International Civil Aviation Organization

The Third Meeting of Automatic Dependent Surveillance – Broadcast (ADS-B) Study and Implementation Task Force (ADS-B TF/3)

Bangkok, 23-25 March 2005

Agenda Item 3: **Review the progress made by ADS-B related ICAO panels**

RFG PROGRESS

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SUMMARY

This paper provides a brief outline of the Eurocontrol-FAA RFG Activity

1 Background

1. The Requirements Focus Group (RFG) will become an important organisation for ADS-B standards development for air to air surveillance applications.

2 What is RFG?

2.1 The Requirements Focus Group has been set up by FAA and Eurocontrol to harmonise ADS-B requirements between these two large and powerful organisations. It sees its role as developing the ADS-B documents and then delivering these documents to ICAO, Eurocae and RTCA – with the expectation that ICAO, RTCA & Eurocae will accept these as world wide interoperable documents and produce equivalent ICAO SARP and Industry MOPS.

2.2 The group output will be quite powerful since RFG is also supported by Boeing, Airbus and the bodies mentioned above.

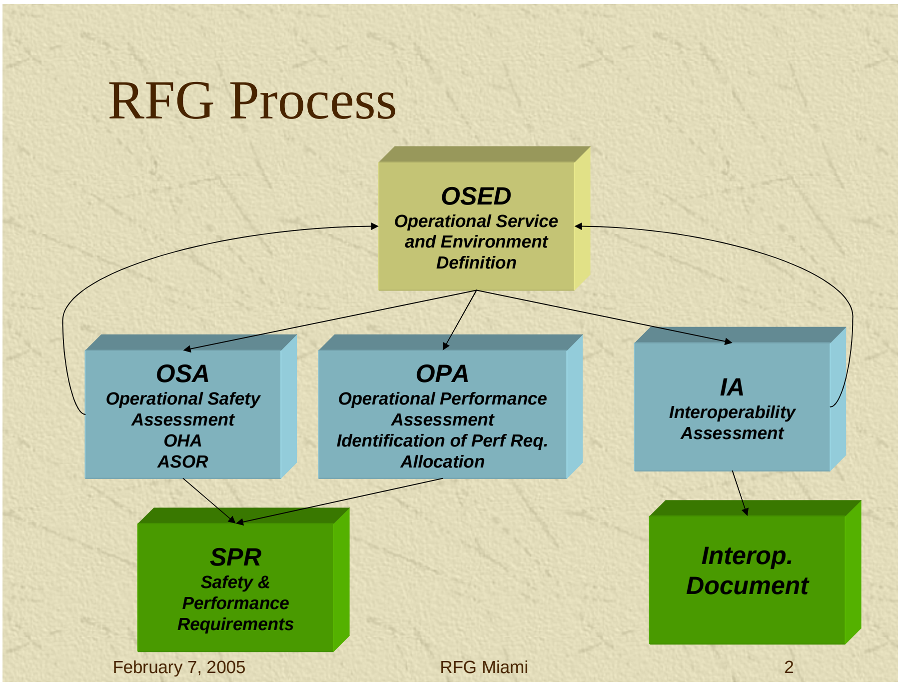
The weaknesses are that RFG:

- is Europe/USA centric in their views (although they welcome AsiaPacific input)

- is slow to produce deliverables. This is mainly because they have adopted a Eurocae/RTCA document/safety development methodology ED-78A/DO-264 and because of the large amount of co-ordination required to reach consensus. The main outputs are the documents shown in the diagram below. The group say that they will deliver these 6 documents for each of the "Package 1 ADS-B application" by mid2006. This timetable is unlikely to be achieved. The European Safety process will get in the way and lots of re-writes will occur.

3 What will RFG produce?

3.1 The main output from the RFG is expected to be a coherent set of documents developed according to the ED-78A/DO-264 methodology. These are :



4 What is the RFG Terms of Reference?

4.1 Extracts from the RFG Terms of Reference are :

To support the operational implementation of ASA/GSA Package I, the Requirements Focus Group will:

- *Harmonise the definition of the applications contained in ASA/GSA Package I between Europe and the US as a step towards world-wide interoperability.*

- *Establish the operational safety and performance requirements, and interoperability requirements through the application of a "Co-ordinated Requirements Determination" process. These requirements will provide the recommended basis for the qualification activities throughout the life cycle of the implementation of ASA/GSA Package I.*

- *Produce deliverables that will be proposed as input to and in co-operation with the International Civil Aviation Organisation (ICAO) panels, regional co-ordinating groups, standards organisations (e.g. EUROCAE, RTCA) and regulatory authorities, as appropriate, in order to support world-wide interoperability.*

- *As a by-product, the group may, as appropriate, propose amendments to the methodology guidelines (ED-78A/DO-264).*

- *Where relevant, reference shall be made to existing requirements and standards, including the review and use of the EUROCONTROL ADS-B Requirements and TIS-B Requirements, and RTCA ADS-B MASPS, TIS-B MASPS and ASA MASPS..*

- *Guidance, in form of validation objectives, shall be provided to validation activities related to the ASA/GSA Package I applications and corresponding enablers. The feedback from these activities shall be verified in order to facilitate the formulation of validated requirements.*

Organisation

The Requirements Focus Group consists of its Plenary Group and two Sub-groups: the Application Definition (AD) Sub-group, responsible for the OSED document, and the Safety and Performance Requirements (SPR) Sub-group, responsible for the SPR standard. The creation of a third sub-group, the Interoperability (INTEROP) Sub-group, shall be considered as appropriate, awaiting the progress of the other two Sub-groups. As an interim measure, operational interoperability matters are addressed by the AD SG, and technical interoperability matters are addressed by the SPR SG.

The RFG Plenary Group and its Sub-groups shall be co-chaired by both a European and a US representative.

Membership

The RFG will comprise experts representing EUROCONTROL, EUROCAE, FAA and RTCA and relevant stakeholder organisations.
Additional membership shall be encouraged and pursued.

Schedule
The final versions of the deliverables shall be completed by June 2006.
Intermediate deliveries of the various documents shall be foreseen.

5 What ADS-B applications are the RFG addressing?

5.1 The applications included in “Package 1” are :

- Four Ground Surveillance applications:
  - ATC surveillance in radar areas (ADS-B-RAD);
  - **ATC surveillance in non-radar areas (ADS-B-NRA); ** Being “fast tracked”**
  - Airport surface surveillance (ADS-B-APT);
  - Aircraft derived data for ground tools (ADS-B-ADD).
- Six Airborne Surveillance applications:
  - Enhanced traffic situational awareness on the airport surface (ATSA-SURF);
  - Enhanced traffic situational awareness during flight operations (ATSA-AIRB);
  - Enhanced visual separation on approach (ATSA-VSA);
  - **Enhanced sequencing and merging operations (ASPA-S&M); ** Being “fast tracked”**
  - In-trail procedure in oceanic airspace (ASPA-ITP);
  - Enhanced crossing and passing operations (ASPA-C&P).

5.2 The inclusion of ASPA-C&P was controversial at the time of determination of Package1, since it is quite demanding on avionics fit. The RFG now finds itself in the situation that no-one is spending effort to develop the documents for it – because there is no major demand for it. Hence Package 1 is evolving.

6 State of Non Radar Application (NRA) RFG DRAFT WORKING Documents

6.1 The RFG has available a number of DRAFT WORKING documents which are attached for your information. It must be noted that these documents are NOT final. RFG would welcome any feedback that you may care to provide.

- APPLICATION DESCRIPTION (OSED) FOR NRA v1-2g
- ALLOCATION OF SAFETY OBJECTIVES AND REQUIREMENTS (ASOR) FOR NRA _v0.1
- SAFETY AND PERFORMANCE REQUIREMENTS (SPR) FOR NRA v0.1
- ADS-B OPERATIONAL HAZARD ASSESSMENT (OHA) for NRA v0.8
- OPERATIONAL PERFORMANCE ASSESSMENT (OPA) for NRA v1.0

The meeting is reminded that these are draft working documents and are not yet suitable for use. They are provided to give insight into the work being undertaken.

7 What will be the impact of RFG to Asia Pacific?

7.1 The group have a desire to leverage from the work that Australia and Asia Pacific has done however, the ability of the group to produce useful deliverables in time for our “Non Radar application” seems remote.

RFG will have a powerful influence on the future development of ADS-B especially air-air applications. There are too many powerful influences there for us to ignore it. We need to stay connected with the RFG group to ensure that the needs of non USA/Europe interests are protected.

8 Recommendation

8.1 The meeting is invited to note the existence of the RFG – and the future potential impact of its work.

Package I Requirements Focus Group
SPR Sub-group

Package I

Non Radar Area
(ADSB-NRA)

Operational Hazard Assessment
(OHA)

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Document Change Record

The following table records the complete history of the successive editions of the present document.

EDITION	DATE	REASON FOR CHANGE	SECTIONS PAGES AFFECTED
0.1	17/06/04	First issue	All
0.2	07/07/04	Internal review	OHA tables
0.3	13/07/04	Internal review	OHA tables
0.4	25/07/04	Update based on new modelling	OHA tables
0.5	17/11/04	Update based on new modelling	OHA tables
0.6	17/12/04	Update based on new modelling	OHA tables
0.7	21/01/05	Update based on Meeting in Washington (11-13/01/05) discussions	OHA tables
0.8	21/02/05	Eurocontrol comments + re-formatting	All

Table of Contents

Acronyms

OHA	Operational Hazard Assessment
ADS-B	Automatic Dependent Surveillance – Broadcast
OSED	Operational Service and Environment Description
ASOR	Allocation of Safety Objectives and Requirements
S&M	Sequencing and Merging application
ASPA	
SPR	Safety and Performance Requirements
CNS	Communication, Navigation and Surveillance
VHF	Very high Frequency
OH	Operational Hazard
OC	Operational Consequence
OSA	Operational Safety Assessment
ASAS	Airborne Separation Assurance System
MM	Mitigation Means
EMM	External Mitigation Means
IMM	Internal Mitigations Means
AE	Abnormal Event

References

[Ref.1] EUROCAE ED78A / RTCA DO264: Guidelines for Approval of the Provision and Use of air Traffic Services Supported by Data Communications, March 2002.

[Ref.2] RFG AD SG: Package I – ADSB-NRA – Application Description, version 1.2c, December 2004.

[Ref.3] RFG SPR SG: Guidance document for SPR development, version 0.1.

1. INTRODUCTION

1.1 Document Objectives

The objective of this document is to provide the results of the OHA related to the Non radar Area (ADSB NRA) application, one of the Package I applications to be studied in the frame of the RFG safety work.

1.2 OHA purpose and scope

The purpose and scope of this OHA is to qualitatively assess operational hazards related to the NRA application defined in Package I, and to establish candidate safety requirements related to identified hazard.

During the OHA, phases forming the application are examined to identify operational hazards but also abnormal event that could adversely affect the application and to classify OH, only. A hazard may result from an action that could not occur or could be erroneously performed. The effects of hazard are described at sufficient level of detail in order to deduce possible effects on operations (i.e. accident, major, minor incidents) and air navigation services.

External mitigation means, already existing in the environment and described in the OSED, which could relieve the effect of the hazards, are identified as part of the application description.

Hazards are classified according to the severity of its effects on operations as per a common classification scheme.

The OHA will serve as the basis for an allocation of safety objectives and requirements (ASOR) among components (e.g. airborne and ground-based components) of the Communication, Navigation, Surveillance / Air Traffic Management (CNS/ATM) system and organisations responsible for those components.

1.3 Document overview

Section 1 is the introduction.

Section 2 presents an overview of the process adopted to perform the OHA.

Section 3 includes a high level description of the application to be assessed and identifies the important information to take into account during the OHA.

Section 4 presents the results of the OHA, which encompass the list of the operational hazards per consequence and the candidate safety requirements.

Annex A includes the hazard classification matrix (operational consequences) used to perform the assessment.

Annex B presents the detailed description of each Operational Hazard in a tabular form.

2. SAFETY ASSESSMENT APPROACH

This section includes an overview of the methodology adopted to perform the Operational Hazard Assessment. This process is explained in more detail in the SPR Guidance document [Ref.3] .

2.1 Process overview

The application to be studied is described at the phase, sequence, and action level, and is presented in a tabular form (included in the OSED [Ref.2]) and modelled in a diagram (presented in next section).

Operational Hazards are obtained by applying the following failure modes to each of the identified actions:

- *loss*: action not available or not executed
- *incorrect*: action is performed incorrectly or is performed using incorrect information
- *misdirection* (with air/ground communication): message sent to an unintended aircraft
- *others*: actions executed in non-suitable conditions, or executed out of sequence.

An Operational Hazards is defined as "TBD". It should not be misled with Abnormal Event defined as "TBD".

Before starting the safety assessment, a list of External Mitigation Means (EMM) and Internal Mitigations Means (IMM) are identified from the environment (EMM) and application (IMM) description (included in the OSED [Ref.2]). External Mitigation Means are factors that help in reducing the impact of a hazard once the hazard has occurred. Internal Mitigations Means are factors that help in reducing the likelihood of occurrence and therefore are only considered during the ASOR process.

This list is updated and completed during the safety assessment, and the Candidate Safety Requirements finally identified in the list will be further analysed during the ASOR.

The objective of the safety assessment is to determine the severity of the operational hazards based on the potential operational consequences and resulting effects. The effects of the OHs to be considered are presented and classified in the ED78A/DO264 Hazard Classification matrix (included in Annex A). In this matrix, effects are classified per hazard class, and per type of effect, addressing effects on operations, on occupants, on air crew and on air traffic services.

In addition to the operational consequences (OC) proposed in ED78A/DO264, the RFG SPR SG has included a new row called "Examples of ASAS operational consequences" obtained from operational consequences proposed in ED78A/DO264 and ESARR4 matrices, but also those proposed following RFG SPR SG internal discussion.

Once OH and EMM are identified, the next step is to perform the assessment. A double assessment of each OH is performed:

- Taking into account the mitigation factors identified (i.e. when the OH is detected and eased)
- Considering that no mitigation factors are available or that they fail to mitigate the OH (i.e. when the OH is undetected or not eased).

This approach provides a first idea of the relevance of the EMM already identified from the OSED. The impacts of the OH are then identified based and the hazard class corresponding to the most severe and credible consequence is assigned.

2.2 OHA Results presentation

The main results obtained from the OHA following the above described approach are:

- Operational Hazards list
- Hazard Class (severity / SO) per OH
- Candidate Safety Requirements (EMM that help in reducing the safety impact)

These results will be presented in a tabular form as following:

OH#	OH	EMM	Assessment with MM (i.e. OH is detected and eased)		Assessment without MM ((i.e. OH is not detected or not eased)	
			OC	HC	OC	HC
OHxxxx	***OH Description***	Mitigation Means identified (also called CSR)	Operational Consequence with EMM (i.e. when OH is detected and eased)	Hazard Class with EMM	Operational Consequence without EMM (i.e. when OH is not detected or not eased)	Hazard Class without EMM

The results obtained are presented in this way in section 4.1, and the list of candidate safety requirements (i.e. EMM) is provided in section 4.2.

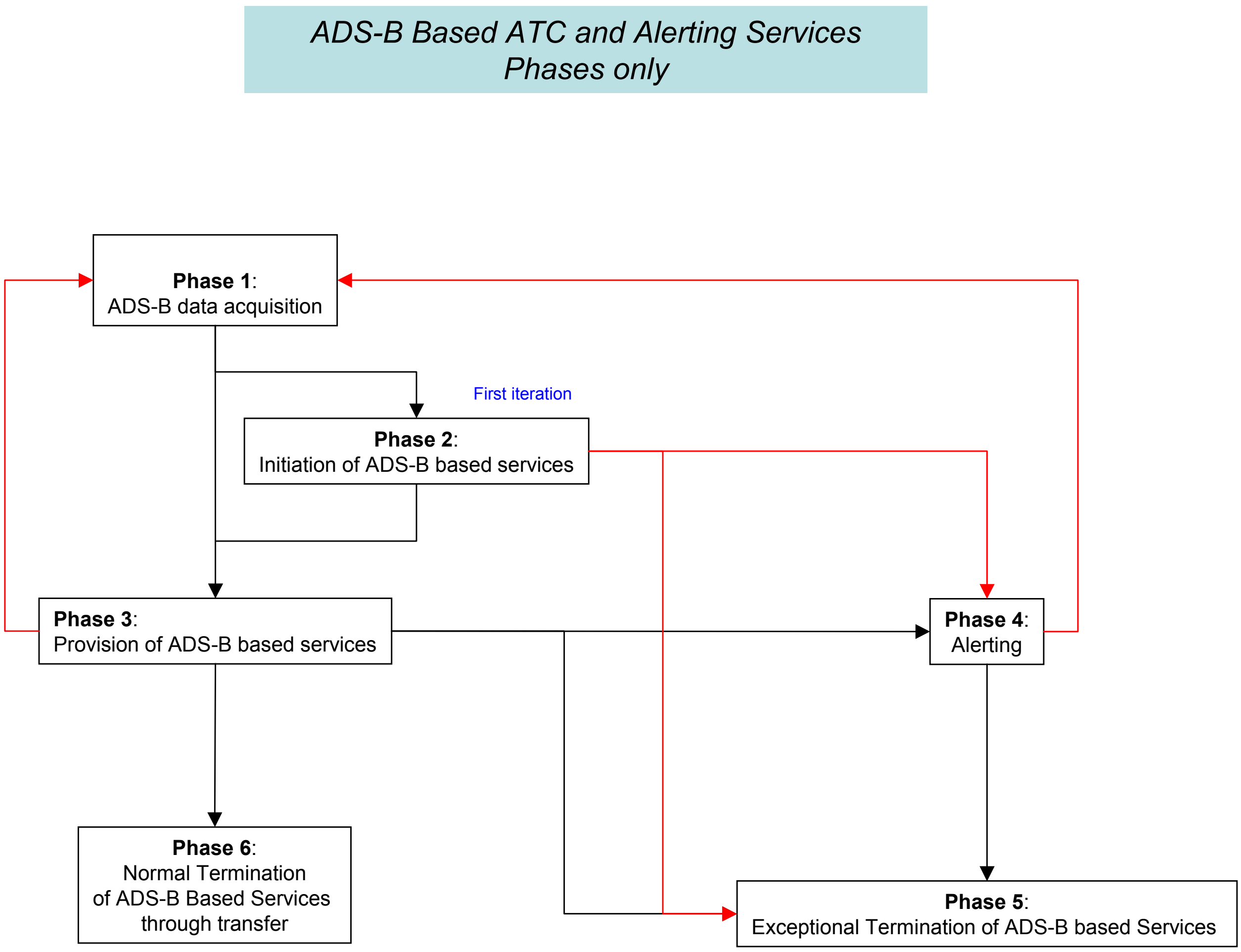
The detailed safety assessment is included in Annex B.

3. APPLICATION DESCRIPTION

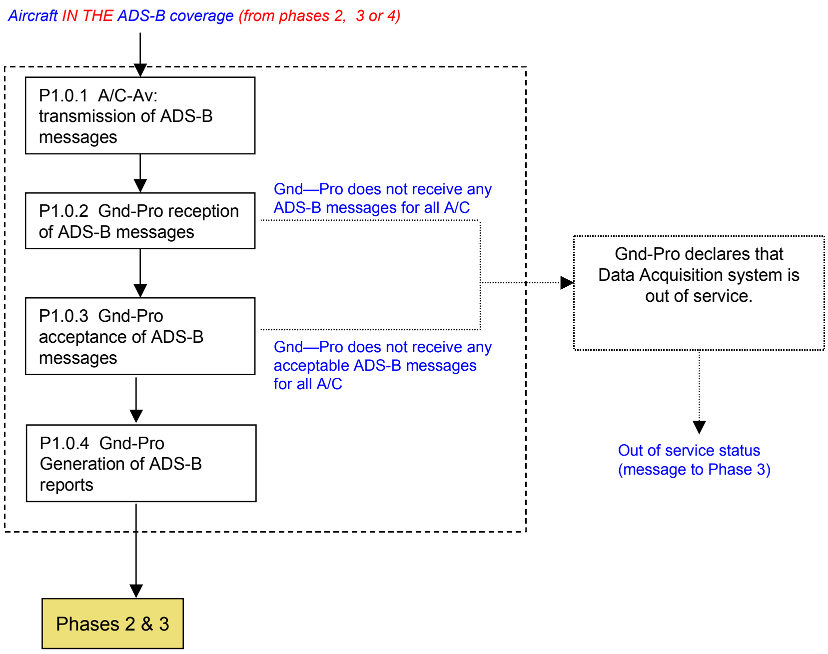
The NRA application studied in this OHA is extensively described in the NRA OSED [Ref.2] .

