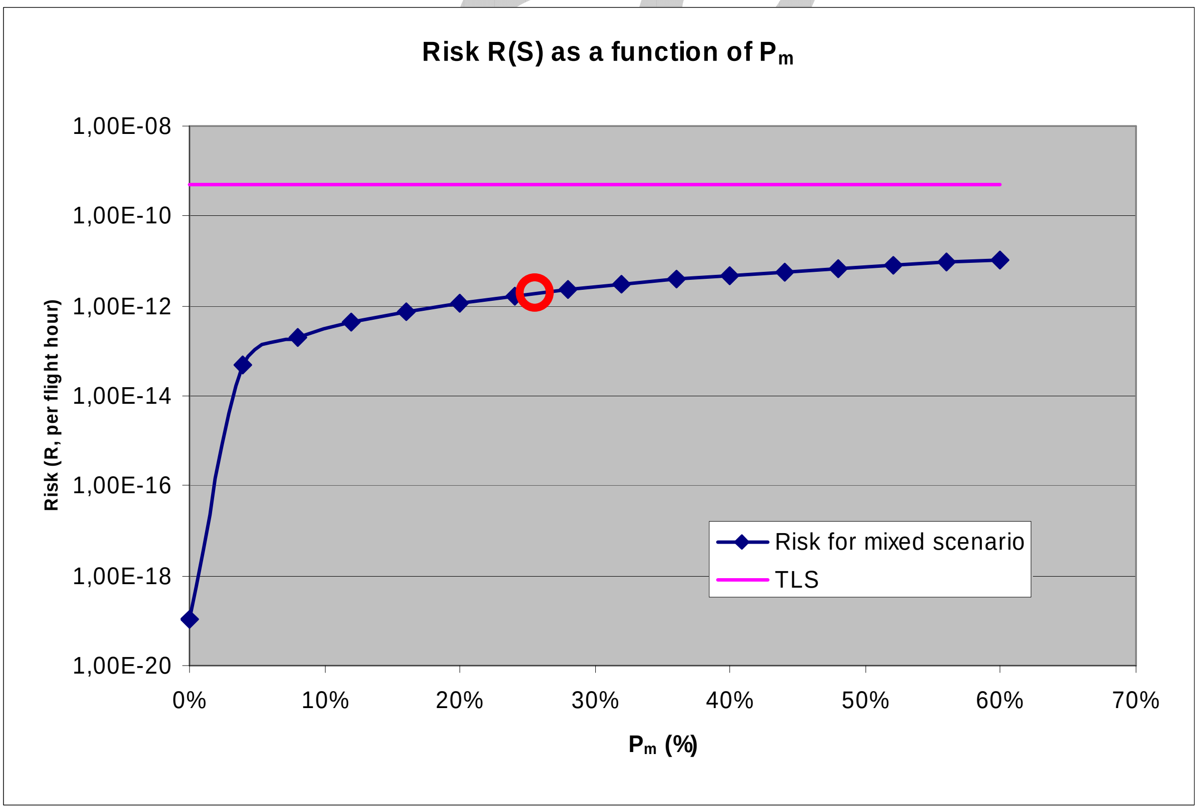


**Figure 50: Risk R(S) as a function of $P_m$**

## H - 4 Model parameters and model results for 3 NM separation

For the 3 NM separation application the following specific model parameters have been set:

- Update interval 5 seconds
- Common aircraft speed 400 knots
- Frequency of use of surveillance system 2 times per flight hour
- $Q_1$ = 0.001 (probability of an error larger than $D_1$ during one flight hour) $D_1$ = 1.5 NM
- $Q_2$ = 0.00005 (probability of an error larger than $D_2$ during one flight hour) $D_2$ = 1.8 NM

The following figures depict the results of the model for the 3 NM separation application and in particular the sensitivity of the following parameters:

- Common aircraft speed,
- Probability of update,
- Update period,
- Horizontal separation minimum,
- Probability of target report missing given that preceding one is missing.

The red circle indicates the point on the curve corresponding to the selected parameters, this point correspond to a risk of 2.50 $10^{-12}$ per flight hour. Therefore there is margin of a factor of more than 100 with the maximum acceptable risk (5. $10^{-10}$).