3.1 NRA Modelling

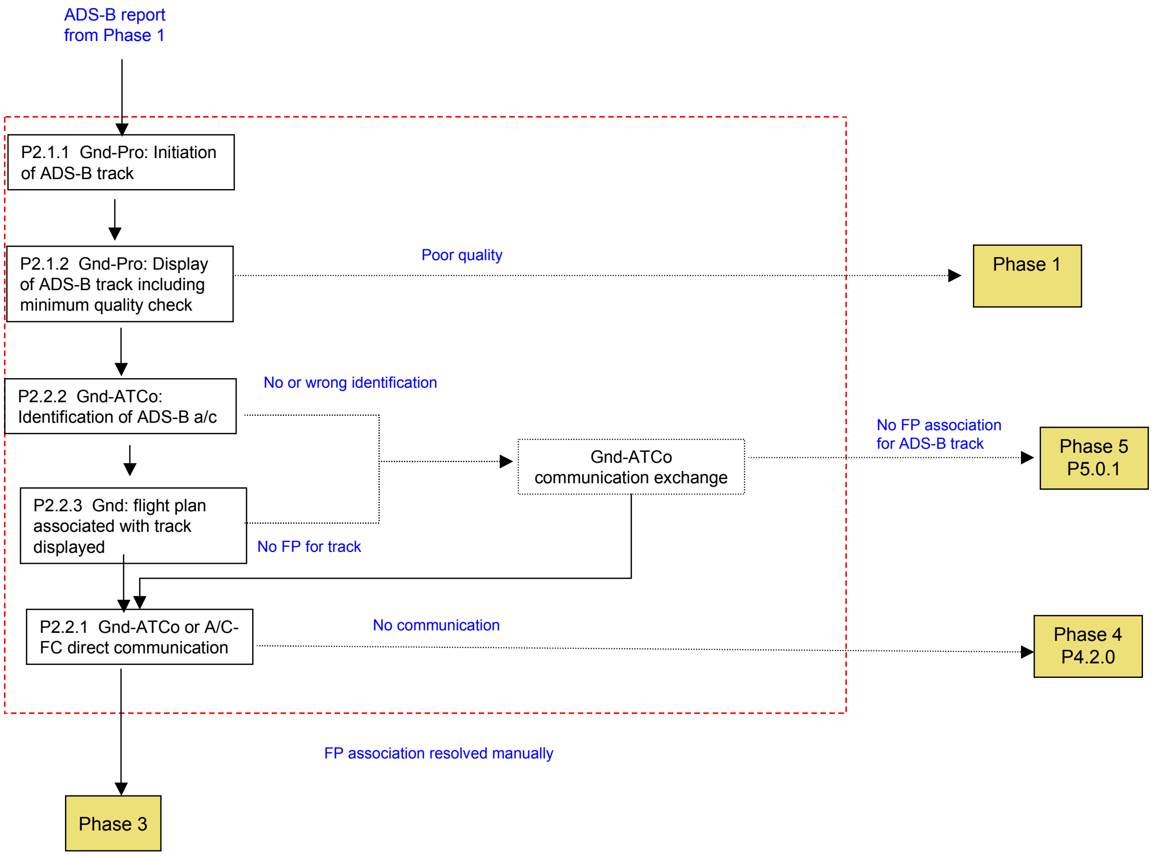
The NRA OHA is based on the following modelling

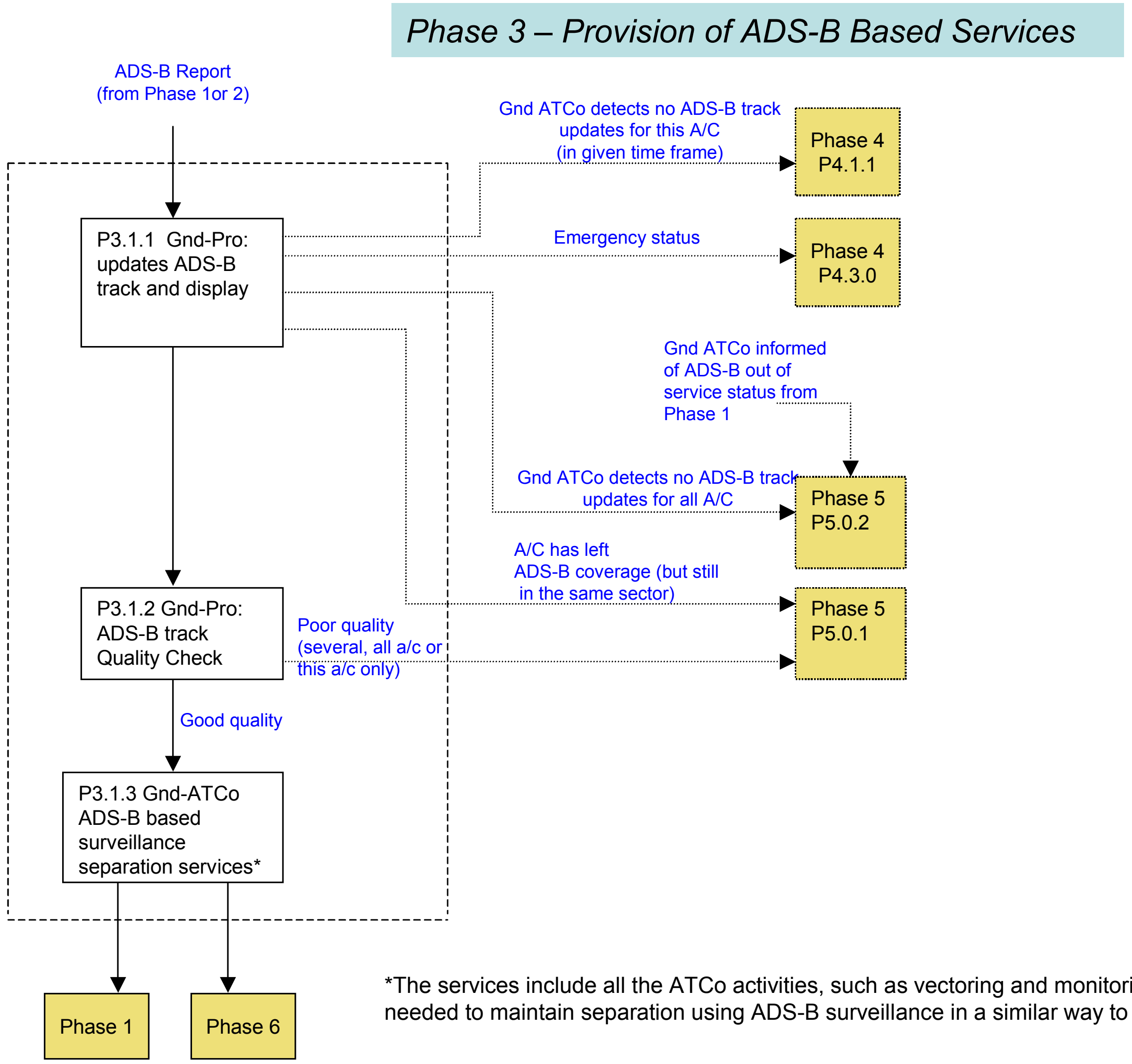


Phase 1 – ADS-B Data Acquisition



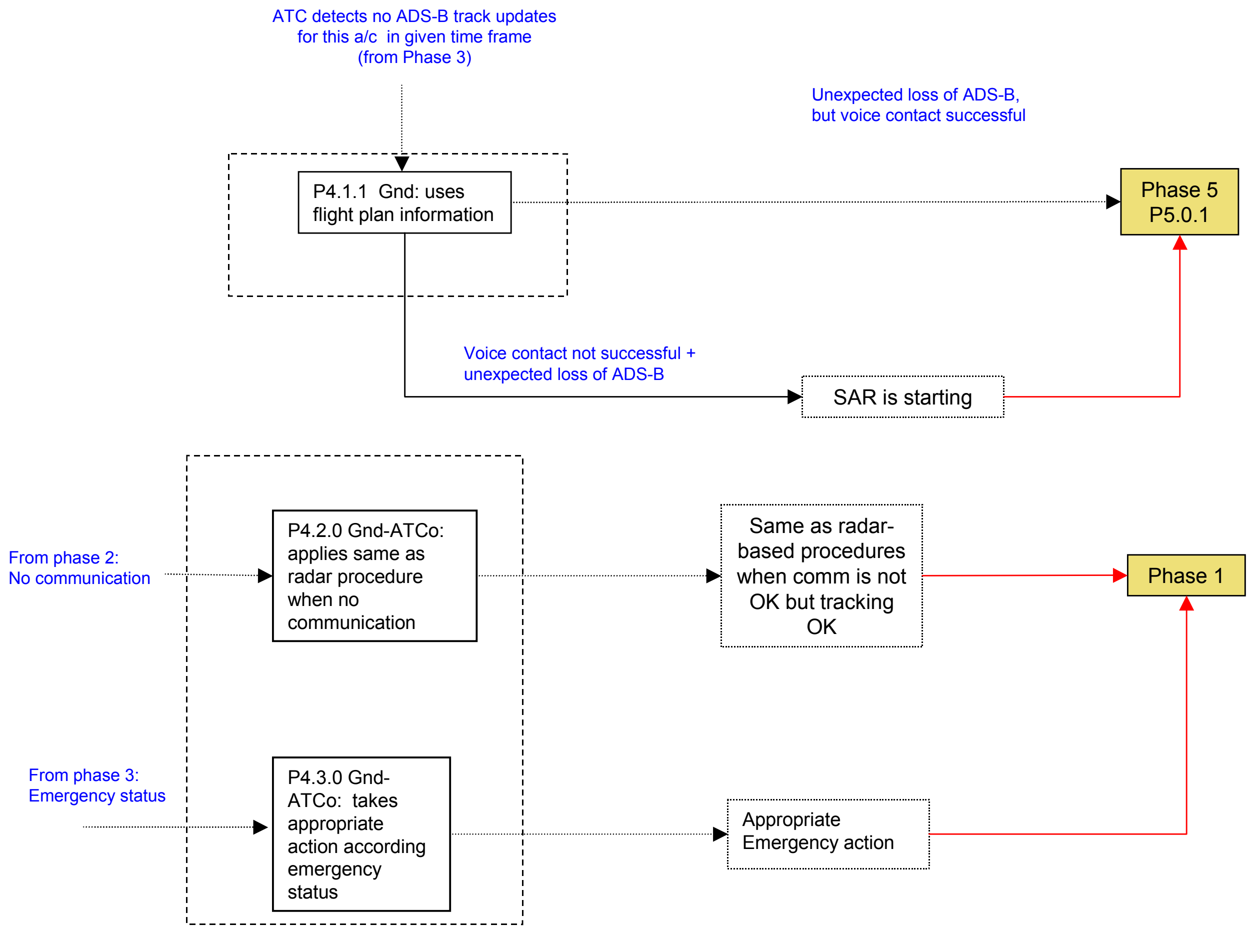
Phase 2 – Initiation of ADS-B based services



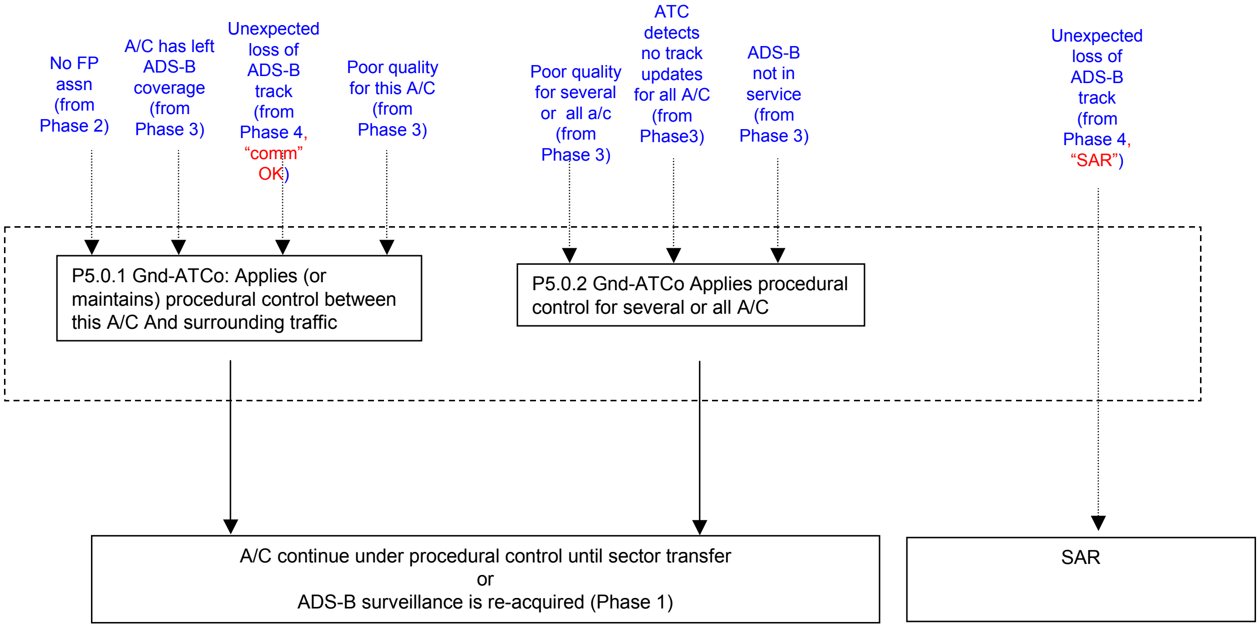


*The services include all the ATCo activities, such as vectoring and monitoring, needed to maintain separation using ADS-B surveillance in a similar way to radar

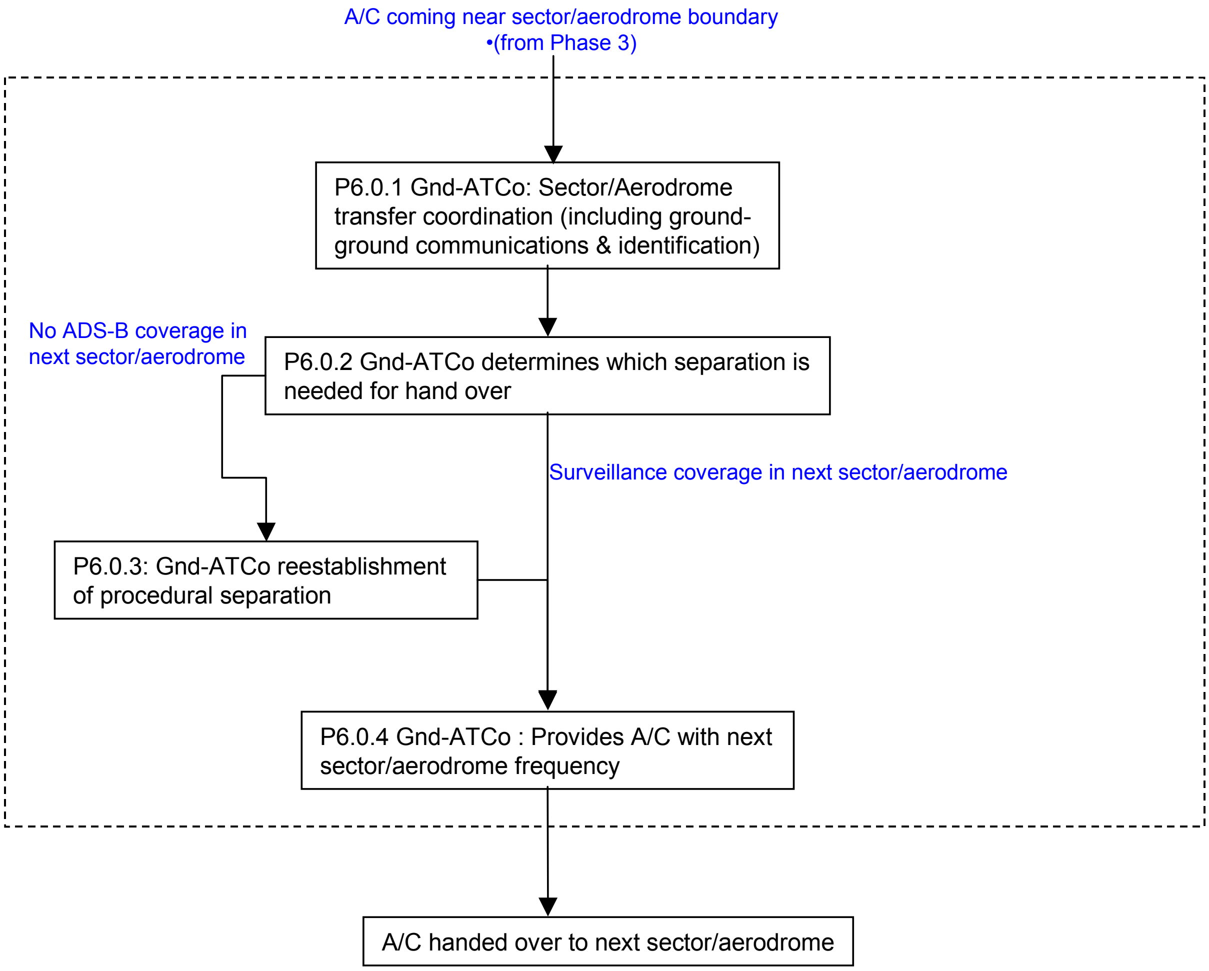
Phase 4 – Alerting



Phase 5 – Exceptional Termination of ADS-B Based Services



Phase 6 – Normal Termination of ADS-B Based Services through transfer



3.2 Identification of Abnormal Events and OH from the modelling

RFG definitions of Abnormal Event and Operational Hazard are provided below:

Abnormal Event:

Operational Hazard

Abnormal Events and Operational Hazards are identified from the application modelling provided in section 3.1. The two following table provide the list of AE and OH per phases:

AE #	AE Description
Phase 1: ADS-B data acquisition	
AE 1.0.1-1	A/C-Av fails to transmit ADS-B messages
AE 1.0.1-2	A/C-Av transmits ADS-B messages with incorrect Id

AE 1.0.1-3	A/C-Av transmits ADS-B messages with incorrect position
AE 1.0.1-4	A/C-Av transmits ADS-B messages with incorrect quality indicator
AE 1.0.1-5	A/C-Av transmits ADS-B messages with incorrect altitude
AE 1.0.1-6	A/C-Av transmits ADS-B messages without Id
AE 1.0.1-7	A/C-Av transmits ADS-B messages without position
AE 1.0.1-8	A/C-Av transmits ADS-B messages without quality indicator
AE 1.0.1-9	A/C-Av transmits ADS-B messages without altitude
AE 1.0.2-1	Gnd-Pro does not receive ADS-B message
AE 1.0.2-2	Gnd-Pro incorrectly receives ADS-B message
AE 1.0.3-1	Gnd-Pro does not perform acceptance check
AE 1.0.3-2	Gnd-Pro incorrectly performs acceptance test
AE 1.0.4-1	Gnd-Pro does not generate ADS-B reports
AE 1.0.4-2	Gnd-Pro generates ADS-B reports with incorrect Id
AE 1.0.4-3	Gnd-Pro generates ADS-B reports with incorrect position
AE 1.0.4-4	Gnd-Pro generates ADS-B reports with incorrect quality indicator
AE 1.0.4-5	Gnd-Pro generates ADS-B reports with incorrect altitude
AE 1.0.4-6	Gnd-Pro generates ADS-B reports without Id
AE 1.0.4-7	Gnd-Pro generates ADS-B reports without position
AE 1.0.4-8	Gnd-Pro generates ADS-B reports without quality indicator
AE 1.0.4-9	Gnd-Pro generates ADS-B reports without altitude
Phase 2: Initiation of ADS-B based services	
AE 2.1.1-1	Gnd-Pro does not initiate ADS-B track
AE 2.1.1-2	Gnd-Pro initiates ADS-B track with incorrect Id
AE 2.1.1-3	Gnd-Pro initiates ADS-B track with incorrect position
AE 2.1.1-4	Gnd-Pro initiates ADS-B track with incorrect quality indicator
AE 2.1.1-5	Gnd-Pro initiates ADS-B track with incorrect altitude
AE 2.1.1-6	Gnd-Pro initiates ADS-B track without Id
AE 2.1.1-7	Gnd-Pro initiates ADS-B track without position
AE 2.1.1-8	Gnd-Pro initiates ADS-B track without quality indicator
AE 2.1.1-9	Gnd-Pro initiates ADS-B track without altitude
AE 2.1.2-1	Gnd-Pro does not display ADS-B track
AE 2.1.2-2	Gnd-Pro displays ADS-B track with incorrect Id
AE 2.1.2-3	Gnd-Pro displays ADS-B track with incorrect position
AE 2.1.2-4	Gnd-Pro displays ADS-B track with incorrect altitude
AE 2.1.2-5	Gnd-Pro displays ADS-B track without Id
AE 2.1.2-6	Gnd-Pro displays ADS-B track without position
AE 2.1.2-7	Gnd-Pro displays ADS-B track without altitude
AE 2.1.2-8	ADS-B track display of a/c with incorrect quality check performed

AE 2.1.2-9	ADS-B track display of a/c without quality check performed
AE 2.2.1-1	No identification of ADS-B A/C
AE 2.2.1-2	Incorrect identification of ADS-B A/C
AE 2.2.2-1	No association between track displayed and any Flight Plan
AE 2.2.2-2	Incorrect association between track displayed and Flight Plan
AE 2.2.3-1	No direct communication between Gnd-ATCo and FC
AE 2.2.3-2	Gnd-ATCo contacts an incorrect FC
Phase 3: Provision of ADS-B Based Services	
AE 3.0.1-1	Gnd-Pro does not update ADS-B track
AE 3.0.1-2	Gnd-pro: ADS-B report update with incorrect Id
AE 3.0.1-3	Gnd-pro: ADS-B report update with incorrect position
AE 3.0.1-4	Gnd-pro: ADS-B report update with incorrect quality indicator
AE 3.0.1-5	Gnd-pro: ADS-B report update with incorrect altitude
AE 3.0.1-6	Gnd-pro: ADS-B report update without Id
AE 3.0.1-7	Gnd-pro: ADS-B report update without position
AE 3.0.1-8	Gnd-pro: ADS-B report update without quality indicator
AE 3.0.1-9	Gnd-pro: ADS-B report update without altitude
AE 3.0.1-10	ADS-B report update assigned to another a/c
AE 3.0.2-1	Gnd-Pro does not perform quality check
AE 3.0.2-2	Gnd-Pro performs an incorrect quality check
Phase 4: Alerting	
AE 4.1.0-1	Gnd does not use flight plan information
AE 4.1.0-2	Gnd uses an incorrect flight plan
Phase 6: Normal Termination of ADS-B Based Services through transfer	
AE 6.0.1-1	Gnd-ATCo does not perform sector transfer coordination
AE 6.0.1-2	Gnd-ATCo incorrectly performs sector transfer coordination
AE 6.0.2-1	Gnd-ATCo does not determine which separation is needed for hand over
AE 6.0.2-2	Gnd-ATCo incorrectly determines which separation is needed for hand over
AE 6.0.4-1	Gnd-ATCo does not provide A/C with next sector frequency
AE 6.0.4-2	Gnd-ATCo provides A/C with incorrect frequency

OH #	OH Description
Phase 3: Provision of ADS-B Based Services	
OH 3.0.3-1	Gnd-ATCo does not provide ADS-B based surveillance separation services (no data available from one a/c)
OH 3.0.3-2	Gnd-ATCo does not provide ADS-B based surveillance separation services (no data available from all a/c)
OH 3.0.3-3	Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect Id.

OH 3.0.3-4	Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect position.
OH 3.0.3-5	Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect altitude.
OH 3.0.3-6	Gnd-ATCo provides ADS-B based surveillance separation services although Id is not available
OH 3.0.3-7	Gnd-ATCo provides ADS-B based surveillance separation services although altitude is not available
Phase 4: Alerting	
OH 4.3.0-1	Gnd-ATCo does not take action according emergency status
OH 4.3.0-2	Gnd-ATCo takes incorrect action
Phase 5: Exceptional Termination of ADS-B Based Services	
OH 5.0.1-1	Gnd-ATCo does not apply procedural control for one a/c
OH 5.0.1-2	Gnd-ATCo applies procedural control to an incorrect A/C
OH 5.0.2-1	Gnd-ATCo does not apply procedural control for all a/c
Phase 6: Normal Termination of ADS-B Based Services through transfer	
OH 6.0.3-1	Gnd-ATCo does not re-establish procedural separation
OH 6.0.3-2	Gnd-ATCo re-establishes incorrect separation

Only OHs are further analysed in the OHA. AE will be analysed during the ASOR process.

3.3 Identification of Mitigation Means

RFG definitions of External Mitigation Means and Internal Mitigation Means are provided below:

External Mitigation Means:

Internal Mitigation Means:

Only External Mitigation Means are used in the OHA in order to assess the operational consequences and define severity for each individual OH.

3.3.1 External Mitigation Means

This sub-section presents External Mitigations means extracted from the Environment Description.

EM1. ATC Separation are provided as if radar would be available

EM2. ATC Vectoring are provided as if radar would be available

EM3. Airspaces, where ADS-B NRA will be implemented, include RNAV operations, Limited crossing tracks, Limited reciprocal tracks, Limited altitude transitions, RVSM (en- route), SIDs & STARs (TMA)

EM4. Traffic density is low

EM5. ATS Communication (Controller/Controller) capabilities and performances are required to support Controller/Controller coordination (Inter Sector communications) as described in ICAO Annex 11 (chapter 6) and doc 4444 (chapter 10)

EM6. ATS Communication (Pilot/Controller) capabilities and performances are required to support the above Air Traffic Services

EM7. Navigation capability is at least RNP 20

EM8. Surveillance capabilities and performances are required to support the above Air Traffic Services. Including in particular the following capabilities: ADS-B GS, SDPD, CWP,

EM9. ATS tools includes Flight Plan update using aircraft track;

3.3.2 Internal Mitigations Means

This sub-section presents Internal Mitigations means extracted from the Application Description.

IM1. ADS-B NRA applies to airspace classes (A to G) where radar surveillance currently does not exist

IM2. The provision of radar-like services to aircraft in a particular NRA will also depend upon the availability and coverage of appropriate air-ground communications.

IM3. The procedures and services are essentially the same as can be done with SSR radar.

IM4. ADS-B surveillance information should be presented to the controller in a similar way to radar.

IM5. Any ADS-B equipment failure or service degradation (including for individual aircraft) must be recognised so that reversion to non-radar procedures can be done safely.

IM6. It is expected that the aircrew will interface to the ADS-B equipment in a similar way to a SSR (or Mode S) transponder.

IM7. It is desirable that the flight crew are able to check (and possibly change) the aircraft identification information set on board the aircraft and subsequently transmitted by the ADS-B equipment.

IM8. When the aircraft identification information received from the ADS-B system (as seen on the controller's display), differs from that expected, procedures similar to dealing with a discrepancy in Mode A code or in Mode S aircraft identification shall apply.

IM9. Verification of the barometric flight level provided by ADS-B is expected to be the same as current verification procedures for use of SSR Mode C.

IM10. The system must provide the controller with indications of the working status of ADS-B ground sensors (including sensors of different link types)

IM11. It is desirable to provide an indication of when the accuracy of ADS-B position reports is likely to be degraded by the deterioration of navigational sources

IM12. Aircraft identification and transfer of identification procedures for ADS-B will be done directly from the aircraft identification information sent in the ADS-B reports.

IM13. Vectoring of ADS-B aircraft by the controller may be expected to be done in a similar way to radar, although the heading information used by the controller will be air derived.

IM14. In circumstances of degraded accuracy, separations should be increased or procedural separations applied

IM15. In event of an aircraft reporting or appearing from the ADS-B surveillance information to be in an emergency situation, then the same emergency procedures as for radar control will apply.

IM16. The emergency status indicators in ADS-B shall be used and displayed by the system in a similar way to present SSR Mode A emergency codes.

IM17. Additional emergency status indicators may also be available in the ADS-B report (e.g. low fuel) and these may be displayed by the system.

IM18. Similar procedures as described for the failure of an aircraft transponder are required for the failure of the aircraft ADS-B transmitter in airspace where equipage is mandatory.

IM19. Procedures in the event of a complete failure of the ADS-B system will be similar to procedures for radar equipment failure.

IM20. Therefore it is vital, at local level, to devise a manner in which procedural and ADS-B traffic can co-exist safely whilst still allowing those aircraft which are suitably equipped to gain benefit from the new surveillance procedures. In some airspace environments, it may be appropriate to segregate equipped and non-equipped aircraft, for instance, to different geographical areas or by different flight levels.

IM21. For all procedures, it would be the responsibility of the adjoining control agencies to ensure that appropriately equipped aircraft were sent to the appropriate entry points with the correct separation in place before transfer of control took place. This would be done, of course, in co-ordination with the receiving controller.

IM22. Phraseology for aircraft in ADS-B surveillance should be very similar to that used today in radar surveillance services.

IM23. , to gain the full control benefits from the introduction of ADS-B into the environment, it would be sensible to maximise the VHF coverage of the environment as well.

IM24. An ADS-B ground infrastructure is required

IM25. The ADS-B ground system provides radar-like processing for ADS-B data: e.g. creation, maintenance and suppression of tracks based on ADS-B reports and display of these tracks on the CWP.

IM26. Ground-air communications similar to those required for provision of ATC radar services (in particular, VHF coverage for tactical control).

IM27. The following list of surveillance parameters are required by the controller:

- Aircraft identity (and/or Mode A code in some environments)
- Position
- Indication of the quality of ADS information (in particular, to indicate whether it is good enough for certain separation purposes).
- Barometric Altitude

IM28. Aircraft will be required to equip with an ADS-B transmitter, including interfaces to the on-board data sources.

4. OHA RESULTS

The tables included in this section summarise the main results obtained from the assessment done in Annex B.

4.1 Operational Hazards

The following table provides a list of the Operational Hazards identified during the OHA (classified per actions) along with the external mitigation means and the assigned hazard class.

These external mitigation means are referred as candidate safety requirements and should be validated during the ASOR phase. The hazard class is assigned to the operational consequence of the operational hazard both considering the identified MM (i.e. when OH is detected and eased) and supposing that they fail or that they are not available (i.e. when OH is undetected or not eased).

OH#	OH	EMM	Assessment with MM (i.e. when OH is detected and eased)		Assessment without MM (i.e. when OH is undetected or not eased)	
			OC	HC	OC	HC
OH 3.0.3-1	Loss of ADS-B information for one a/c to which ADS-B based surveillance is provided.	EMM 4	Significant increase in ATCo workload	4	Large reduction in separation	2
OH 3.0.3-2	Loss of ADS-B information for several a/c to which ADS-B based surveillance is provided	EMM 4	Significant reduction in separation	3	Mid-air collision	1
OH 3.0.3-3	Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect Id.		None	5	Significant reduction in separation	3
OH 3.0.3-4	Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect position.	EMM 4	o Large reduction in separation (several a/c) o Significant increase in ATCo workload.	2 3	o Mid Air collision o Large reduction in separation (several a/c)	2 1
OH 3.0.3-5	Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect altitude.		Slight increase in ATCo workload	4	Significant reduction in safety margin	3

OH#	OH	EMM	Assessment with MM (i.e. when OH is detected and eased)		Assessment without MM (i.e. when OH is undetected or not eased)	
			OC	HC	OC	HC
OH 3.0.3-6	Gnd-ATCo provides ADS-B based surveillance separation services although Id is not available		Significant increase in ATCo workload	4	n/a	n/a
OH 3.0.3-7	Gnd-ATCo provides ADS-B based surveillance separation services although altitude is not available		None	5	n/a	n/a
OH 4.3.0-1	Gnd-ATCo does not take action according emergency status		Slight increase in ATCo workload	5	Slight increase in flight crew workload	4
OH 4.3.0-2	Gnd-ATCo takes incorrect action		Significant increase in ATCo workload	4	Significant reduction in safety margin	3
OH 6.0.3-1	Gnd-ATCo does not re-establish procedural separation		Significant increase in ATCo workload	4	Large reduction in separation	2
OH 6.0.3-2	Gnd-ATCo re-establishes incorrect separation		Significant reduction in safety margin	3	Large reduction in separation	2

4.2 Candidate Safety Requirements

The following table presents the mitigation means used in the current assessment along with the reference of the action or condition from which they have been obtained (described in the OSED [Ref.2]). When applicable, the reference to the related assumptions described in section 3.3.2 has also been included.

External Mitigation Means	Actions / conditions / assumptions related
EMM4: Traffic density is low	

The following table presents a list of recommendations proposed during the assessment process. They have to be review by operational and system experts people and once validated, they will be considered as Mitigation Means and taken into account in the assessment as the initial MM obtained from the OSED.

Recommendations (To be validated)	Comments
REC.1 -	
REC.2 -	

ANNEX A. HAZARD CLASS MATRIX: OPERATIONAL CONSEQUENCES LIST

The following table present the Operational Consequences used during the safety assessment. Note that these consequences are classified per hazard class and per type of consequence (set of consequences), and they encompass effects on operations, on aircraft, on occupants, on flight crew and on Air traffic services.

Hazard Class	**1 (most severe)**	**2**	**3**	**4**	**5 (least severe)**
Effect on Operations	Normally with hull loss. Total loss of flight control, mid-air collision, flight into terrain or high speed surface movement collision.	Large reduction in safety margins or aircraft functional capabilities.	Significant reduction in safety margins or aircraft functional capabilities.	Slight reduction in safety margins or aircraft functional capabilities.	No effect on operational capabilities or safety
Effect on Occupants	Multiple fatalities.	Serious or fatal injury to a small number of passengers or cabin crew.	Physical distress, possibly including injuries.	Physical discomfort.	Inconvenience.
Effect on Air crew	Fatalities or incapacitation.	Physical distress or excessive workload impairs ability to perform tasks.	Physical discomfort, possibly including injuries or significant increase in workload.	Slight increase in workload.	No effect on flight crew.
Effect on Air Traffic Service	Total loss of separation.	Large reduction in separation or a total loss of air traffic control for a significant period of time.	Significant reduction in separation or significant reduction in air traffic control capability.	Slight reduction in separation or in ATC capability. Significant increase in air traffic controller workload.	Slight increase in air traffic controller workload.

Hazard Class	**1 (most severe)**	**2**	**3**	**4**	**5 (least severe)**
Example of ASAS operational consequences	• *Mid-air collision* • *Controlled flight into terrain* • *Total loss of flight control* • *High speed surface movement collision (i.e. collision in runway)* • *Leaving a prepared surface at high speed.*	• *Large reduction in separation or safety margins* • *Loss of separation resulting in wake vortex encounter at low altitude.* • *Large reduction in safety margins like abrupt manoeuvre is required to avoid mid-air collision or CFIT (e.g. one or more aircraft deviating from their intended clearance)* • *Large reduction in aircraft functional capabilities* • *Total loss of air traffic control for a significant period of time*	• *Significant reduction in separation or safety margins* • *Loss of separation resulting in wake vortex encounter at high altitude.* • *Low speed surface movement collision (i.e. collision in taxiway)* • *Leaving a prepared surface at low speed* • *Significant reduction in aircraft functional capabilities* • *Significant reduction in air traffic control capability*	• *Slight reduction in separation or safety margins* • *Significant increase in air traffic controller workload* • *Slight increase in flight crew workload*	• *No effect on operations /traffic* • *Slight increase in air traffic controller workload* • *No effect on flight crew*

ANNEX B. OHA TABLES

OH#	OH	EMM	Effects when detected	Effects when undetected	Recommendations Comments
P3	***Provision of ADS-B based service***				
3.0.3	ADS-B based surveillance separation services				
3.0.3-1	Loss of ADS-B information for one a/c to which ADS-B based surveillance is provided.	EMM 4 (traffic density is low)	a/c has left the ADS-B coverage: lead to phase 5 a/c encounters problem with its ADS-B system: lead to phase 5 In both cases, ATCo will apply procedural separation to this a/c, increasing its workload. Last possibility is that a/c has a major problem, not ADS-B related: lead to phase 4. For possibilities 1&2, same kind as consequence as for a loss of transponder. Hazard Class: 4 OC: Significant increase in ATCo workload.	ATCo does not notice that the affected a/c is no more displayed on CWP and does not apply procedural separation to this a/c. In the worst case, this may lead to reduction in separation. Hazard Class: 2 OC: Large reduction in separation	Comment: When detected, this event lead to phase 4 (loss of a/c) or phase 5 (loss of ADS-B system on board)
3.0.3-2	Loss of ADS-B information for several a/c to which ADS-B based surveillance is provided	EMM 4 (traffic density is low)	ATCo to ensure safe separation until back to procedural separation although no means are available except vocal communication. Same kind of consequence	Such event should eventually be detected. However, if it takes too long, separation may be infringed without ATCo detection or late detection. Hazard Class: 1	Recommendation from last doc 4444 version: “use of flight levels spaced by half the applicable vertical separation minimum may be resorted to

OH#	OH	EMM	Effects when detected	Effects when undetected	Recommendations Comments
			as for loss of radar Hazard Class: 3 OC: Significant reduction in separation	OC:Mid Air collision	temporarily if standard procedural separation cannot be provided immediately.
3.0.3-3	ADS-B based surveillance separation services provided to an a/c with incorrect Identity.	None	A/C should be highlighted with a specific symbol. ATCo requests FC to put the correct Id, when possible? Hazard Class: 5 OC: None Same kind of consequence as for incorrect mode A	In the worst case, an instruction may be sent to incorrect a/c. Hazard Class: 3 OC: Significant reduction in separation	
3.0.3-4	ADS-B based surveillance separation services provided to a/c broadcasting incorrect position	EMM 4 (traffic density is low)	ATCo has to separate affected a/c, although he/she cannot rely on any reliable information, from other traffics in order to ensure safe separation Hazard Class: o 2 (several a/c) o 3 (one a/c) OC: o Large reduction in separation (several a/c) o Significant increase in ATCo workload.	ATCo has no means to guide a/c appropriately. Hazard Class: o 1 (several a/c) o 2 (one a/c) OC: o Mid Air collision o Large reduction in separation (several a/c)	Comment: Maybe detected in case of large deviation from the route, but not with a small one
3.0.3-5	Gnd-ATCo provides ADS-B based surveillance separation services to a/c broadcasting incorrect altitude	None	Same effect as in radar environment with incorrect mode C.	Separation service will be provided using incorrect altitude Hazard Class: 3	

OH#	OH	EMM	Effects when detected	Effects when undetected	Recommendations Comments
			Hazard Class: 4 OC: Slight increase in ATCo workload	OC: Significant reduction in safety margin.	
3.0.3-6	Gnd-ATCo provides ADS-B based surveillance separation services to an a/c without identity	None	ATCo shall contact the a/c based on last identity information Hazard Class: 4 OC: Significant increase in ATCo workload.	N/A	Such hazard does not sound operational.
3.0.3-7	Gnd-ATCo provides ADS-B based surveillance separation services to an a/c without altitude	None	No impact Hazard Class: 5 OC: None As with radar if mode C is missing	N/A	
P4	***Alerting***				
4.3.0	Gnd-ATCo does not take action according emergency status				
4.3.0-1	Gnd-ATCo does not take action according emergency status	None	Appropriate action will be taken with some delay. Hazard Class: 5 OC: Slight increase in ATCo workload	This should eventually detected by pilot leading nevertheless to some additional delay. Hazard Class: 4 OC: Slight increase in flight crew workload	
4.3.0-2	Gnd-ATCo takes incorrect action according emergency status	None	Appropriate action will be taken with some delay. Hazard Class: 4 OC: Significant increase in ATCo workload	This should eventually detected by pilot leading nevertheless to some additional delay. Hazard Class: 3 OC: Significant reduction in safety margin	
P6	***Normal Termination of ADS-B Based Services through transfer***				

OH#	OH	EMM	Effects when detected	Effects when undetected	Recommendations Comments
6.0.3	Gnd-ATCo reestablishment of procedural separation				
6.0.3-1	Gnd-ATCo does not re-establish procedural separation		ATCo will re-establish procedural separation with delay Hazard Class: 4 OC: Significant increase in ATCo workload	If next sector has no surveillance means, this can lead to large reduction in separation. Hazard Class: 2 OC: Large reduction in separation	
6.0.3-2	Gnd-ATCo re-establishes incorrect separation		ATCo will re-establish procedural separation with delay Hazard Class: 3 OC: Significant reduction in safety margin	If next sector has no surveillance means, this can lead to large reduction in separation. Hazard Class: 2 OC: Large reduction in separation	

Package I

Non Radar Area (ADS-B-NRA)

Operational Performance Assessment

Edition	:	1.0
Edition Date	:	23 February 2005
Status	:	Working Draft
Class	:	RFG Internal Document

Document Change Record

The following table records the complete history of the successive editions of the present document.

EDITION	DATE	REASON FOR CHANGE	SECTIONS PAGES AFFECTED
0.1f	2 Feb-2005	First Draft for RFG5	
1.0	23 Feb- 2005	Processing of comments received at RFG5 + additional improvements	All

Table of Contents

List of Figures and Tables

1 INTRODUCTION

1.1 Purpose

The purpose of this document is to provide the initial results of the Operational Performance Assessment (OPA)[1] for the Non Radar Area (ADS-B-NRA) application (ref 1&2). These initial results are inputs to the validation process for consolidation.

This document was developed in accordance with the following guideline documents:

- "Proposed approach for ADS-B-NRA OPA on ATC separation" (ref 3)
- "Proposed approach for integration on the GSA SPR process of results available from the existing studies on Separation Minima and ADS-B" (ref 8)

Consideration of the "RFG guidance" and other relevant guidance documents have not fully been taken into account at this stage.

1.2 References

The reference material used is:

1. NRA Application Description version 1.2g, dated January 2005.
2. NRA Environnent Description version 0.4, dated November 2004.
3. Proposed approach for ADS-B-NRA OPA on ATC separation version 1.7, dated November 2004.
4. NRA OHA version 0.7, dated 21st of January 2005.
5. Manual for the Determination of Separation Minimum, ICAO Doc 9689, 1998
6. ADS-B Surveillance Requirements to Support ATC Separation Standards, MITRE Technical Report, Staley Jones (presently in draft)
7. Eurocontrol Standard Document for Radar Surveillance in En-Route Airspace and Major Terminal Areas. Edition 1.0, dated March 1997.
8. Proposed approach for integration on the GSA SPR process of results available from the existing studies on Separation Minima and ADS-B

1.3 The CNS/ATM system

A functional description of the CNS/ATM system required for NRA operations is depicted in Figure 1. It consists of the following elements:

- Aircraft domain;
- Ground domain.

[1] These results will have to be reconciled together with those from the separate ADS-B-NRA Operational Safety Assessment (OSA) in order to derive the Safety and Performance Requirements (SPR) – see annex B.

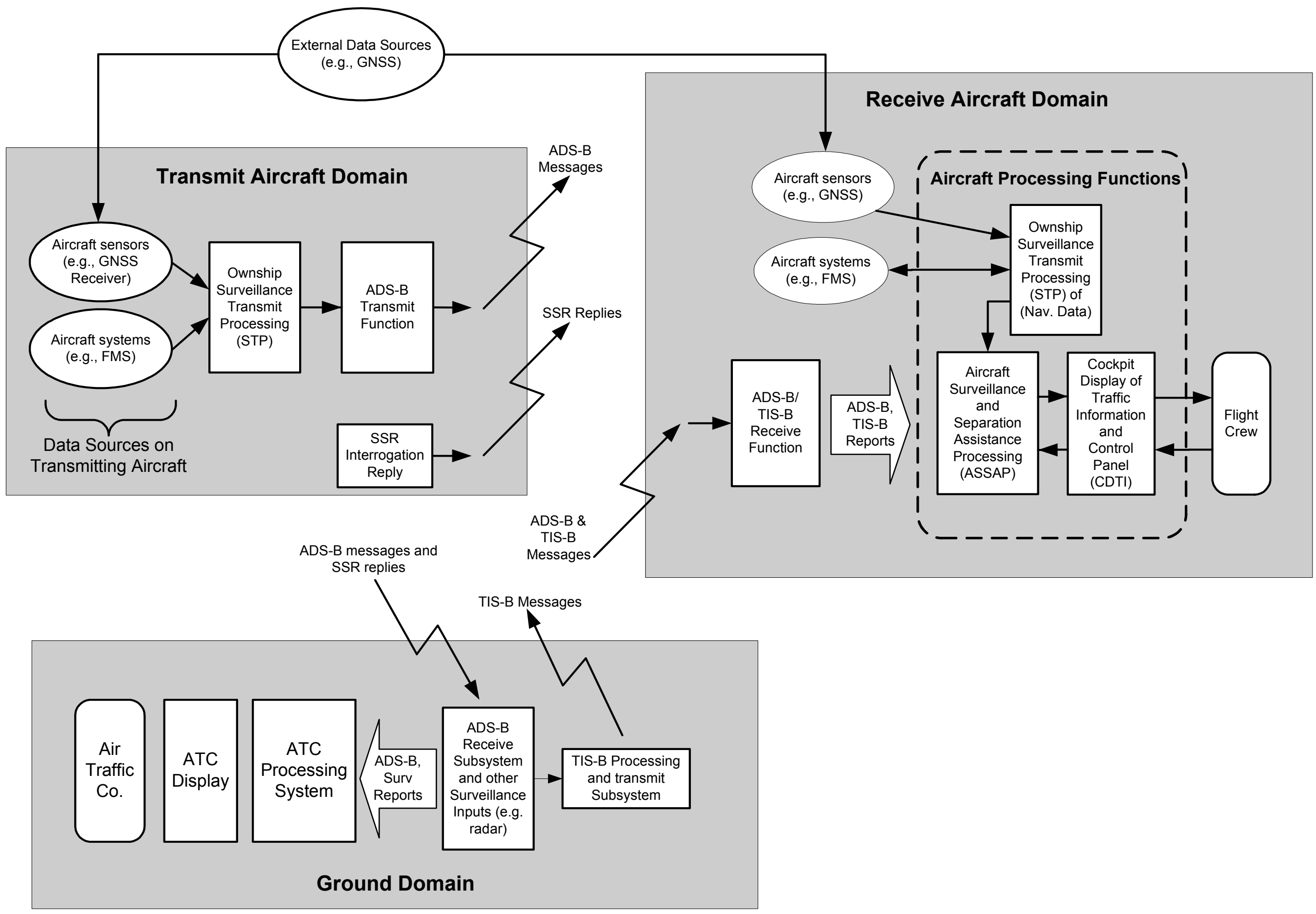


Figure 1: Functional system description

1.4 Acronyms

Acronyms	
ADS-B	Automatic Dependent Surveillance Broadcast
ATC	Air Traffic Control
ATCo	Air Traffic Controller
CWP	Controller Working Position
CNS/ATM	Communication, Navigation, and Surveillance/ Air Traffic Management
OPA	Operational Performance Assessment
OSA	Operational Safety Assessment
SPI	Special Pulse Ident
SPR	Safety & Performance Requirements
TMA	Terminal Manoeuvring Area

Table 1: Table of acronyms

1.5 Glossary of terms

To be completed.