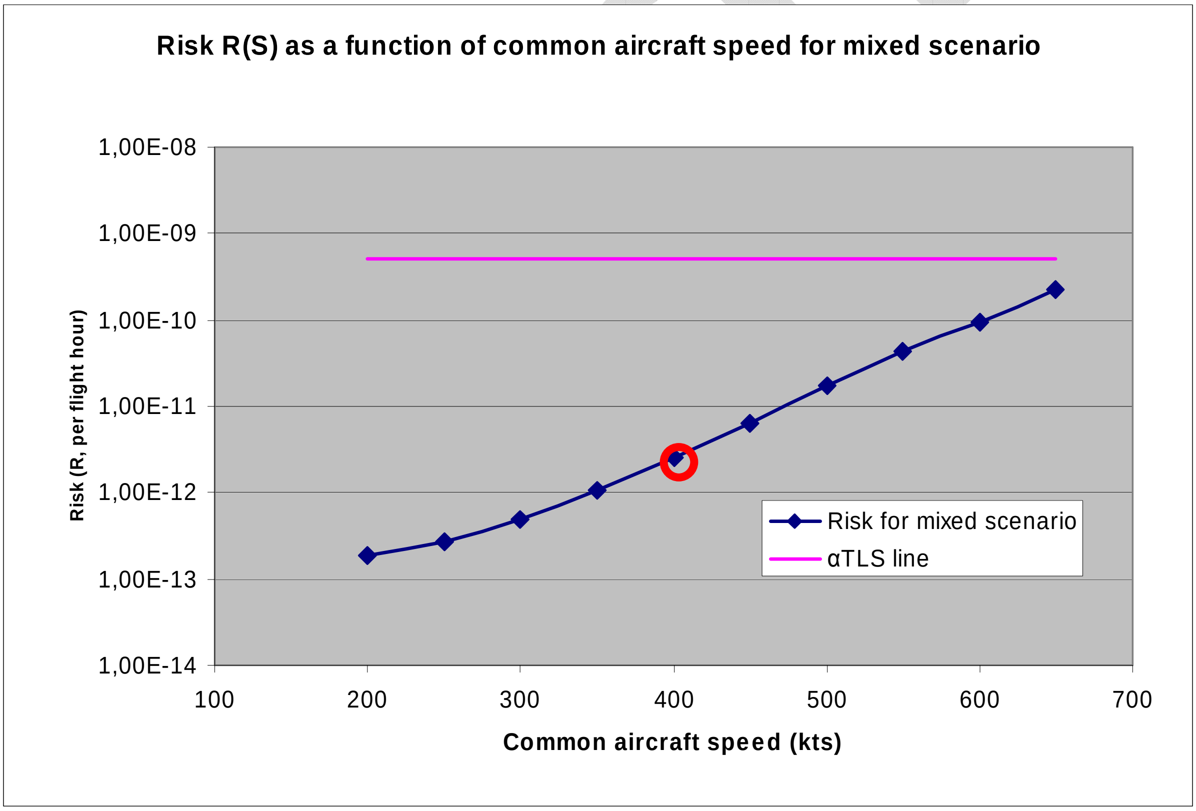


**Figure 51: Risk R(S) as a function of common aircraft speed**

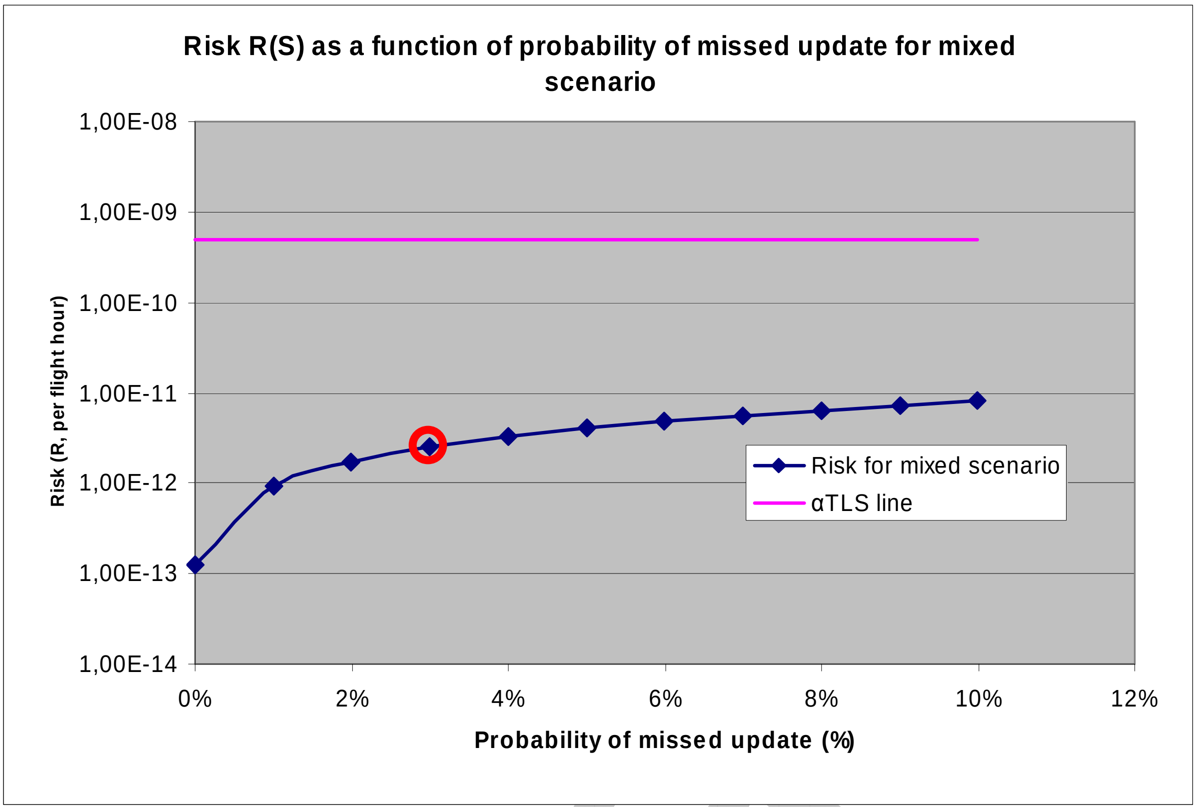


**Figure 52: Risk R(S) as a function of probability of