Note: Surveillance performance parameters are described in section 4

Term	Definition
ADS-B Message	An ADS-B message is a package of information broadcast by the aircraft/vehicle. Each ADS-B message contains a defined set of aircraft/vehicle parameters and these parameters may be only a subset of the available parameters. The format of the message is link specific, as is the number of different messages required for providing all the available set of parameters. Generally, the message will contain additional error protection information to reduce the risk of undetected errors in the decoding of the message by the receiving system.
ADS-B Out	Represents the functional capability of the transmitting aircraft. ADS-B Out functions include the on-board navigation sensors, altitude sensors, Surveillance Transmit Processing (STP) function and ADS-B transmission function.
ADS-B Report	An ADS-B report contains aircraft/vehicle parameters assembled from ADS-B messages received and successfully decoded by the receiving system. The data format of the report should be independent of the particular type of ADS-B link. From an ADS-B-NRA perspective, there are 3 different types of reports containing different types of minimum information 1. **Position** = containing at least position, barometric height, quality indicators and ICAO 24 bit airframe address. 2. **Identity** = containing at least the operational identity (flight id or Mode A code) and ICAO 24 bit airframe address. 3. **Emergency** = containing at least the emergency status indicators (or SPI) and ICAO 24 bit airframe address. [When the flight crew sets such a condition].
Minimum ATC Separation	The prescribed distance, measured vertically in feet, and laterally and longitudinally in distance (NM) and time, applied between aircraft, or aircraft and obstacles, that ensures an acceptable collision risk exists.

Table 2: Glossary of terms

2 ADS-B-NRA OPA APPROACH

The ADS-B-NRA OPA approach is described in references 3 and 8. The following subsections summarise the major elements of the approach.

2.1 Scope of the ADS-B-NRA OPA

The ADS-B-NRA application (ref 1) generally expects that certain ATS capabilities would be enabled by ADS-B surveillance (and aircraft are suitably ADS-B equipped) in a similar way as when radar is available. In particular, for the separation services, it is assumed that ADS-B can be used to support similar separation minima to radar if the ADS-B technical surveillance performance is "equivalent or better than radar" (see 2.2). Hence, it is assumed that all other non-technical surveillance aspects of the service (i.e. people and procedures) will be largely unchanged.

Consequently, the scope of this OPA is

- focused on surveillance <u>technical</u> aspects
- focused on the <u>separation task</u> that is assumed to be the most demanding ATS for ADS-B requirements

In addition, this document provides sections for provision of:

- Surveillance requirements relating to the transition from nominal to non-nominal mode of operation (max transition rate, time-to-alert). See section 5.6
- Apportion of surveillance requirements to airborne and ground segments (section 6)

Note, the OPA does not cover the any effects of illegal interference, either accidental or malicious, on the surveillance system (either for radar or ADS-B in comparison).

2.2 Comparative approach and reference radar

The comparison approach described in reference 3 requires a **reference radar** for which the relevant quality of service attributes are known (or can be defined). It is assumed that the reference radar would be capable of supporting safe ATC separation services with the required separation minima up to a certain operating range. The required ADS-B surveillance attributes are then derived in comparison with the reference radar attributes. Comparison is therefore conducted **at single radar level.**

The comparisons of surveillance quality of ADS-B and radar is conducted at the **input of the "ATC Processing System"** and ADS-B requirements are therefore expressed at report level, as illustrated in the following Figure 2.

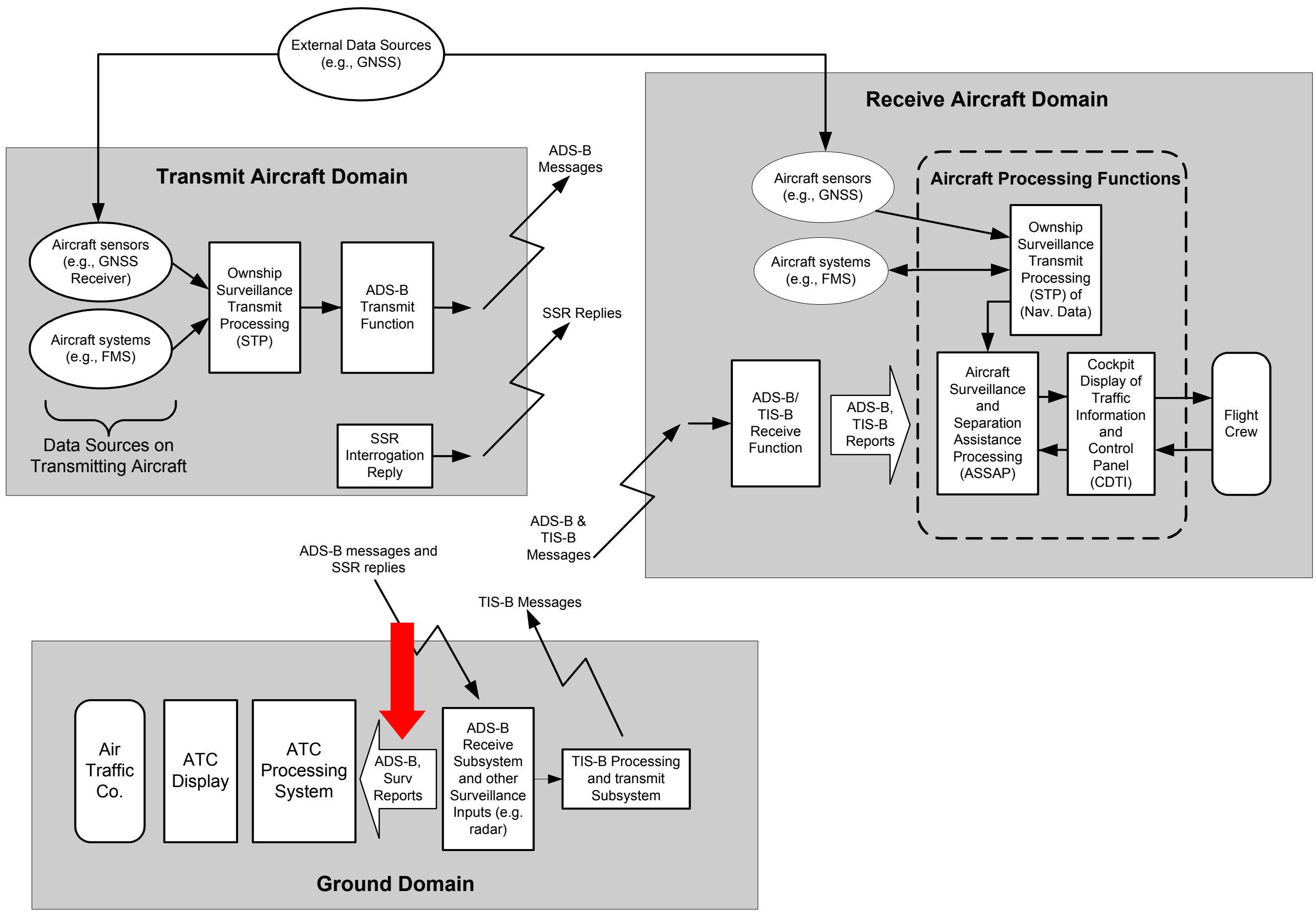


Figure 2: where ADS-B requirements are expressed

3 REQUIRED DATA ITEMS AT THE INPUT OF THE "ATC PROCESSING SYSTEM"

3.1 List of required surveillance data items

As indicated in section 2, the ADS-B requirements are expressed in this document **at the input of the ATC system** (where the comparison with radar reports is performed). At this level, the following set of data items is required[2]:

Required Surveillance Data Items	Reference Radar (SSR)	ADS-B (report level)
Operational identity	Mode 3/A;	Flight identification (call sign) or registration marking; and/or Mode 3/A code;
Special identity	SPI	SPI
Horizontal Position	Range; azimuth	Latitude; longitude
Barometric Altitude	Mode C from SSR	Barometric altitude from ADS-B
Time stamp	Time of measurement from signal reception at the input of the radar	Time of applicability of ADS-B
Quality indicators affecting all a/c	Radar status: radar working properly or not.	ADS-B receive sub-system: working properly or not [3] ADS-B external data source (e.g. GNSS) working properly or not [4]?
Quality indicator affecting individual a/c	Radar range, imposes limits for certain separation minima (affects surveillance quality of individual a/c according to their range)	Quality Indication on an individual a/c basis to indicate whether position accuracy and integrity are suitable for radar-like separation
Emergency indicators	From mode A codes	Emergency indicators in ADS-B messages

Table 3: Required data Items

[2] Annex A contains the list of data items as required at ADS-B-NRA Application Description level (Controller's perspective)

[3] Need to identify in OSED version 1.2g

[4] Need to identify in OSED version 1.2g

A quality indicator is required to indicate to the controller whether or not the surveillance information is good enough for a certain purposes, in particular for the use of certain separation minima. In radar, the quality indicator is assumed when the radar is working properly and the controller knows the range from the radar of individual aircraft. In ADS-B, in addition to the working status of the systems that will affect all aircraft, a quality for individual aircraft is required. **Hence, the ADS-B system is expected to provide information on the position accuracy and integrity of individual aircraft**. The ADS-B-NRA application will use this information with certain thresholds to decide whether or not the accuracy and integrity are of sufficiently good levels for a certain purposes, in particular for the application of a certain separation minima. The required performance information specified in this OPA, as determined from a reference radar, can then be used to define the required thresholds with respect to the ADS-B accuracy and integrity information. [Note that other applications may use different thresholds on the ADS-B quality information].

ADS-B-NRA application may require ground velocity at controller level. As this may be determined by the system from successive position updates, it is therefore not considered as a required item at the output of the ground data acquisition function (but could be used if available/required by another application[5]).

[5] Ground velocity may be provided directly by ADS-B or determined by the ground system from tracking of surveillance positions. If ground velocity is provided by ADS-B, it should be at least as good as velocity determined from radar positions. Otherwise, there are no further requirements expressed for velocity in this OPA.

3.2 Detailed surveillance data item requirements

These data item requirements are expressed at the input of the ATC processing system. "*ADS-B shall provide…….*" is to be understood as "**at the input of the ATC processing system, the ADS-B report shall contain…….**"

Note these requirements will eventually be moved to the INTEROP document. They are retained here until the INTEROP activities start.

3.2.1 Identity Requirements

<u>ICAO 24 bits airframe address</u>

ADS-B **shall** provide the ICAO 24 bits airframe address.

<u>Operational Identity</u>

ADS-B **shall** provide an Operational identity through the provision of at least one of the following:

- flight identity (call sign),
- registration marking
- mode A code [6]

ADS-B **shall** be able to provide SPI information[7]

3.2.2 Horizontal Position Requirements

ADS-B **shall** provide the target horizontal position (latitude, longitude)

The horizontal latitude and longitude target positions **shall** be provided as a geometric position referenced to the WGS-84 system

3.2.3 Barometric altitude Requirements

ADS-B **shall** be able to provide a "measured" Barometric altitude[8]

The barometric altitude **shall** be reported with reference to the International Standard Atmosphere for Dry Air as defined by ICAO 1964

It is assumed that the reporting capability of the track barometric altitude[9] may be available but is not essential to be provided by ADS-B for ADS-B-NRA application

[6] In some regions, Mode A code may be required for compatibility with existing radar or flight plan data processing systems

[7] The provision of this information may be optional for some low capability aircraft fits that may be appropriate to certain local environments.

[8] it is assumed that an extrapolated barometric altitude would not be appropriate/accepted and therefore that a "measured" one is required.

[9] E.g. 25/100 feet

3.2.4 Time Requirements

Each ADS-B report **shall** include a time of applicability

The Time Of Applicability of an ADS-B Report **shall** be valid for all data items of a report

3.2.5 Quality Indicator Requirements

ADS-B **shall** provide an indication of accuracy and integrity of position information of individual a/c for the purpose of being used by the ATC Processing System to determine whether the report (and therefore the track update and display) can be used to support safe separation task or not.

ADS-B **shall** provide an indication of whether the functions affecting all a/c are working properly or not.(e.g. “ADS-B receive sub-system” or “External data source sub-system”)

3.2.6 Emergency Indicator Requirements

Status Information Reporting Capability

ADS-B **shall** be able to provide an indication of whether the mobile supports reporting of emergency or priority status [Ref 4]. To be discussed.

Status Information

ADS-B **shall** be able to provide an indication of emergency or priority status.

3.3 ADS-B data item resolution and range characteristics requirements

This is expressed at the input of the “ATC Processing System”.

To be completed.

A possible approach could be to derived ADS-B required resolution from comparison with those of the reference radar.

4 DEFINITION OF THE PERFORMANCE PARAMETERS

This section addresses the following groups of surveillance parameters:

- Update interval and update probability
- Accuracy
- Integrity
- Reliability
- Other surveillance parameter definitions
- Parameters relating to the transition from nominal mode of operation to non-nominal mode of operation

4.1 Update interval and update probability

Performance parameter definitions: update interval and update probability	
Term	**Definition**
Update Interval	The time interval between surveillance report receipts For radar this is fixed by the radar antenna scan. Furthermore, all the required surveillance report information (position, Mode C barometric height, Mode A identity, emergency indicators and SPI) is gathered each scan [and there is no more than one report each scan] For ADS-B the required surveillance information may be spread between more than one type of ADS-B reports and each of these may be produced at different times and rates. The reports are linked to the same aircraft by the ICAO 24 bit airframe address. Hence, for the purposes of comparison in this OPA, the update interval between the following types of ADS-B report is distinguished: 4. **Position** = containing at least position, barometric height, quality indicators and ICAO 24 bit airframe address. 5. **Identity** = containing at least the operational identity (flight id or Mode A code) and ICAO 24 bit airframe address. 6. **Emergency** = containing at least the emergency status indicators (or SPI) and ICAO 24 bit airframe address. [When the flight crew sets such a condition]. Note that after an Identity report (2) has been received, its information can be used to identify position reports (1) using a link with the common ICAO 24 bit airframe address.
Update probability	Probability that a report with the required information is received within the required **update interval** For radar: Probability that a radar target report is generated (i.e. detected by the radar) Probability of Mode A code validated Probability of Mode C code validated Probability of Emergency code (or SPI) validated Probability of code validation is the probability that, for each radar target report, the correct validated code data, corresponding to the interrogation modes, is produced. For ADS-B: The probability is expressed separately for each type of ADS-B report information (position, identity, emergency) – see definition of update interval above.

Table 4: Update interval and update probability parameters definition

4.2 Accuracy

Performance parameter definitions: accuracy	
Term	**Definition**
Accuracy	This is essentially the position measurement error distribution.
Accuracy Horizontal Position	This is essentially the horizontal position measurement error For radar, accuracy horizontal position is normally expressed in terms of range and azimuth dimensions and each is considered to have the following component errors: • Core errors (usually expressed as a standard deviation σ) • Tail errors (outliers, jumps) • Systematic biases The significance of each of these component errors to the comparison with ADS-B is explained further in Section 4.2.1. For ADS-B, accuracy horizontal position is usually defined as the radius of a circle centred on the target's reported position such that the probability of the target's actual position being inside the circle is 95%. The required accuracy is derived from comparison with radar accuracy at some nominal range of operation, in particular the range within which a certain radar separation minimum is supported. The 95% limit is assumed to be equivalent to the radar 2σ position error value at this range. See section 4.2.1.
Accuracy Vertical Position	This is essentially the vertical position measurement error distribution. For both radar and ADS-B, an encoder on the aircraft provides the altitude and the encoded data is transmitted to the radar or ADS-B ground station. Therefore, vertical accuracy at ATC processing depends on • altimeter accuracy (Avionics standard - reference ? - define the altimeter accuracy requirements) and • transmission errors • resolution

Table 5: Accuracy Parameter Definitions

4.2.1 Accuracy horizontal position components for comparison

Although radar errors are quantified in range and azimuth dimensions, in practice the azimuth errors are of most significance, firstly because azimuth is more problematic for a radar to measure than range and secondly, because azimuth errors are magnified by range in projected plan position. [Azimuth errors are sometime referred to as 'cross range' errors when projected in plan]. The error distribution is considered to have the following components:

1. Core errors
2. Tail errors
3. Systematic biases

The core errors are typically due to the inherent accuracy limits in the particular radar sensor (such as receiver signal to noise, quantisation, interrogation rate, beam shape). Typically, the core errors for a particular type of radar are well known and relatively easy to measure. The radar measurement performance is usually expressed as a standard deviation (σ) from the mean. The distribution of core errors is generally Gaussian in shape within the 2σ bounds.

Tail errors are the larger errors (sometimes called outliers or jumps). They are typically caused by various local radar site factors (such as local multi-path, diffraction, multiple target resolution). Furthermore, the tail errors are often highly correlated for the same target from scan to scan.

Generally, the numbers of errors in the tails are much higher than would be expected theoretically by the standard deviation of the core Gaussian distribution. Consequently, the overall radar error distribution of azimuth measurement ‘a’ is sometimes described by a double distribution function:

$$Pe(a) = (1-\alpha)\, Pc(a) + \alpha Pt(a)$$

Where:
Pc(a) is the core error distribution
Pt(a) is the tail error distribution
α is a weighting factor.

The error distribution function is critical to the technical assessment of radar separation minima, using the method as described in the ICAO manual for the determination of separation minimum [Reference 5, Appendix 6]. The method uses the error distribution function to calculate the probability that an aircraft pair will actually overlap when their apparent radar separation is equal to the radar separation minimum (i.e. the collision risk). Further studies into the collision risk using various error distributions can be found in Reference 6.

Note that the radar error distribution for this assessment is assumed for **no fault** conditions (i.e. radar in nominal operation). The errors (and particularly the tails) are considered to be an inherent part of the nominal characteristics of the radar. [See how they are related to integrity risk in section 4.3].

Radar systematic biases will cause a common offset in position for all targets seen by the same radar. However, for the comparative assessment, we assume the best-case radar separation situation of two targets seen by the same radar. Hence, all radar systematic biases are discounted.

4.3 Integrity

4.3.1 Integrity issues concerning radar and ADS-B surveillance.

Integrity concerns the level of trust in a particular piece of information and specifically concerns the likelihood of errors beyond a certain magnitude being detected.

The integrity of the surveillance information from radar and ADS-B is to be compared at the input of the ATC processing function. At this point the resultant integrity of the surveillance information is determined from the series of:

a. The integrity of the on-board avionics sources (including external navigation sources).
b. The integrity of the data link to the sensor system.
c. The integrity of the processing in the sensor (such as radar signal processing).
d. The integrity of the data link from the sensor to the ATC processing system.

Obviously, the contributions to integrity from (a), (b) and (c) above will differ between radar and ADS-B, whilst the contribution from (d) is assumed to be the same for both.

ADS-B is expected to have integrity monitoring of the navigational sources, so that the reported aircraft horizontal position will be qualified by a level of integrity, as well as a level of accuracy [i.e. the ADS-B quality indicators – individual aircraft].

In contrast, the overall integrity of radar systems is not generally quantified. It is usually expected that combinations of various internal self-tests and external monitoring methods will ensure, with very high integrity, that the radar equipment is working properly (or otherwise a fault is detected quickly). Whilst the radar is declared to be in a fault free operation, then there is no other error detection (or integrity values) in the radar plot measurements provided to the ATC system. Hence, in fault free operation, radar plot position errors of any magnitude are all passed as undetected errors and the likelihood of an error being beyond a certain magnitude is entirely determined from the radar error distribution function (see radar accuracy in 4.2.1).

For separation purposes, the collision risk from the misrepresentation of surveillance position information may be expressed as:

Risk from surveillance position error = Fn (Accuracy) + Fn (fault detection limits)

Since the integrity of radar cannot be quantified, we assume for comparison that it is always working in a fault-free condition, i.e. *Fn (fault detection limits)* = 0 for radar.

For ADS-B, *Fn (fault detection limits)* is not zero and it will depend upon the integrity checking capability of the navigational position. In practice, it is expected that the probability of an undetected position error outside a certain magnitude (i.e. containment radius) is quantified by an integrity level indicated by the ADS-B quality indicators (individual aircraft). Consequently, the surveillance risk from ADS-B integrity limits [i.e. *Fn (fault detection limits)*] can be determined.

Hence, if the bounds of the ADS-B integrity containment radius is better than radar's *Fn(Accuracy)*, then the collision risk of ADS-B surveillance position may be assumed to be no worse than that of radar. The method of doing the comparison is detailed in Reference 6.

In this OPA, the tails of the radar accuracy distribution are given in terms of the likelihoods of undetected position errors beyond magnitudes (i.e. containment radii) of 0.5, 1 and 2NM for comparison with ADS-B surveillance integrity level thresholds.

Performance parameter definitions: integrity	
Term	**Definition**
Integrity	The integrity is usually expressed in terms of the probability that an error larger than a certain threshold in the information is undetected (i.e. alerted) for more than a time to alert threshold.
Integrity Horizontal position	The probability that the surveillance horizontal position error is outside a given distance (containment radius) for a given duration (time to alert) without alert. For radar: Integrity is not quantified directly, but is expressed with respect to the nominal error distribution function (see 4.3.1). For ADS-B, the proposed definition can be used directly.
Integrity Vertical Position	The probability that the surveillance vertical position error at the ATC processing level is outside a given vertical distance, without alert. Therefore, integrity vertical position depends on: a) Altimeter integrity (Avionics standard, i.e. the specified barometric altimeter accuracy requirements). b) The integrity of the data link to the sensor system c) The integrity of the processing in the sensor (such as radar signal processing) For both radar and ADS-B, (a) is assumed to be the same. For radar The resultant of B and C can be described by the probability of a validated Mode C error in a SSR plot report. For ADS-B The resultant of B and C for comparison is the probability of the vertical position being transmitted or decoded incorrectly.
Integrity Identification	The probability of the identification information being incorrect and not alerted. Therefore, integrity identification depends on a) Integrity of a/c setting b) Integrity of the data link to the sensor system. c) Integrity of the processing in the sensor (such as radar signal processing) For both radar and ADS-B, (a) is assumed to be the same. For radar The resultant of (b) and (c) can be described by the probability of a validated Mode A error in a SSR plot report. For ADS-B The resultant of (b) and (c) for comparison is the probability of the operational identity being transmitted or decoded incorrectly.

Performance parameter definitions: integrity	
Term	**Definition**
Integrity SPI :	This concerns an additional method of identification, usually activated by the pilot under instructions from ATC for the purposes of further confirmation of identification or to recognise an unidentified aircraft on the surveillance picture. The SPI is also required to acknowledge R/T instructions in the case of aircraft R/T transmitter failure (and not receiver failure). For radar: same integrity as for SSR mode A codes For ADS-B: same integrity as for the operational identity.
Integrity on Emergency indicators	This concerns the ability to detect correct aircraft emergency information For radar: same integrity as for SSR mode A codes For ADS-B: same integrity as for the operational identity.
Integrity on the Object of Interest (i.e. false target rate)	Probability of occurrence of false target reports. A false report does not represent a real aircraft. For radar: False SSR target reports are caused by various reasons (FRUIT, reflections, side-lobes etc). The maximum rate of such reports from the reference radar, expressed as a proportion of targets reports, is used for comparison. For ADS-B: In principle, false ADS-B reports could be caused by undetected corruption of ADS-B messages (albeit very unlikely). Note: as indicated in section 2.1, false reports due to malicious interference are outside the scope of the expected ADS-B performance.