missed update**[6]

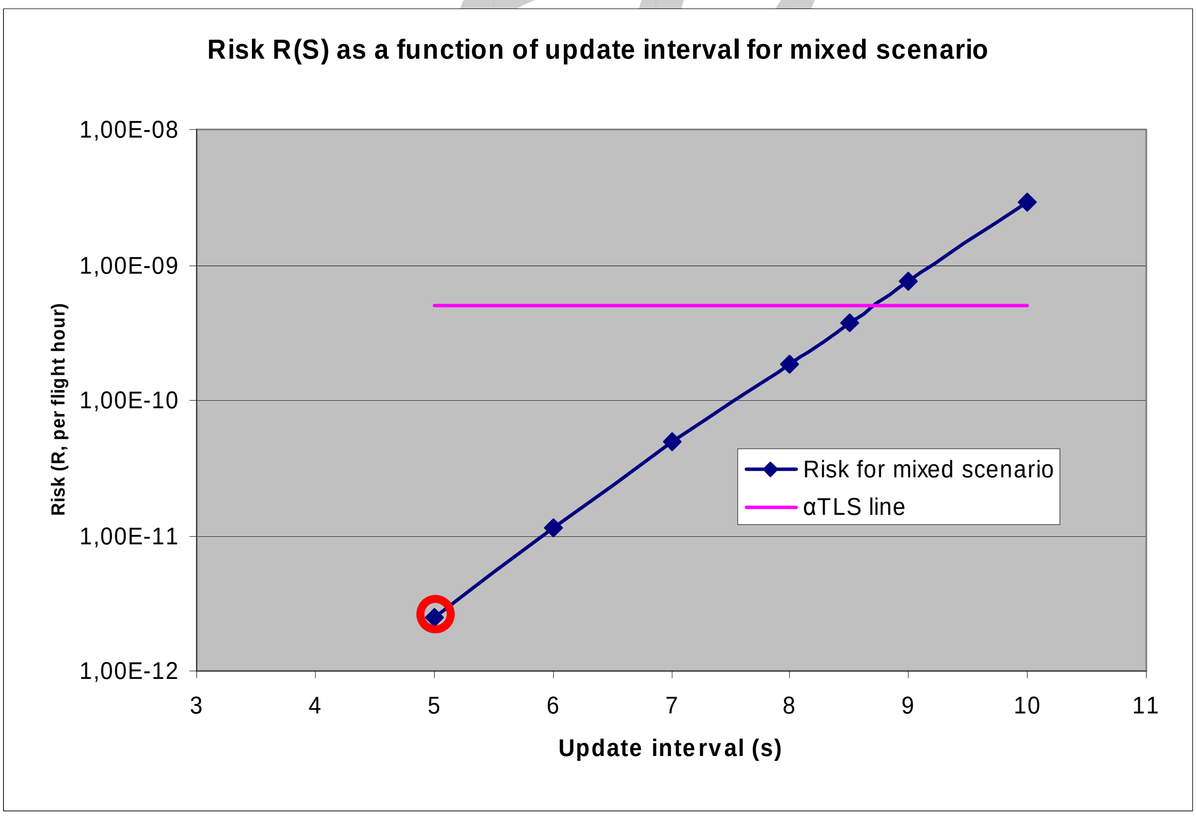


**Figure 53: Risk R(S) as a function of update interval**

[6] the probability of missed update is equal to 1 minus the probability of update

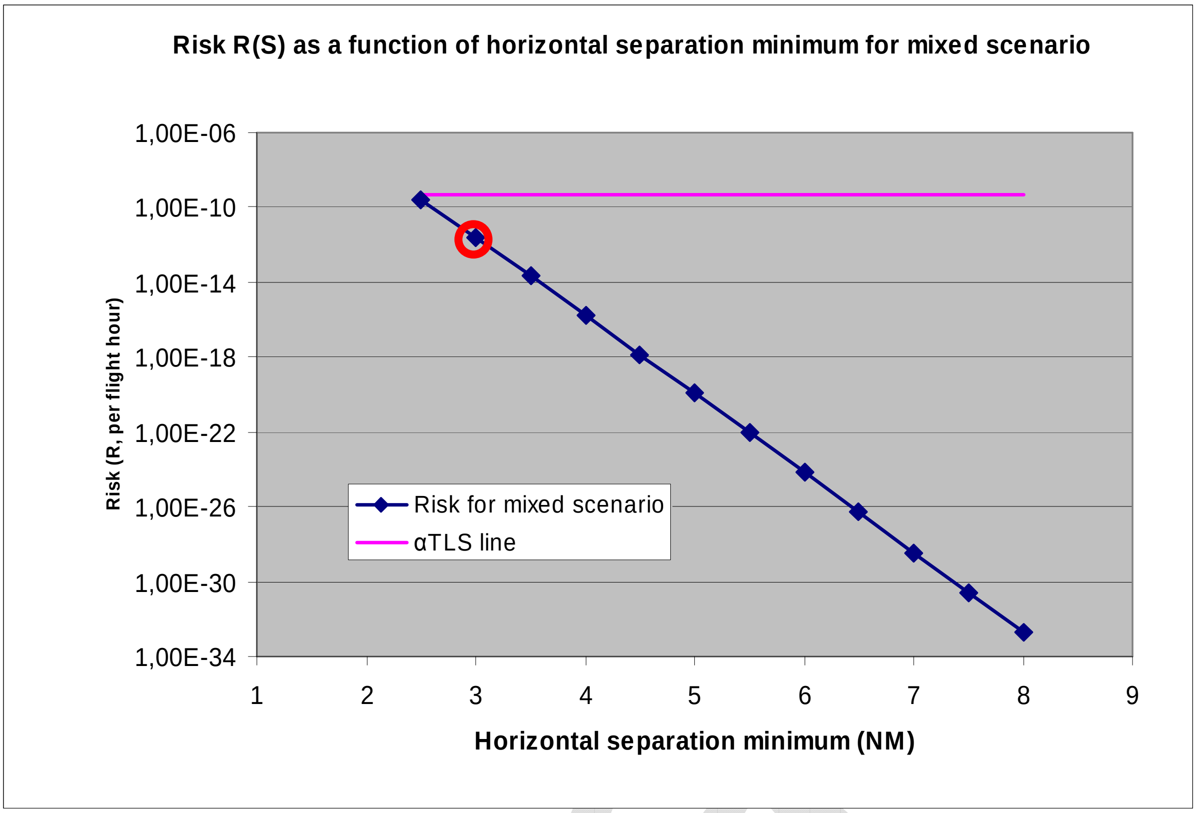


**Figure 54: Risk R(S) as a function of horizontal separation