Table 6: Integrity Parameter Definitions

4.4 Reliability

Performance parameter definitions: reliability	
Term	**Definition**
Availability	The probability of a system to perform its required function at the initiation of the intended operation. It is quantified as the proportion of the time the system is actually available to the time the system is planned to be available. Periods of planned unavailability (i.e. maintenance) are taken into account of separately Overall availability is composed of • the availability of functions affecting all a/c (e.g. external positioning function, ground data acquisition function) : • the availability of system affecting only one a/c (e.g. transponding function): expressed per flight hour.
Continuity	The probability of a system to perform its required function without interruption, assuming that the system is available when the procedure is initiated. Overall continuity is composed of • the continuity of functions affecting all a/c (e.g. satellite function, ground data acquisition function): expressed in a number of disruption per year. • the continuity of system affecting only one a/c (e.g. transponding function): expressed per flight hour.

Table 7: Reliability Parameter Definitions

4.5 Other Surveillance parameter definitions

Performance parameter definitions: other items	
Term	**Definition**
Capacity	Capacity 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 or azimuth sector. The capacity figures do not necessarily imply the processing capability of a single sensor, since the overall capacity may be achieved by a number of sensors distributed geographically.
Coverage	The geographical volume in which all the service surveillance attributes can be provided. Coverage of ADS-B will depend upon the detection range and locations of ground sensors. In practice, the required coverage will be determined by local operational environment and will require confirmation by flight trials.
False information due to interference	**False information due to interference** (either intentional or accidental): In radar systems, interference may produce many random false plots. However, it is difficult to introduce a false sequence of target reports that would appear to be from a real aircraft. In comparison, it is more possible for aircraft-like ADS-B messages to be introduced intentionally (i.e. spoofing). However, as indicated in section 2.1, the performance of ADS-B against interference is considered to be outside the scope of this OPA.
Latency	The age of the measured or sampled surveillance information when it is received at the point of use (in our case, for a surveillance report at the input of the ATC processing system). This may be quantified in terms of a probability of the age of a report being no longer than a certain time, or in terms of a maximum age for any report. Latency is particularly of significance to the use of position and barometric altitude information.
Accuracy Time stamp	This is the accuracy to which the time of measurement is determined (by time information in the message or by timing in the detection system) For radar, this will depend upon the time stamping accuracy of the received radar returns and the method of time synchronisation with the user system. For ADS-B, this will depend upon the on-board sampling rate and the time stamping of ADS-B messages at the reception by the ground system. Note, a time stamping inaccuracy in position will be seen as degradation in the position accuracy.

Table 8: Other parameter Definitions

4.6 Definition of performance parameters related to the transition from nominal to non-nominal mode of operation

Definitions to be revisited w.r.t. the updated OHA

Performance parameter definitions: parameter relating to transition	
Term	**Definition**
Loss of nominal service detection time	This concerns the time to automatically recognise that the surveillance service is deficient in some significant attribute in order to trigger transition to the non-nominal mode of operation. Hence, it not only concerns the complete failure of a sensor, but also concerns the detection of other possible degradation (e.g. loss of expected coverage). In radar, this may be accomplished by various self-test methods, including monitoring of known targets (i.e. site monitors or ‘parrots’). In ADS-B, this may also include various integrity monitoring (e.g. RAIM at airborne level or ground monitoring of the GNSS satellite constellation).
Max Transition rate	Max acceptable rate of transition from nominal mode of operation to non-nominal mode of operation (e.g. transition from radar-like separation to procedural) – unplanned loss of service

5 PERFORMANCE REQUIREMENTS AT THE INPUT OF THE “ATC PROCESSING SYSTEM”

This section addresses the required performances for the following groups of surveillance parameters:

- Update interval and update probability
- Accuracy
- Integrity
- Reliability
- Other surveillance parameter definitions
- Parameters relating to the transition from nominal mode of operation to non-nominal mode of operation

Performances expressed in the following tables are required to be reached for maximum Capacity figures as expressed in Table 13: Other performance Requirements.

Performance figures are subdivided into **TMA** and **En-route** cases, where it is generally assumed that the most demanding case of **3NM** and **5NM** separation minima respectively will apply.

5.1 Update interval and update probability Requirements

Update interval and update probability Requirements	Value (En-route)	Value (TMA)
Update interval		
Radar systems: Update interval (all items) = radar scan period	≤10 s	≤5 s
ADS-B systems: Update interval for: 1. Position report (equivalent to a radar scan) 2. Identity report (acquisition time)* 3. Emergency/SPI report * Acceptable acquisition time assumed to be the equivalent of two radar scans	≤10 s ≤20 s ≤10 s	≤5 s ≤10 s ≤5 s
Update probability		
Reference radar: - Target report (with at least lateral position): - Mode A code validation (per target report) - Mode C code validation (per target report) - Emergency/SPI code validation (same as for Mode A code validation)	> 0.97 > 0.98 > 0.96 > 0.98	> 0.97 > 0.98 > 0.96 > 0.98
ADS-B systems: Probability of update for 1. Position report (same as for radar target) 2. Identity report 3. Emergency report Note: different update intervals for each type of ADS-B report are specified above.	> 0.97 > 0.95 > 0.95	> 0.97 > 0.95 > 0.95

Table 9: Update interval and update probability Requirements

5.2 Accuracy Requirements

Accuracy Requirements	Value (En-route)	Value (TMA)
Accuracy Horizontal Position		
Reference radar system: *Core accuracy:* Described by the standard deviation (σa) value of the azimuth error distribution multiplied by the range of application of the separation minimum to give the plan position error distribution (σp): [These figures are representative of Monopulse SSR] - Azimuth error standard deviation (σa) - Range of applicability (for separation minimum) - Plan position error (σp)at range of applicability *Tail error distribution:* See Tables 10a and 10b	σa < 0.08 degrees 180 NM (5NM) σp < 465 m See Table 10a	σa < 0.08 degrees 60 NM (3NM) σp < 155 m See Table 10b
ADS-B system: Described by 95% bound in absolute plan position errors. Theses values are determined from the reference radar 2×σp errors at the range of applicability. - 95% bound (= 2σp of radar)	< 930 m	< 310 m
Accuracy Vertical Position		
Reference radar system: - Altimeter accuracy - Resolution in Mode C	Avionic standard ≤100 ft	Avionic standard ≤100 ft
ADS-B system	- Same as above	- Same as above

Table 10: accuracy performance Requirements

5.2.1 Tail error distribution

The tail error distribution is somewhat uncertain for the reference radar. In practice, the tail error distribution can be very variable from site to site and requires extensive analysis of large numbers of plot measurements to determine. However, some tail error distributions have been specified or modelled as conservative estimates as follows:

A. From the Eurocontrol Surveillance Standard specification, azimuth errors > 1° are assumed to be < 0.025% of plots [Reference 7]
B. The USA sliding window, best case assumption is that the core azimuth accuracy (of 0.23°) is continued in Gaussian fashion for all azimuth errors [Reference 6]
C. The USA sliding window model is widened in its tails by a double Gaussian distribution [Reference 6]
D. (other models?)

Reference radar error model	**Probability of position error exceeding**		
	0.5 NM	**1.0 NM**	**2.0 NM**
A. Eurocontrol Surveillance Standard	5.02×10^{-2}	2.69×10^{-3}	1.01×10^{-3}
B. USA, sliding window, best case	4.89×10^{-1}	1.66×10^{-1}	5.64×10^{-3}
C. USA, sliding window, widened	5.20×10^{-1}	2.05×10^{-1}	2.04×10^{-2}

Table 10a – Radar tail error distribution for En-route 5NM separation (at 180 NM applicability)

Reference radar error model	**Probability of position error exceeding**		
	0.5 NM	**1.0 NM**	**2.0 NM**
A. Eurocontrol Surveillance Standard (60 NM range of applicability)	1.69×10^{-3}	2.81×10^{-4}	6.68×10^{-7}
B. USA, sliding window, best case (40 NM range of applicability)	1.85×10^{-3}	4.73×10^{-10}	1.30×10^{-35}
C. USA, sliding window, widened (40 NM range of applicability)	1.15×10^{-2}	2.88×10^{-5}	1.02×10^{-14}

Table 10b – Radar tail error distribution for TMA 3NM separation

5.3 Integrity Requirements

Integrity Requirements	Value (En-route)	Value (TMA)
Integrity Horizontal Position		
Reference radar system: Not directly specified, but risk of surveillance position error can be described accuracy performance, see sections 4.3.1 and 5.2.1	See tail accuracy Table 10a	See tail accuracy Table 10b
ADS-B System: Integrity of navigational position is provided in quality indicators. See sections 4.3.1 and 5.2.1 of how this can be compared with radar risk of surveillance position error.	See Table 10a	See Table 10b
Time to alert for detection of integrity loss (Comparison is two radar scans)	<20 s	<10s
Integrity Vertical Position		
Reference radar: - Altimeter source integrity - Probability of incorrect Mode C validation	Avionic standard <0.001	Avionic standard <0.001
ADS-B system: - Altimeter source integrity - Probability of incorrect height information (i.e. different to altimeter source) based on radar Mode C validation comparison.	Avionic standard <0.001	Avionic standard <0.001
Integrity Identification		
Reference radar: - Mode A source integrity - Probability of incorrect Mode A validation - Probability of incorrect SPI - Probability of incorrect Emergency codes	Avionic standard <0.001 as for Mode A as for mode A	Avionic standard <0.001 as for Mode A as for mode A
ADS-B system: - Identity source integrity (includes flight identity, address, as well as Mode A setting) - Probability of incorrect identity information (i.e. different to identity source) based on radar Mode A validation comparison - Probability of incorrect SPI - Probability of incorrect emergency codes	At least as good as SSR Mode A <0.001 as for identity as for identity	At least as good as SSR Mode A <0.001 as for identity as for identity
Integrity Object of Interest (False Target Rate)		
Reference radar: - False target to real report ratio [Figure from Eurocontrol SSR radar standard – ref7]	< 0.001	< 0.001
ADS-B system: - False target to real report ratio	< 0.001	< 0.001

Table 11: integrity performance Requirements

5.4 Reliability Requirements

5.4.1 Special Considerations

Reliability (i.e. Availability and Continuity) of ground systems will depend upon various equipment and environment factors such as the amount of equipment redundancy, local site conditions, accessibility etc. Whilst reliability of ground systems can be improved by increased expenditure on equipment and maintenance infrastructure, there are of course cost effectiveness considerations to be made by the local ATS administration. In particular, the consequences of loss of service with respect to the traffic levels in the region will be important considerations. Hence, the reliability of ground systems is really a local issue. Some figures are included for typical radars for information only.

The reliability of the on-board "ADS-B out" and the avionics equipment supplying the ADS-B information (excluding navigation sources) is expected to be similar to present SSR transponders and the sources of Mode A/C on the same type of aircraft.

Furthermore, in ADS-B, the reliability of the external navigation sources is also to be considered, in particular the GNSS satellite sources. The reliability not only concerns complete failure (however unlikely) but also the occasions where the quality of the information may fall below that required for a certain separation (e.g. when numbers of satellites and their geometry is unfavourable). These conditions may affect all or a substantial proportion of aircraft in the locality and the likelihood of occurrence has to be considered with respect to the local ATC environment. However, it is possible to predict when satellite conditions will be unfavourable and this might be used as mitigation against the loss of availability (i.e. the outages become planned).

Reliability Requirements	Value (En-route)	Value (TMA)
Availability all a/c		
Reference radar system - Single radar availability (figures for information only)	≥0.997	≥0.999
ADS-B system - Ground data acquisition function - External airborne navigational sources.	Local issues (see 5.4.1) ≥0.997 (unscheduled)	Local issues (see 5.4.1) ≥0.999 (unscheduled)
Availability single a/c		
Reference radar system: SSR mode A/C transponding function - Civil commercial aircraft - General aviation	≥10000 h MTBF ≥3000 h MTBF (figures to be confirmed)	≥10000 h MTBF ≥3000 h MTBF
ADS-B system: - ADS-B out transponding function - Avionics availability affecting only this a/c	As for radar	As for radar
Continuity all a/c		
Reference radar system - Unscheduled disruptions (failures of radar) - Continuity probability per hour	≤ 3 per year >0.999	≤ 3 per year >0.999
ADS-B system (including ground data acquisition function + airborne external data source function) - Unscheduled disruptions (failures of ground data	Local issues (see 5.4.1)	Local issues (see 5.4.1)

acquisition function + failures and degradations of airborne external navigational data sources) Planned outage - Continuity probability per hour		
Continuity single a/c		
Reference radar system - Continuity of SSR mode A/C transponding system	0.9999 per flight hour ? Check with SM	0.9999 per flight hour ?
ADS-B system - Continuity of ADS-B out function - Continuity of avionics positional sources (affecting only this a/c)	Equivalent or better than above (transponding part)	As above? tbd

Table 12: Reliability performance Requirements

5.5 Other Parameter Requirements

Surveillance Performance Parameter (at the surveillance report level)	Value (En-route)	Value (TMA)
Latency		
Reference radar system - Maximum age for any report	2 s	2 s ? tbc Peter (Stan)
ADS-B system - Maximum age for any report	2 s	2 s
Time Stamp		
Reference radar system - Max Time accuracy of position measurement (range and azimuth measurement)	0.2 s	0.2 s
ADS-B system - Max Time accuracy of sampled position (including airborne transmission and ground receiving system timing).	0.2s	0.2 s
Capacity		
Capacity refers to the ADS-B-NRA Environment Description (ref 2)		
Reference radar system - Total load (max number of a/c)	150 a/c	50 a/c
ADS-B system	Same as above	Same as above

Table 13: Other performance Requirements

5.6 Requirements related to transition from nominal to the non-nominal mode of operation

Transition from nominal to non-nominal conditions relate to the surveillance system and are limited to it. **It does not cover the controller reaction time that is assumed to be the same as for the radar case.**

To be discussed w.r.t. the list of hazards identified in the OHA 0.8.

6 REQUIREMENT BREAKDOWN BETWEEN GROUND AND AIRBORNE SEGMENTS

To be completed.

7 REQUIRED DATA ITEMS AT AIRBORNE LEVEL

7.1 Detailed data item Requirements at the output of the "ADS-B Transmit function"

To be completed.

7.2 ADS-B Data Item Resolution and Range Characteristics Requirements at the output of the "ADS-B Transmit function"

To be completed.

8 PERFORMANCE REQUIREMENTS AT THE OUTPUT OF THE "ADS-B TRANSMIT FUNCTION"

To be completed.

1. ANNEX A - CONSIDERATION OF ADS-B-NRA OSED

<u>**Warning**</u>: this section **Error! Reference source not found.** relates to the OSED and the data items are expressed <u>at controller level</u>. In the rest of the chapter 3, data items are expressed at the input of the "ATC Processing System" level.

ADS-B-NRA Application Description (reference v1.2g), section 8.3 requires the following **initial list** of data items – text extracted –

"The following list of surveillance parameters are required <u>by the controller</u> for ADS-B-NRA:

- *Operational identity;*
- *Position*
- *Barometric Altitude*
- *Indication of the quality of ADS information (in particular, to indicate whether it is good enough for certain separation purposes).*
- *In some environments, where partial radar coverage exists, an indication of whether the track is supported by radar and/or ADS may be required (to be discussed…)*

- *An emergency indicator** [10]
- *SPI* *[11]
- *Ground velocity (see below* [12]*)*

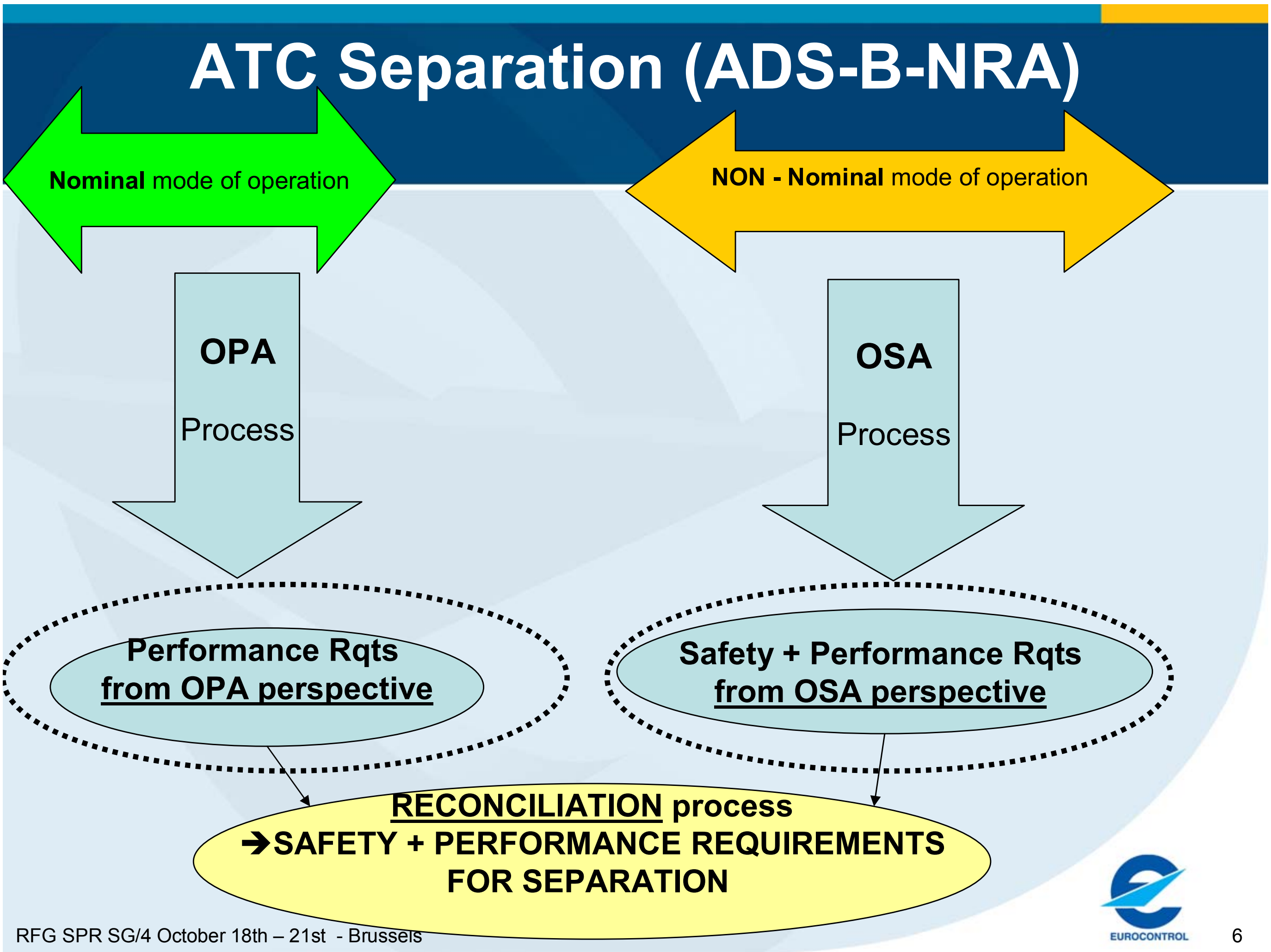
[ADS-B-NRA Application Description and in particular the list of data items, will be updated once the SPR work is completed].

10 * The provision of this information may be optional for some low capability aircraft fits that may be appropriate to certain local environments.

11 The provision of this information may be optional for some low capability aircraft fits that may be appropriate to certain local environments.

12 Ground velocity may be provided directly by ADS-B or determined by the ground system from tracking of surveillance positions. If ground velocity is provided by ADS-B, it should be at least as good as velocity determined from radar positions. Otherwise, there are no further requirements expressed for velocity in this OPA.

2. ANNEX B – OPA/OSA RECONCILIATION PROCESS



Package I Requirements Focus Group
Application Definition Sub-group

Package I

ATC Surveillance for
Non-radar Areas
(ADS-B-NRA)

Application Description

Edition	:	1.2.g
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Document Change Record

The following table records the complete history of the successive editions of the present document.

EDITION	DATE	REASON FOR CHANGE	SECTIONS PAGES AFFECTED
1.0.a	13-Feb-2004	RFG Baseline Version	ALL
1.1.a	30-April-2004	Response to 1.0a comments	ALL
1.1.b	14-May-2004	Response to 1.1a comments	ALL
1.1.c	7-June-2004	Response to 1.1b comments	various
1.1.d	16-July-2004	Response to 1.1c comments and discussions at RFG meeting in Toulouse. Replacement of Phase diagrams with v0.7 diagrams from Philippe Caisso Alignment with revisions of OSED environment descriptions.	Various
1.2	3-Dec-2004	Some simplifications of Phase diagrams following discussions about SPR issues and response to remaining comments	Various
1.2.b	15-Dec-2004	Further clarifications of Phase diagrams following comments from John Brown	Phase diagrams
1.2 g	24-January-2005	Processing of comments received + further clarification of phase diagrams following comments received	Phase diagrams

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Table of Contents

1. INTRODUCTION

The ADS-B-NRA application will apply to en-route and terminal phases of flight in airspace classes (A to G) where radar surveillance currently does not exist (note that radar area cases are covered by ADS-B-RAD).

Examples are remote, off-shore, oil rig and small island environments, which, due to the level of traffic, location or the cost of the equipment, could not justify the installation of radar. Also it will include areas where existing radar is to be de-commissioned and the replacement costs are not justified.

The ADS-B-NRA application is designed to enhance the following ICAO Air Traffic Services [Reference 1, chapters 3 to 5].

- Air Traffic Control Service and Flight Information Service principally for:
  - Operation of air traffic control service (chapter 3.3).
  - Separation minima (chapter 3.4)
  - Transfer of responsibility for control (chapter 3.6)
  - Air traffic control clearances (chapter 3.7)
  - Scope of flight information service (chapter 4.2)
- Alerting Service, principally for:
  - Notification of rescue co-ordination centres (chapter 5.2)
  - Plotting of aircraft in a state of emergency (chapter 5.4)

Note that the Air Traffic Services also include the provision of Air Traffic Advisory Services in advisory airspace.

The introduction of ADS-B will provide enhancements to these services (compared to current capabilities) in a similar way as would occur by the introduction of SSR radar, especially when (and where) many aircraft become ADS-B equipped. [The target state in many regions will be to have all aircraft equipped].

In particular, the Air Traffic Control Service will be enhanced by providing controllers with better situational awareness of aircraft positions and the possibility of applying separation minima much smaller than what is presently used with current procedures. The Alerting Service will be enhanced by more accurate information on the latest position of aircraft. Furthermore, ADS-B is able to broadcast emergency status information which will be displayed to the controller independently from any radio communications.

Hence, it is expected that this application will provide benefits to capacity, efficiency and safety in a similar way as could be achieved by the introduction of SSR radar.

Currently, air traffic management procedures in non-radar airspace are in accordance with those defined in ICAO Procedures for Air Navigation Services, Air Traffic Management [Reference 2 = PANS-ATM Document 4444], but of course excluding those procedures that specifically require radar surveillance. Hence, the intention of the ADS-B-NRA application is to allow the procedures using radar surveillance to be enabled by ADS-B, assuming that the quality of service of ADS-B surveillance is similar to (or better than) SSR radar and that appropriate air-ground communications coverage is available.

The approach to procedures taken in this document is to assume that PANS-ATM procedures using radar will be essentially unchanged by using ADS-B, but where there are some particular differences between ADS-B and radar that may affect the procedures, then these are indicated. This approach should also be applicable to any alternative source of surveillance data (e.g. surveillance from multi-lateration).

Whilst the role of the controller and pilot remain unchanged, there may be impact on their workloads because of new control procedures and the provision of enhanced services. [There is also the potential to increase traffic because of the capacity benefits of ADS-B surveillance]. On the other hand, there may be some reduction in workload because of lessened need for voice position reports, since the aircraft parameters will be broadcast and received automatically via ADS-B. The flight crews may interface to the ADS-B transmitter in a similar way to that of a SSR transponder.

This application is not complex. It is very mature. The challenge is the demonstration and validation of the separation service with the target architecture (Safety Case).

2. CONTEXT

Currently, air traffic services within non-radar airspace are based upon procedural methods. Because the knowledge of the position of the aircraft is not as accurate as that provided in radar controlled airspace then separation is typically much larger. Furthermore, the provision of traffic information, traffic advisory or alerting information is limited.

The ADS-B-NRA environment is described in Annex B of the general Operational Services and Environment Definition [Reference 3], but some aspects of this are further highlighted below.

Target application:

- Will apply to airspace classes (A to G) where radar surveillance currently does not exist (note that radar areas cases are covered by ADS-B-RAD).
- Will apply to aircraft (in the general sense, e.g. including helicopters). Ground vehicles are not covered.
- Will include en-route and terminal phase of flight.

Minimum surveillance infrastructure:

- Ground: ADS-B Ground Data Acquisition, SDPD (Surveillance Data Processing & Distribution), CWP (Controller Working Position).
- Airborne: “ADS-B out”

Note that the SDPD system required for ADS-B processing may be very simple and could be limited to the reception, format conversion and distribution of ADS-B information to the CWP.

The provision of radar-like services to aircraft in a particular NRA will also depend upon the availability and coverage of appropriate air-ground communications. In particular, VHF coverage is important to maximise the air traffic service benefits from the introduction of ADS-B into the environment.

The possible enhancements of services will depend upon the proportion of aircraft with ADS-B equipage. The target environment will be to have all aircraft equipped.

3. OBJECTIVE

In terms of function, the objective of ADS-B-NRA is to provide radar-like services in non-radar airspace using ADS-B. This will significantly increase the controller's situational awareness of traffic in the air and enable the traffic to be handled in a more efficient way than today's procedures. These benefits will also serve as incentives for aircraft operators to equip, in turn leading to even wider ADS-B benefits. Hence, the objective will be to provide the following benefits:

Safety Benefits:

- Improved controller situational awareness provides controllers with better ability to recognise and resolve potentially unsafe situations.
- Improved monitoring of flights crossing sector or FIR boundaries (in particular to check proper co-ordination between centres).
- Automatic safety nets (such as STCA, MSAW, AIW etc) may be used to alert controllers to potentially hazardous situations.
- Automatic trajectory compliance monitoring tools may be used to inform controllers of deviations from an expected route or flight level.
- More precise traffic advisory and traffic information issued to flight crews.
- Improved quality of information for Alerting Services providing improved search and rescue response capabilities.

Capacity and Efficiency Benefits

- Reduction of the need for pilot position reports
- Likely reduction in separation minima (compared to procedural) for pairs of suitably equipped aircraft.
- Ability to use tactical manoeuvring (vectoring) to achieve more efficient traffic flow, particularly for crossing and merging traffic situations.
- Improved co-ordination and hand-over of flights crossing sector or FIR boundaries
- Enabler to improved operational flexibility (e.g. choice of routes, flight level etc.)
- Enabler to improved ability to support airline operational control through provision of surveillance data to airlines.

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Strategic benefits

- Enabler for flexible use of airspace and user preferred routes

Note that many of these benefits will apply to both controlled and uncontrolled airspace (as defined in Reference 3).

4. PROCEDURE DESCRIPTION

4.1 Current procedures

Current procedures are in accordance with those defined in Reference 2 (i.e. PANS-ATM Document 4444), but excluding those procedures that specifically require radar surveillance.

Essentially, ATS situational awareness for the management of air traffic is currently achieved by knowledge of flight plan information, updated by occasional positions reports from aircrew at designated reporting points or at agreed times (e.g. passing over way points, at sector hand-over).

Separation is achieved by the procedural methods (as described in Reference 2, Chapter 5). Most significantly, these procedures require substantial lateral distances or flight time margins to be imposed for aircraft on merging or crossing routes where their flight levels are the same or are crossing.

4.2 Proposed procedures

The ADS-B NRA application can provide the controllers with very similar facilities and control benefits to those available from SSR radar. Consequently, the intention is that the procedures using radar services (as described in Chapter 8 of Reference 2) will be enabled by ADS-B, assuming that the quality of service of ADS-B surveillance data is similar to (or better than) SSR radar and that air-ground communications (VHF) coverage is available.

Some parts of the current procedures in Reference 2 for SSR radar services will be affected (or modified slightly) by the introduction ADS-B based surveillance and these parts are addressed by the sub-sections below. Otherwise, the procedures and services will essentially be the same as can be done with SSR radar.

4.2.1 Radar system capabilities (Chapter 8.1)

ADS-B surveillance may be expected to provide similar (or better) levels of reliability, availability and integrity as SSR ground sensors and aircraft transponders.

However, the ADS-B position information is entirely dependent (as compared to SSR horizontal position measurement with aircraft dependent Mode C altitude) and its accuracy and integrity may vary between aircraft or vary with time for the same aircraft. Note also that the ADS-B transmissions are expected to be much less error prone than the SSR Mode A/C transmissions which may be corrupted in ‘garble’ situations. Furthermore, the ADS-B report provides some information about its expected accuracy and integrity (as determined by the aircraft equipment). This information should be used by the ground system to indicate to controllers whenever the ADS-B surveillance quality of particular aircraft or the ADS-B system as a whole falls below acceptable limits for particular purposes (e.g. for application of certain separation minima).

The ADS-B transmitter is not necessarily the same for all ADS-B aircraft – presently there are three different types of ADS-B data links (using different frequencies and formats). Hence, it is assumed that for effective use of ADS-B surveillance that either all aircraft are equipped with the same type of ADS-B transmitter or that ground sensors for each type exist and have similar coverage in the area of concern.

In some states, it is recognised that SSR Mode A code will be required in ADS-B reports for compatibility with existing radar and flight data processing systems (i.e. these systems require Mode A code for correlation with flight plans to obtain aircraft identification). However, ADS-B will also transmit the aircraft identification and also the aircraft address [see Reference 2, Appendix 2 for aircraft identification, registration and aircraft address]. Future systems should be capable of using the aircraft identification from ADS-B directly for display. Furthermore, the aircraft identification and/or aircraft address from ADS-B may be used for correlation with the flight plan.

ADS-B contains additional aircraft information (beyond that provided by SSR Mode A/C) and this may be used by the system to enhance the facilities available to controllers and also to enhance other automatic monitoring tools and safety nets.

4.2.2 Presentation of Radar Information (Chapter 8.2)

ADS-B surveillance information should be presented to the controller in a similar way to radar (assuming that the quality of service of ADS-B data is sufficient).

In some areas it may be appropriate to provide the controller with an indication that surveillance is based on ADS-B information. For example in an area that abuts a radar area.

4.2.3 Provision of Radar Services (Chapter 8.4)

The same services as are supported by SSR can be supported by ADS-B surveillance, providing that ADS-B surveillance quality and equipage are sufficiently high. Any ADS-B equipment failure or service degradation (including for individual aircraft) must be recognised so that reversion to non-radar procedures can be done safely.

Automatic functions, such as flight plan correlation, safety net and flight path monitoring can be enabled (and enhanced) by the availability of ADS-B surveillance.

4.2.4 Use of SSR Transponders (Chapter 8.5)

It is expected that the aircrew will interface to the ADS-B equipment in a similar way to a SSR (or Mode S) transponder. It is expected that the operating procedures for ADS-B equipment will be defined (in a similar way to PANS-OPS Document 8168).

It is desirable that the flight crew are able to check (and possibly change) the aircraft identification information set on board the aircraft and subsequently transmitted by the ADS-B equipment.

When the aircraft identification information received from the ADS-B system (as seen on the controller’s display), differs from that expected, procedures similar to dealing with a discrepancy in Mode A code or in Mode S aircraft identification shall apply.

Verification of the barometric flight level provided by ADS-B is expected to be the same as current verification procedures for use of SSR Mode C.

4.2.5 General Radar Procedures (Chapter 8.6)

Controller procedures for performance checks on the ADS-B surveillance data will be required, in a similar way to those specified for radar surveillance data. The system must provide the controller with indications of the working status of ADS-B ground sensors (including sensors of different link types). Furthermore, it is desirable to provide an indication of when the accuracy of ADS-B position reports is likely to be degraded by the deterioration of navigational sources (for example by ground monitoring the GNSS satellite state).

Aircraft identification and transfer of identification procedures for ADS-B will be done directly from the aircraft identification information sent in the ADS-B reports.

Vectoring of ADS-B aircraft by the controller may be expected to be done in a similar way to radar, although the heading information used by the controller will be air derived.

4.2.6 Use of Radar in the Air Traffic Control Services (Chapter 8.7)

Separation minima applied between ADS-B equipped aircraft will depend upon the ADS-B surveillance quality (in terms of accuracy, integrity and availability) in the particular environment. These factors need to be considered by the local ATS authority in determining the appropriate separation minima for the environment. It is anticipated that ADS-B surveillance will enable the use of separation minima much smaller than present procedural separation. Furthermore, where the quality of ADS-B surveillance is similar to, or better than radar, then similar separation minima may be appropriate. Moreover, in some circumstances, separation minima applied to ADS-B surveillance may be smaller than radar (e.g. in comparison with SSR from long range).

However, the possibility of the ADS-B surveillance accuracy of individual aircraft (as indicated by the accuracy and integrity information in the ADS-B report) falling below certain levels also needs to be considered in the separation procedures. In circumstances of degraded accuracy, separations should be increased or procedural separations applied.

The procedures described for transfer of radar control may require to be extended slightly, in particular to deal with transfer between a controller using only ADS-B surveillance and a controller using only radar surveillance (the controller may not have common surveillance information).

4.2.7 Emergencies, Hazards and Equipment Failures (Chapter 8.8)

In event of an aircraft reporting or appearing from the ADS-B surveillance information to be in an emergency situation, then the same emergency procedures as for radar control will apply. Emergency status indicators in the ADS-B report are expected to signify, as a minimum, the same emergency conditions as are presently signified by Mode A emergency codes (i.e. 7700 general emergency, 7600 communications failure and 7500 unlawful interference). Consequently, the emergency status indicators in ADS-B shall be used and displayed by the system in a similar way to present SSR Mode A emergency codes. Additional emergency status indicators may also be available in the ADS-B report (e.g. low fuel) and these may be displayed by the system.

Similar procedures as described for the failure of an aircraft transponder are required for the failure of the aircraft ADS-B transmitter in airspace where equipage is mandatory.

Procedures in the event of a complete failure of the ADS-B system will be similar to procedures for radar equipment failure. [Assuming that there is no radar coverage, as is the case for NRA by definition].

In situations where more than one ADS-B link type operation is supported, the complete failure of one of these links (but not the others) may also need to be considered.

4.2.8 Use of Radar in the Approach Control Service (Chapter 8.9)

ADS-B surveillance information may be used for approach control service functions in a similar way to a surveillance radar. However, the functions of a precision approach radar are considered to be out of the scope of this NRA application. Hence, the functions enabled by a surveillance radar (in particular for monitoring, separation, vectoring) may be enabled by ADS-B providing that the accuracy and integrity of the ADS-B surveillance is considered to be sufficient for each of these functions.

However, present radar approach control using primary radar has the capability of detecting all aircraft in the vicinity and this capability cannot be replaced by ADS-B surveillance unless all aircraft are equipped. The situation of any non-equipped aircraft has to be considered in the control procedures.

4.3 Partial Equipage

Although the objective in many regions will be to have all aircraft equipped to maximise benefits, it is recognised that when ADS-B-based ATC surveillance services are introduced, it may be some considerable time before all aircraft operating in that airspace are suitably equipped. Therefore it is vital, at local level, to devise a manner in which procedural and ADS-B traffic can co-exist safely whilst still allowing those aircraft which are suitably equipped to gain benefit from the new surveillance procedures. In some airspace environments, it may be appropriate to segregate equipped and non-equipped aircraft, for instance, to different geographical areas or by different flight levels.

Changes to routes, airspace boundaries and local procedures may be necessary to achieve efficient control of traffic in a particular environment.

In some airspace, priority may be given to equipped aircraft to provide economic benefits to those aircraft that equip and thereby encourage greater equipage for the benefit of all.

For all procedures, it would be the responsibility of the adjoining control agencies to ensure that appropriately equipped aircraft were sent to the appropriate entry points with the correct separation in place before transfer of control took place. This would be done, of course, in co-ordination with the receiving controller.

4.4 Operational examples

The examples illustrate how, at a local level, operations using ADS-B surveillance may be implemented, in particular to deal with partial equipage. Firstly, an operational example of the procedures used with ADS-B surveillance in the Kiruna environment is given in Appendix A. In this environment, it was appropriate to segregate certain parts of the airspace as being only available to ADS-B equipped aircraft. In contrast, the Australian example of a mixed environment where segregation of equipped and non-equipped aircraft is not necessary is given in Appendix B.

4.5 Roles and responsibilities

There are no fundamental changes in the roles and responsibilities of the aircrew or controllers. The controller remains responsible for the management of the airspace, maintaining separation and providing information to aircrews, whilst the aircrews are responsible for acting upon ATC instructions and providing information to ATC.

However, there may be impact on controller and aircrew workloads because of the possible new control procedures and the provision of enhanced services. [There is also the potential to increase traffic because of the capacity benefits of ADS-B surveillance, but this is not considered as being part of the current definition for this application]. On the other hand, there will be some reduction in workload because of the lessened need for voice position reports, since the aircraft parameters will be broadcast and received automatically by ADS.

4.6 Impact on Phraseology

It is anticipated that phraseology for aircraft in ADS-B surveillance should be very similar to that used today in radar surveillance services. The phraseology may need to be changed slightly for the new information source, e.g. it may be appropriate to change “Radar contact” to “ADS contact”. However, the detailed changes of phraseology are outside the scope of this document and will be subject to validation and ICAO standardisation.

It is anticipated that voice for procedural reporting of position will be reduced.

5. AIRSPACE CHARACTERISTICS AND OPERATIONAL ENVIRONMENT

5.1 General

The generic airspace characteristics and operational environment are described in Annex B of the general Operational Services and Environment Definition [Reference 3]. The sub-sections below highlight the aspects of the airspace characteristics and operational environment that are of particular significance to the ADS-B-NRA application.

5.2 Surveillance Environment

Figure 1 below illustrates the surveillance environment for the application of ADS-B in a non-radar environment.

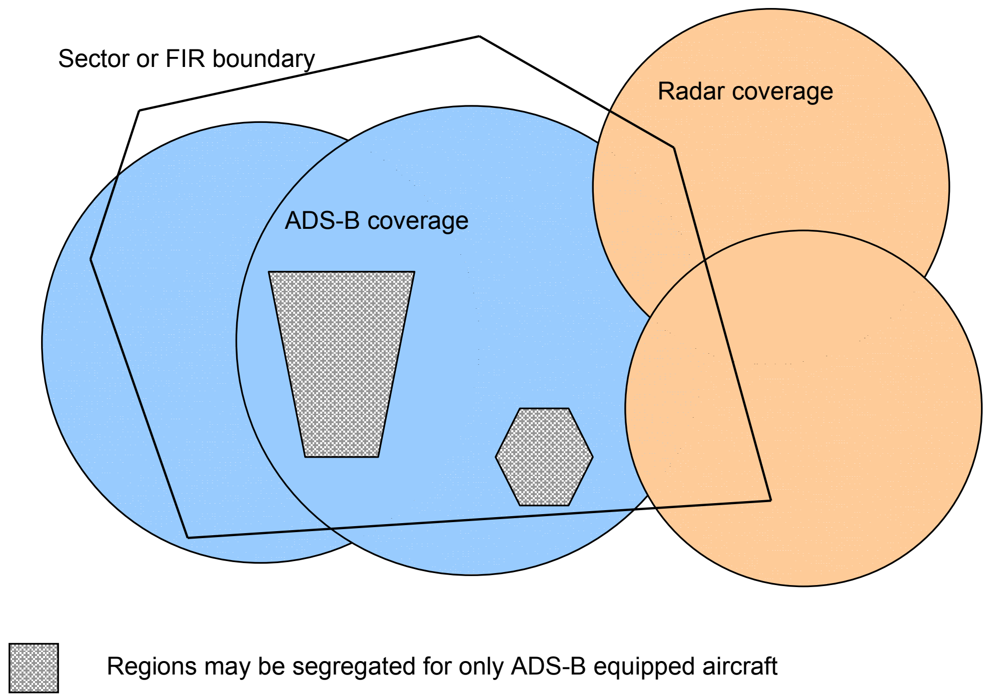

Figure 1. ADS-B in non-radar environment

The environment will contain ADS-B ground sensors to provide surveillance of ADS-B equipped aircraft. If more than one type of ADS-B data link is to be supported, then ground sensors for each type will be required. However ADS-B coverage of the entire sector may not be complete.

In some areas there may be sufficient overlapping coverage of ADS-B sensors to provide multi-lateration measurements of certain types of ADS-B transmitters and also for non-ADS-B equipped aircraft with SSR transponders. The use of multi-lateration may provide additional integrity checks on ADS-B positions and also may enhance some services involving non-ADS-B equipped aircraft in the transition period.

Some parts of the sector may have limited radar coverage and in some places this may overlap with ADS-B cover.

Although in many regions the objective is to have all aircraft ADS-B equipped in the longer term, there may be a mixture of ADS-B equipped and non-equipped aircraft in the shorter term.

In some local environments, it may be most appropriate to segregate regions of airspace for ADS-B only equipped aircraft in a similar way to the present mandatory carriage of SSR transponders is required in many regions of managed radar airspace (such as in the example of Appendix A).

5.3 Ground-Air Communications Environment

Usually, the environment will have ground-air coverage from VHF/HF communications and possibly some form of data link, although these might only partially cover the environment. Clearly, to gain the full control benefits from the introduction of ADS-B into the environment, it would be sensible to maximise the VHF coverage of the environment as well.

5.4 Control in different regions of the environment

The most efficient tactical control of aircraft can be achieved when all aircraft in an airspace are equipped.

In airspace with mixed equipage, the baseline will be procedural separation (as in the present NRA environment). However, in circumstances where two or more ADS-B equipped are seen in the mixed environment then radar-like surveillance separations may be applied between them to achieve more efficient use of the airspace. [There may be non-equipped aircraft in the vicinity – but at procedurally non-conflicting separations or flight levels].

5.5 Adjacent Sector Environment

The transfer of ADS-B equipped traffic between the sector of interest and the adjacent sector is of significance to the control procedures and separation of traffic crossing the sector boundaries. This will depend upon the surveillance environment of the adjacent sector at the boundary. Whilst the sector of interest (i.e. the present NRA where ADS-B surveillance is introduced) has aircraft under ADS-B surveillance at the boundary, the adjacent sector may have any of the following surveillance cases:

1. *No radar, no ADS-B*: The adjacent sector does not have any ADS-B sensors of its own or ADS-B data is not shared.
2. *ADS-B, no radar*: The adjacent sector is in the same surveillance situation as the sector of interest.
3. *Radar, no ADS-B*: The adjacent sector is using radar control (typically ACC or TMA) but it has no view of the ADS-B data (and hence may not know which aircraft are ADS-B equipped). Furthermore, the sector of interest might not share the same radar data.
4. *ADS-B, radar*: The adjacent sector can see the same ADS-B traffic as the sector of interest at the boundary and furthermore has them under its own radar surveillance. However, the sector of interest does not necessarily share the same radar data.

Further considerations of the procedures for intra and inter sector interfaces is presented in Section 6.2.

6. ADS-B CONTROL PHASES AND TRANSITIONS

6.1 Introduction

The control phases presented below concern the use of ADS-B surveillance to support Air Traffic Control (Separation based on ADS-B) and Alerting Services activities (applicable in airspace classes A to E). The Flight Information Services (including traffic advisories) are not represented by phase diagrams because they are considered to be much less critical for safety and performance requirements.

The detailed phase diagrams are contained in Appendix C, but the table below summarises the six phases used in the diagrams and relates the activities involved in each phase to existing PANS-ATM radar services.