minimum**

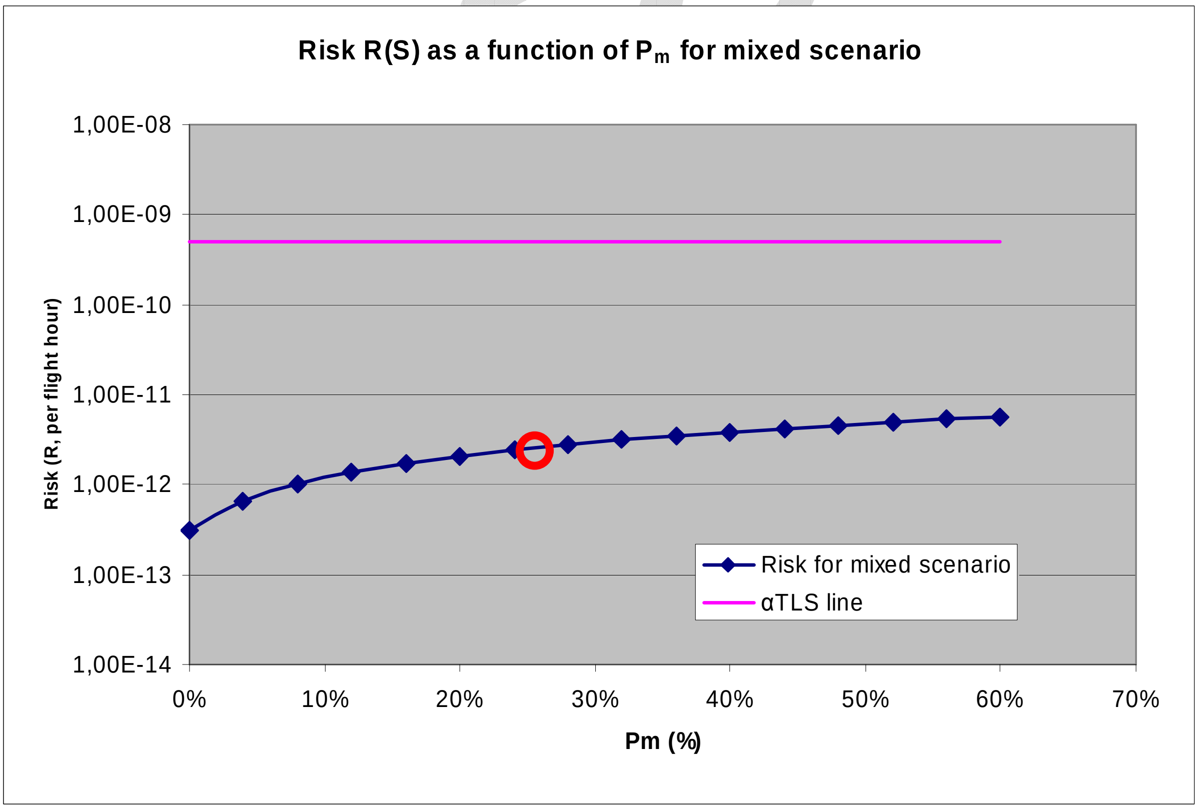


**Figure 55: Risk R(S) as a function of $P_m$**