Phases of operations	Handling of ADS-B equipped traffic
Phase 1 – ADS-B Data Acquisition	The aircraft transmits ADS-B messages. The ground processing receives and validates the ADS-B information. (similar to radar system capabilities in PANS-ATM 8.1)
Phase 2 – Initiation of ABS-D based Services	The ADS-B track automatically appears on the controller's surveillance display. (similar to presentation of radar information in PANS-ATM 8.2) Direct pilot-controller communications established (PANS-ATM 8.3.2) The flight crew receives contact from the ATC to establish ADS-B identification (similar to establishment of radar identification in PANS-ATM 8.6.2) Flight plan association of the ADS-B track is established.
Phase 3 – Provision of ADS-B based separation services	Monitoring of the ADS-B traffic on the surveillance display and applying (radar-like) control procedures similar to PANS-ATM Chapter 8 procedures, in particular for: - ATC service functions (like in 8.4 & 8.7.1) - Co-ordination of equipped and non-equipped traffic (like in 8.7.2) - Separation application (like in 8.7.3 and 8.7.4) - Vectoring (like in 8.6.5 & 8.9) - Radar monitoring [The provision of services requiring appropriate quality of surveillance information (like in 8.1.7)]
Phase 4 – System alerting	System alerting procedures are similar to those define in PANS-ATM procedures for radar emergencies, hazards and equipment failures (Chapter 8.8), in particular for: - Aircraft Emergencies (like in 8.8.1), - Failure of equipment (like in 8.8.3), with 'ADS-B out' failure requiring similar action as for SSR transponder failure - ADS-B equipment failure (like radar equipment failure in 8.8.4)
Phase 5 – Exceptional termination of ADS-B based Service (due to various possible degradations of ADS-B surveillance).	ADS-B Separation can no be longer be applied The controller applies procedural separation.
Phase 6 – Normal termination of ADS-B based Service through transfer	Transfer is co-ordinated with the adjacent sector (or aerodrome). Control procedures similar to PANS-ATM chapter 8: - Co-ordination of traffic (like in 8.7.2) - Transfer of control (like in 8.7.5)

Table 1: Phases for ADS-B based surveillance services

6.2 Transitions between the different types of airspace

This section describes the actions to be performed by the ATS and the flight crew on the following types of transfer:

- Intra-sector transfers when the ADS-B equipped aircraft remains in the same sector of control, but the airspace surveillance varies during the flight
- Inter-sector transfers when the ADS-B equipped aircraft sector crosses a sector boundary of an adjacent sector.

The foreseen actions are summarised in the tables below.

Previous area	Current area No ADS-B coverage	ADS-B coverage (of ADS-B equipped aircraft)	Radar coverage (of all aircraft of concern)
No ADS-B coverage		The ADS-B identification is performed between the ATS and the flight crew. The aircrew is informed of whether or not to continue to send voice position reports. On-going ADS-B surveillance is started.	Radar contact and radar control is established in the same way as present day radar procedures.
ADS-B coverage	The controller informs the aircraft that he is no longer under ADS-B control, and request for positions reports. The controller applies the procedural separation.		Assuming that there is some overlap of the radar and ADS-B coverage at this point, and that the controller is able to see a combined ADS-B and radar surveillance picture, there should be a smooth transition without any need for any specific controller or flight crew action. ATS will have previously informed the flight crew of the required SSR Mode A code before entering radar cover.
Radar coverage	The same as present day procedures. The controller informs the aircraft that he is no longer under radar control, and requests for position reports. .	Assuming that there is some overlap of the radar and ADS-B coverage at this point, and that the controller is able to see a combined ADS-B and radar surveillance picture, there should be a smooth transition without any need for any specific controller or flight crew action. The controller will know which aircraft are ADS-B equipped and ensure appropriate separation is achieved before leaving radar coverage	

Table 2 the Intra-sector transfers: the ADS-B equipped aircraft remains in the same sector of control, but the airspace coverage varies during the flight

Current Sector	Receiving sector			
	No ADS-B or radar coverage	ADS-B coverage (but no radar coverage)	Radar coverage (but no ADS-B coverage)	Radar and ADS-B coverage
No ADS-B or radar coverage	Procedure for both sectors is the same as present day for two NRAs.	Procedure for current sector is the same as today. The receiving sector establishes ADS-B identification and specifies if the flight crew will have to continue to send voice position reports.	Procedure for both sectors is the same as present day for transfer from NRA to ACC or TMA.	Procedure for both sectors is the same as present day for transfer from NRA to ACC or TMA.
ADS-B coverage (no radar)	Procedure for both sectors is the same as present day for two NRAs.	Procedure for ADS-B equipped aircraft should be similar to present day radar transfer between sectors.	Baseline procedure could be the same as for present day procedural transfers between NRA and ACC or TMA but separations of ADS-B equipped pairs could be reduced.	Procedure for ADS-B equipped aircraft should be similar to present day radar transfer between sectors.
Radar coverage (no ADS-B)	Procedure for both sectors is the same as present day for transfer from ACC or TMA to NRA	Baseline procedure could be the same as for present day procedural transfers between ACC or TMA and NRA, but separations of ADS-B equipped pairs could be reduced if aircraft ADS-B capability was known by current sector.	Procedure for both sectors is the same as present day for radar control transfers.	Procedure for both sectors is the same as present day for radar control transfers.
Radar and ADS-B coverage	Procedure for both sectors is the same as present day for transfer from ACC or TMA to NRA.	Procedure for ADS-B equipped aircraft should be similar to present day radar transfer between sectors. Both sectors are aware of ADS-B surveillance capability.	Procedure for both sectors is the same as present day for radar control transfers.	Procedure for both sectors is the same as present day for radar control transfers.

Table 3 Inter-sector transfers: the ADS-B equipped aircraft changes sector.

7. ABNORMAL MODES

The following abnormal modes may occur with ADS-B surveillance data:

1. Failure of the aircraft “ADS-B out” system for a particular aircraft. In this case, procedures will be similar to those used for the failure of a SSR transponder in SSR radar airspace.
2. Complete failure of the ADS-B ground receiving and processing system. In this case, procedures will be similar to those used for the complete loss of radar data in radar airspace.
3. Failure (or planned outage) of an ADS-B ground receiver, giving reduced coverage. Reversion to procedural control in the regions of no cover is required. Status monitoring of the ground receiver systems is required to detect when unexpected deterioration occurs. In this case, procedures will be similar to those used for the failure or planned outage of a radar sensor in radar airspace.
4. Degradation of all ADS-B data due to deterioration of navigational sources (particularly those using GNSS). The navigational accuracy in many ADS-B reports may fall below that required for radar-like separation. Increased or procedural separation will be required. [Note that ADS-B reported barometric flight level information is not affected by GNSS degradation]. Methods of monitoring ADS-system integrity on the ground are desirable to detect and predict when this condition is likely to occur. In this case, procedures could be similar to those used for degradation in performance of radar sensors in radar airspace.
5. Degradation of ADS-B accuracy from a particular aircraft (due to deterioration of that aircraft’s navigational sources). If the indicated position accuracy or integrity falls below a certain limit, then increased separation or procedural control should be applied between this aircraft and the surrounding traffic.
6. Corruption of ADS-B data from a particular aircraft (due to a fault in the aircraft equipment). The corruption could affect any of the ADS-B data fields. It may be necessary to have procedures to confirm the aircraft position when ADS-B contact is made and whenever the aircraft position appears to be inconsistent with its expected route. If corrupt ADS-B information is detected, then control of the aircraft will revert to procedural methods. It may also be helpful to have other ground monitoring checks on the credibility of ADS-B data to detect such anomalies. [The situation is similar to the corruption of Mode C flight level information provided by the aircraft in a SSR radar environment].
7. Degradation of the ADS-B surveillance picture due to intentional generation and broadcasting of false ADS-B targets (spoofing). A separate/independent means of validating ADS-B reports and appropriate procedures may be necessary to protect against such a hazard.

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8. REQUIREMENTS

8.1 General

The general requirements are indicated in Annex B of Reference 3. The sub-sections below highlight particular aspects of relevance to the ADS-B-NRA application. These requirements may be subject to further change as a result of the SPR and INTEROP processes.

8.2 CNS Infrastructure

An ADS-B ground infrastructure is required

The ADS-B ground system provides radar-like processing for ADS-B data: e.g. creation, maintenance and suppression of tracks based on ADS-B reports and display of these tracks on the CWP.

Ground-air communications similar to those required for provision of ATC radar services (in particular, VHF coverage for tactical control).

8.3 ATS

As prerequisites, it is assumed that the CWP is equipped with an Air Situation Display. In addition, the ground may include a Flight Data Processing system and the system may provide a conflict detection tool. Other automatic safety net and trajectory monitoring tools may be provided.

The following list of surveillance parameters are required by the controller:

- Aircraft identity (and/or Mode A code in some environments); SPI
- Position
- Indication of the quality of ADS information (in particular, to indicate whether it is good enough for certain separation purposes).
- Emergency indicators (“general emergency”, “communications failure” and “unlawful interference”).
- In some environments, where partial radar coverage exists, an indication of whether the track is supported by radar and/or ADS may be required.
- Barometric Altitude
- Ground Velocity

Note, these are parameters required by the controller. The ATS system processing may require other information in the ADS-B messages (e.g. time stamp) to provide these parameters, but these details are outside the scope of this document. The ground velocity required by the controller may be determined by the system from successive position updates or taken directly from the ADS-B data (if aircraft derived ground velocity is sent).

8.4 Aircraft

Aircraft will be required to equip with an ADS-B transmitter, including interfaces to the on-board data sources.

8.5 Airport vehicle

Not applicable

8.6 Quality of Service Requirements

The quality of service is expected to be similar to or better than present SSR radar.

9. REFERENCES

1. “Air Traffic Services”, ICAO, Annex 11 to the convention on International Civil Aviation, Thirteenth edition, July 2001.

2. “Air Traffic Management”, ICAO, Procedures for Air Navigation Services, Document 4444, Fourteenth edition, 2001.

3. “Package 1 Operational Services and Environmental Definition (OSED)”, RFG internal document.

10. ABBREVIATIONS

ACC	Area Control Centre
ADD	Aircraft Derived Data
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance - Broadcast
AIW	Area Infringement Warning
ATC	Air Traffic Control
ATCC	ATC Centre
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Service
CWP	Controller Working Position
FDPS	Flight Data Processing System
FIR	Flight Information Region
GNSS	Global Navigational Satellite System
GPS	Global Positioning System
HF	High Frequency
ICAO	International Civil Aviation Organisation
MSAW	Minimum Safe Altitude Warning
MTCD	Medium Term Conflict Detection
NEAN	North European ADS-B Network
NRA	Non Radar Airspace
NUP	NEAN Update Programme
OSED	Operational Services and Environment Description
PANS	Procedures for Air Navigation Services
PSR	Primary Surveillance Radar
SDPD	Surveillance Data Processing and Distribution system
SID	Standard Instrument Departure
SPR	Safety & Performance Requirements
SSR	Secondary Surveillance Radar
STAR	Standard Arrival Route
STCA	Short Term Conflict Alert
TMA	Terminal Control Area
VFR	Visual Flight Rules
VHF	Very High Frequency

A. AN EXAMPLE OF A MIXED OPERATIONS ENVIRONMENT AT KIRUNA

Refer to NUP II local OSED ADS-B Kiruna Application version 2.1, dated 25/09/2002.

B. AN EXAMPLE OF A MIXED OPERATIONS ENVIRONMENT IN AUSTRALIA

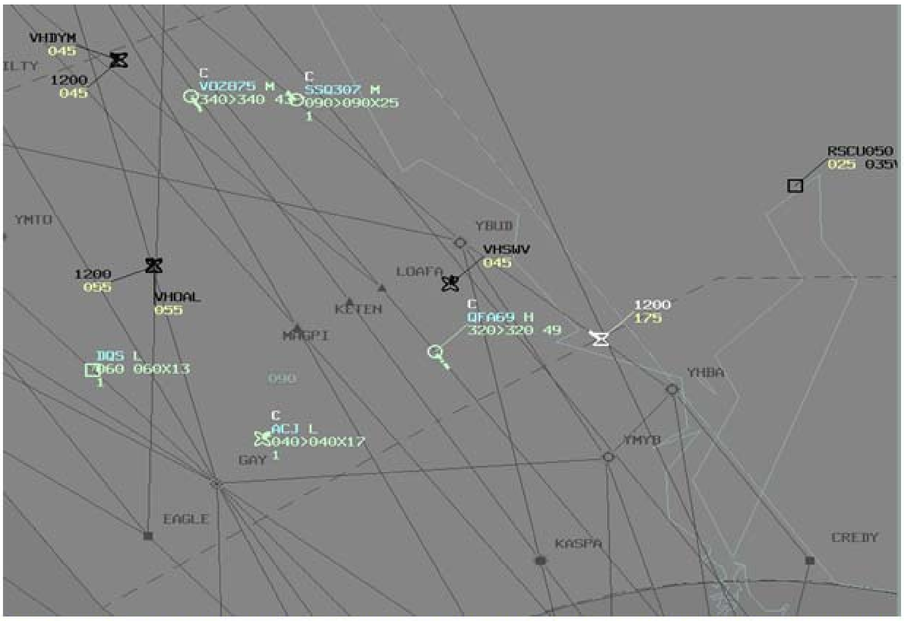
The summary below illustrates the concept in which ADS-B and non-ADS-B are not segregated to allow radar-like services to be executed in an en-route environment.

Environment

The Airspace is non-radar airspace with good VHF voice communication and good ADS-B ground station coverage over the whole continent.

The ATC automation system presents radar, ADS-B, ADS-C and flight plan tracks to controllers as electronic plan view presentation without any paper strips. The whole FIR (all sectors) have all capabilities in an integrated ATM system. Individual ATC sectors have both regions of radar coverage and areas without radar coverage. They also have some aircraft equipped with ADS-B and some without. The controller applies procedural separation standards but may apply radar separation standards to aircraft inside radar coverage and may apply ADS-B separation standards to pairs of aircraft equipped with ADS-B.

Track display indicates to controllers whether the track is based on radar, ADS-B, ADS-C or flight plan data.



Screen capture of Australian air situation display showing radar, ADS-B and flight plan tracks

- O Position derived from RADAR
- ⌘ Position derived from ADS-B (below radar coverage)
- ☐ Flight plan track (no surveillance)

A GNSS availability prediction system provides controllers with estimates of potential loss of ADS-B service. In such a case, procedural control, as applied to non equipped aircraft is used. If loss of ADS-B occurs, the track display transitions to a flight plan track.

Operational

In this environment, division into ADS-B and non ADS-B airspace is not required. No specific airspace entry points or airspace management is required.

Controllers have adequate tools, training, procedures and backup systems to manage mixed equipage.

Controllers are also supported by integrated safety nets (STCA, MSAW, Danger area infringement warning, Route adherence warning, Cleared level adherence warning) and ADS-B updates to the flight plan processing. These tools provide some protection against erroneous ADS-B data.

Operational priority is provided to equipped aircraft.

C. PHASE DIAGRAMS

The following diagrams present the control phases for the use of ADS-B surveillance to support the provision of Air Traffic Control/Separation task and Alerting Services (applicable to airspace classes A to E).

Definitions of Terms used in Phase Diagrams

In the subsequent phase diagrams the following convention is used to indicate who or what is responsible for the task:

Gnd-Pro	= A task performed specifically by the ground processing equipment.
Gnd-ATCo	= A task performed specifically by the ground Air Traffic Controller.
Gnd	= A task performed by ground processing equipment or by Air Traffic Controller or by a combination of both.
A/C-Av	= A task performed specifically by the aircraft avionics
A/C-FC	= A task performed specifically by the aircraft Flight Crew
A/C	= A task performed by the aircraft avionics or by the Flight Crew or by a combination of both.

The meanings of other terms concerning ADS-B surveillance information are further detailed in Appendix D.

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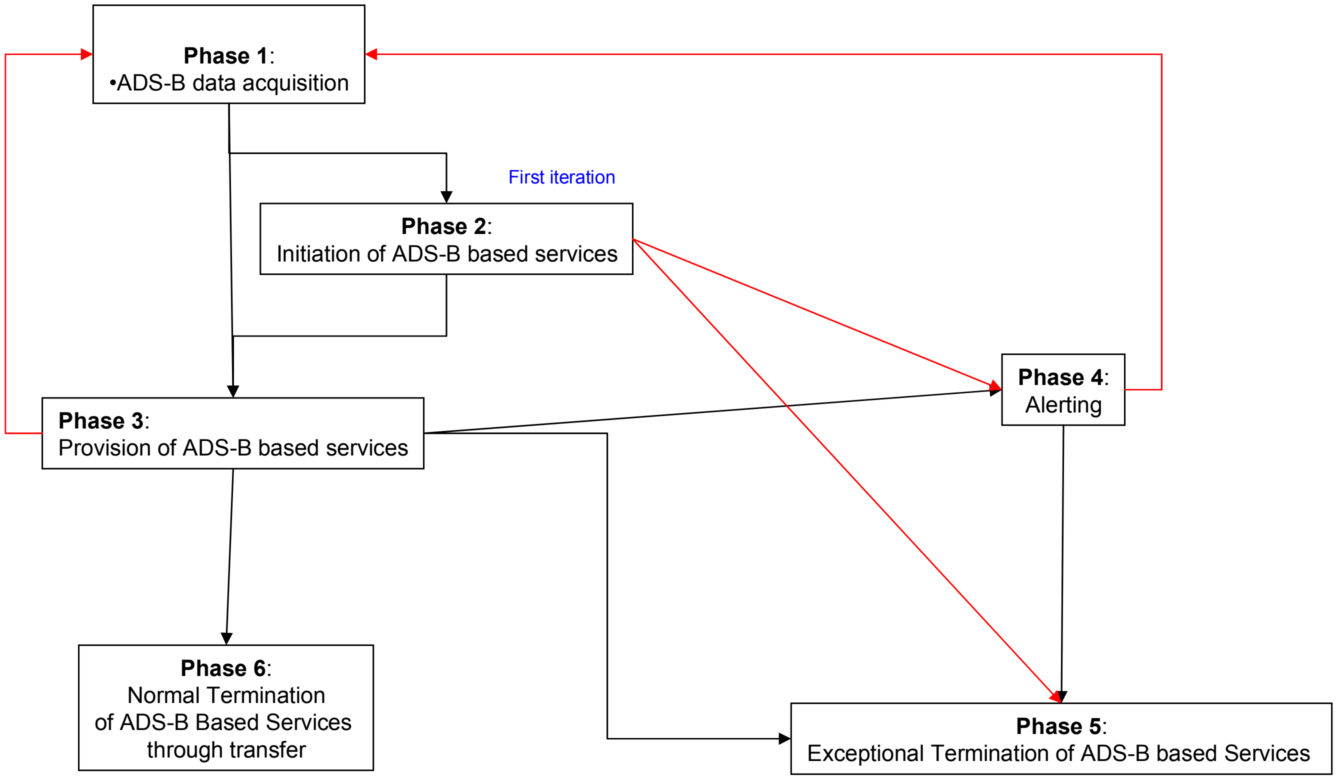
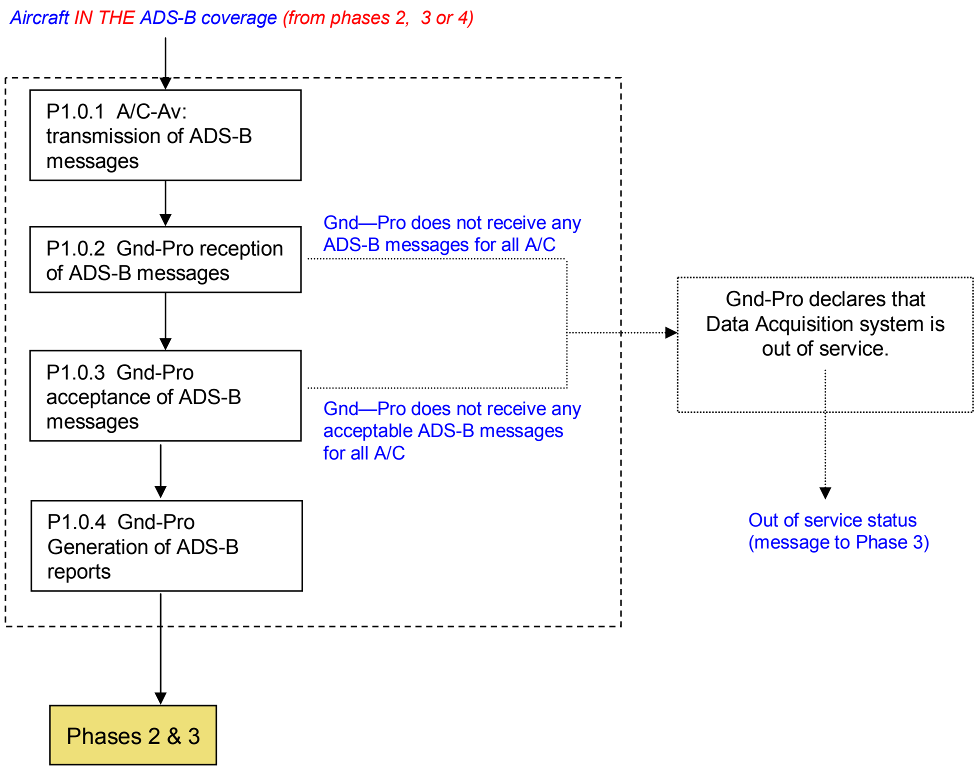
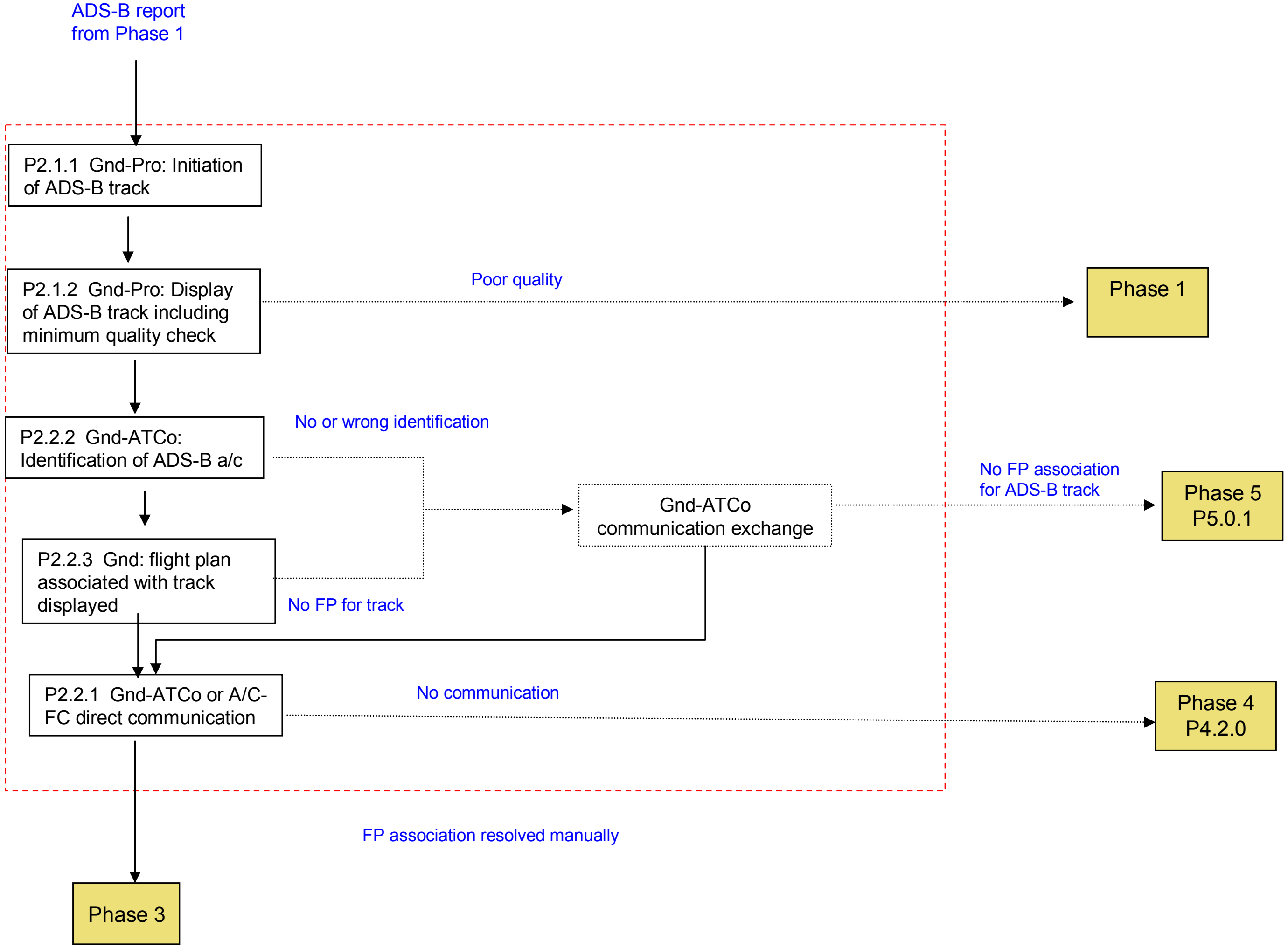
ADS-B Based ATC and Alerting Services Phases only



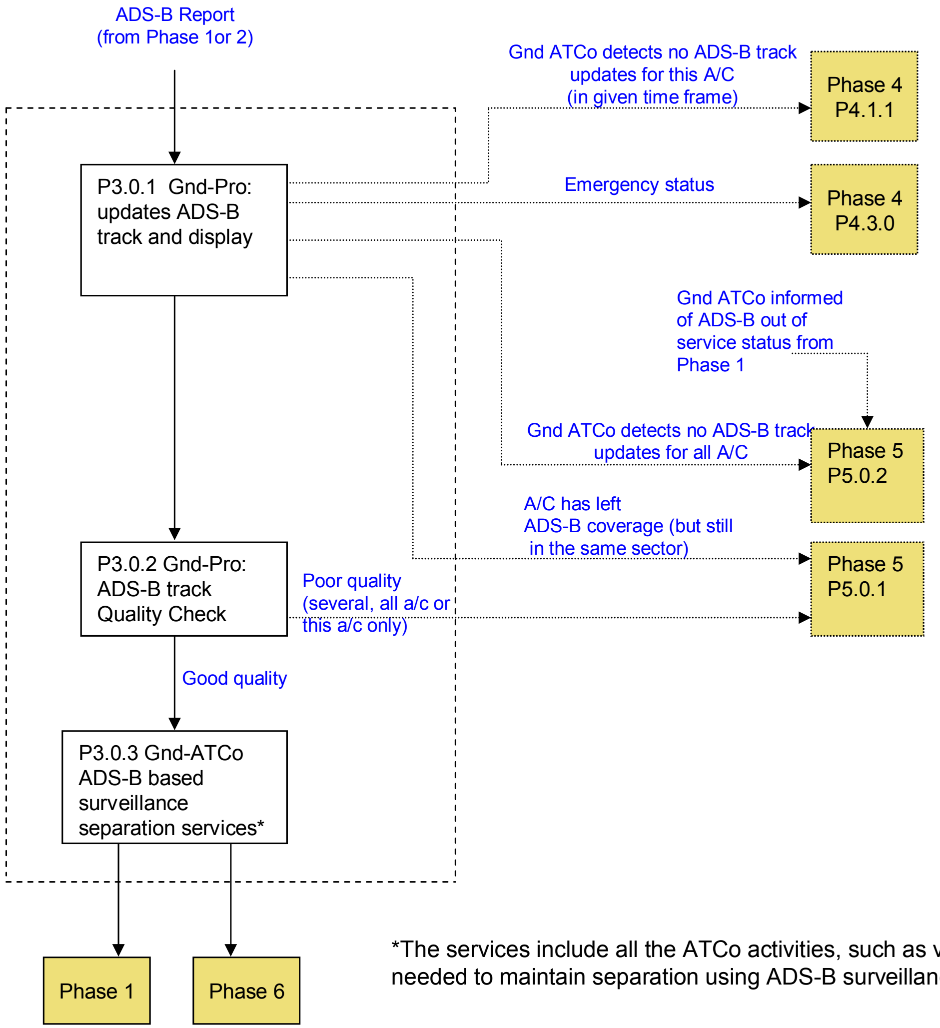
Phase 1 – ADS-B Data Acquisition



Phase 2 – Initiation of ADS-B based services

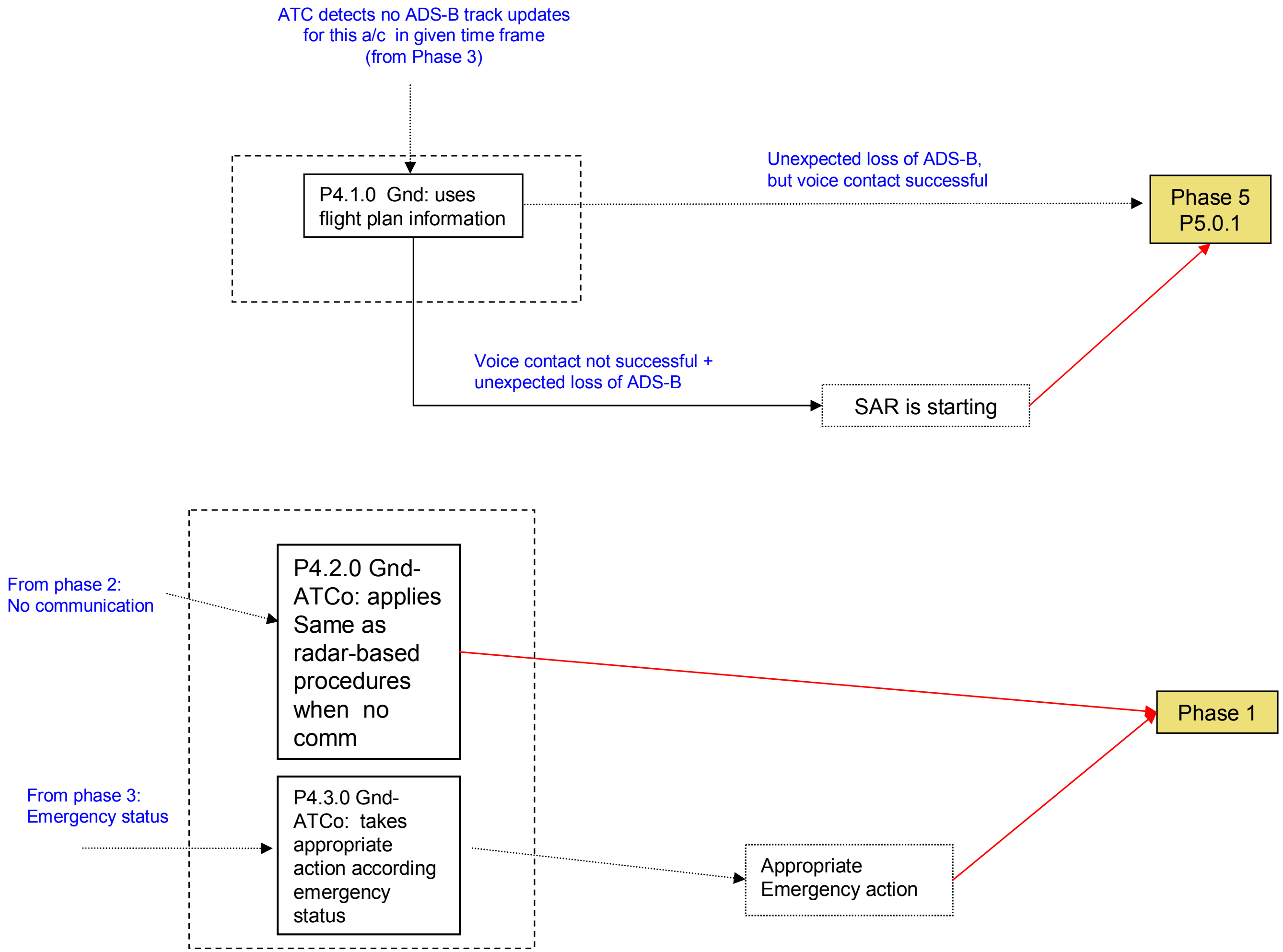


Phase 3 – Provision of ADS-B Based Services

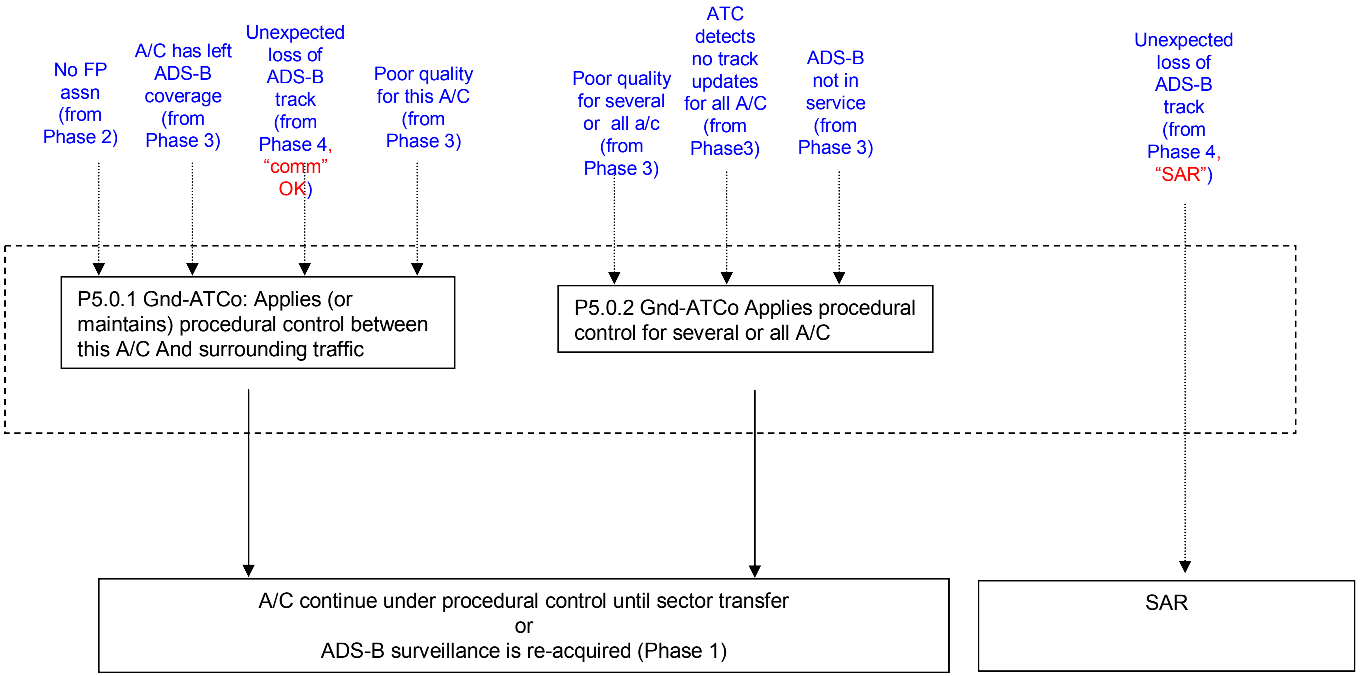


*The services include all the ATCo activities, such as vectoring and monitoring, needed to maintain separation using ADS-B surveillance in a similar way to radar

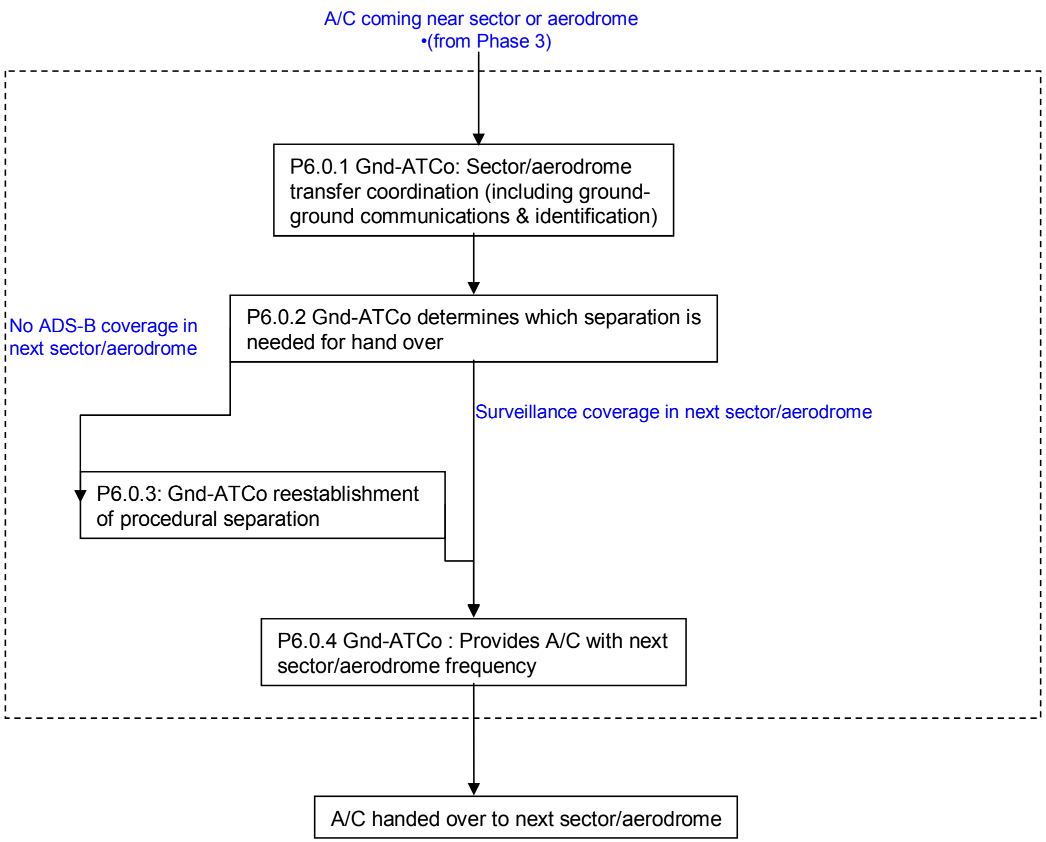
Phase 4 – Alerting



Phase 5 – Exceptional Termination of ADS-B Based Services



Phase 6 – Normal Termination of ADS-B Based Services through transfer



D. DEFINITIONS OF ADS-B SURVEILLANCE TERMS

The meanings various terms and functions concerning ADS-B surveillance, as used in the Phase Diagrams (Appendix C) are defined below:

ADS-B message:

An ADS-B message is a package of information broadcast by the aircraft/vehicle. Each ADS-B message contains a defined set of aircraft/vehicle parameters and these parameters may be only a subset of the available parameters. The format of the message is link specific, as is the number of different messages required for providing all the available set of parameters. Generally, the message will contain additional error protection information to reduce the risk of undetected errors in the decoding of the message by the receiving system.

[The detailed characteristics of the ADS-B messages are defined in each of the particular ADS-B link MOPS].

Acceptance (of ADS-B information)

The objective of the acceptance function[1] is to check that the ADS-B information is correct (or is very likely to be correct). In practice, the acceptance function may involve various levels of checking, as indicated below (not exhaustive).

The basic level of acceptance checking will be to apply the error detection capability inherent in the transmission format of the ADS-B message (this will be link specific). The error detection (and sometimes correction) capability will reduce the likelihood the information in the ADS-B message being decoded incorrectly by the receiving system or will reject incorrect messages. It is assumed that this basic level of checking will be necessary for all ADS-B applications.

In addition, some independent method of checking the acceptability of individual aircraft/vehicle parameters may be applied. This may include, for example, tests on the angle of arrival or relative times of arrival at sensors. In a mixed ADS-B/radar environment, the radar reports may be used to provide independent checking of the ADS-B information. [Such methods may also detect ADS-B spoofing].

Note:

The functioning of the ADS-B system may be checked by various methods, such as the use of known (fixed) ADS-B target emitters. However, these methods are not strictly considered to be part of the process of acceptance of ADS-B information, but are considered to be part of the system checks necessary to determine whether the ADS-B system is working properly and fit for operational purposes.

ADS-B report

An ADS-B report contains aircraft/vehicle parameters assembled from ADS-B messages received and successfully decoded by the receiving sensor system. The report is sent to the user application. The data format of the report should be independent of the particular type of ADS-B link.

A report may be sent immediately when an update of ADS-B parameters is received from an ADS-B message, or sent when an update of all parameters are received (from more than one

[1] *: this function may be implemented in various physical components*

message), or sent at certain update time intervals. How and when the reports are sent will depend upon other system considerations, such as the bandwidth of the available communications and the processing capabilities of the receiving application.

Further information (such as a time stamp) may be added to the report to support the needs of the receiving application.

Quality (of ADS-B information)

Quality particularly concerns the accuracy and integrity of the ADS-B position information. Inherently, the accuracy of ADS-B information will depend upon the navigation source on board the aircraft/vehicle and the integrity will depend upon the capability of checking whether the navigational accuracy is maintained within certain limits. The ADS-B messages are expected to contain quality indicators, as determined by processing of navigational sources on board the aircraft/vehicle.

Furthermore, the receiving system may apply additional checks on the quality of ADS-B information, (for example checks on the age of the information) and additional quality indicators may be added to the ADS-B report by this process.

Deleted: [In the current ADS-B standards, the quality indicators are represented by Navigation Accuracy Category (NAC), Navigation Integrity Category (NIC) and Surveillance Integrity Level (SIL)].¶

ADS-B track (and in general a surveillance track)

A track represents the best estimate of the current state of the aircraft/vehicle (i.e. position, velocity, possibly accelerations etc) as determined from ADS-B (surveillance) reports. The track may be calculated from a sequence of recent reports or more simply represented by the latest ADS-B report.

The track estimate may be provided to the application at times that are not synchronised to the receipt of surveillance reports, for example, to provide a periodic update to a display.

Furthermore, the track processing may also be used to enhance the acceptance checking of ADS-B information by comparing the latest ADS-B information with that predicted from the previous track.

Requirement Focus Group

ADS-B NRA
Allocation of Safety Objectives and Requirements

Version 0.1, dated 04th of February 05

Scope of the OHA

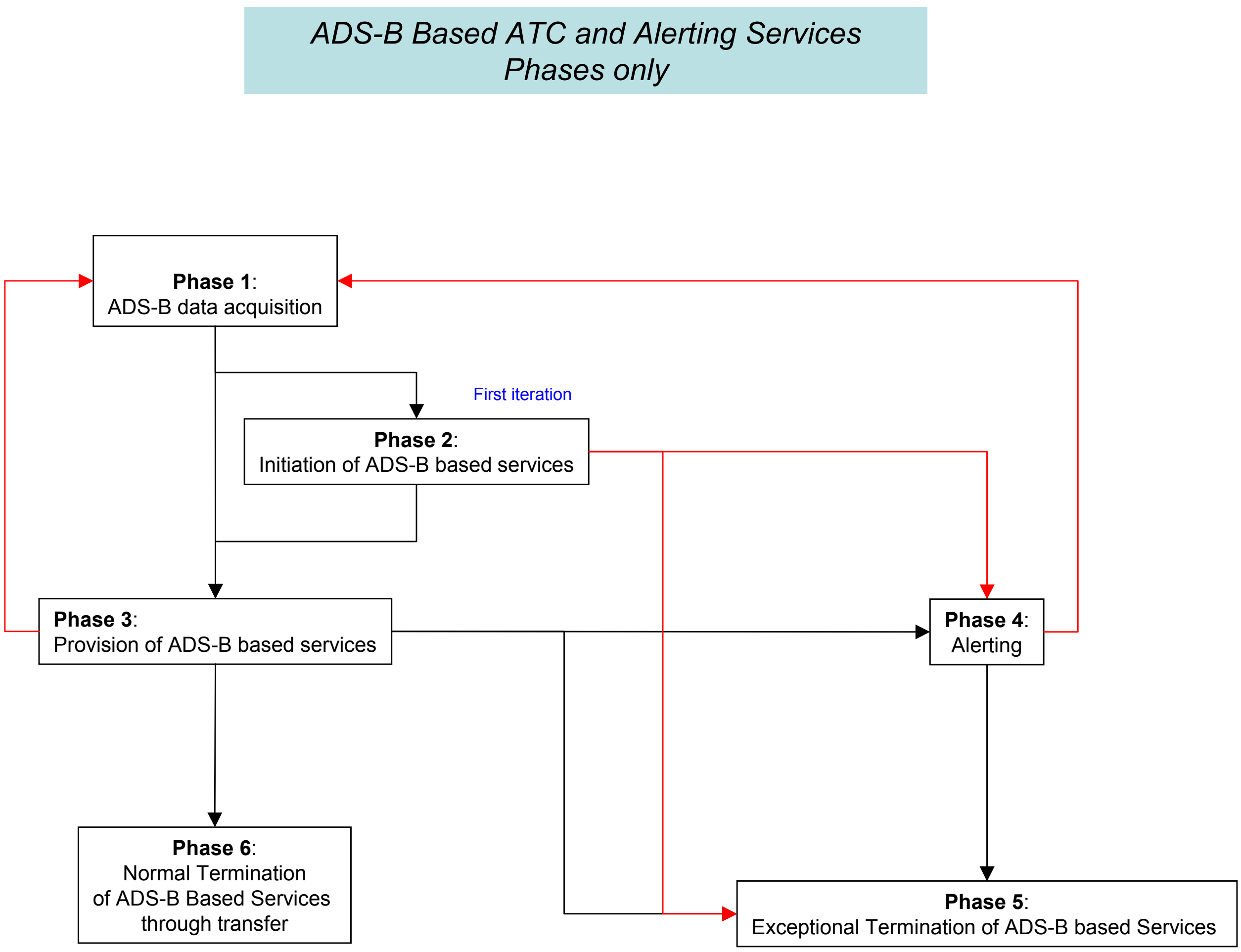
As per RTCA / EUROCAE OSA methodology, the ASOR constitutes the second step of the OSA process, after the OHA. Based on the OHA results gathered in NRA OHA v0.7, the ASOR allocates safety objectives to domains, develops and validates risk mitigation strategy that is shared by multiple organisations and allocates safety requirements to those domains.

As recommended by ED-78A/DO-264, only Operational Hazards whose severity has been determined, according to their operational consequences, less or equal to 3 are further analysed in this ASOR.

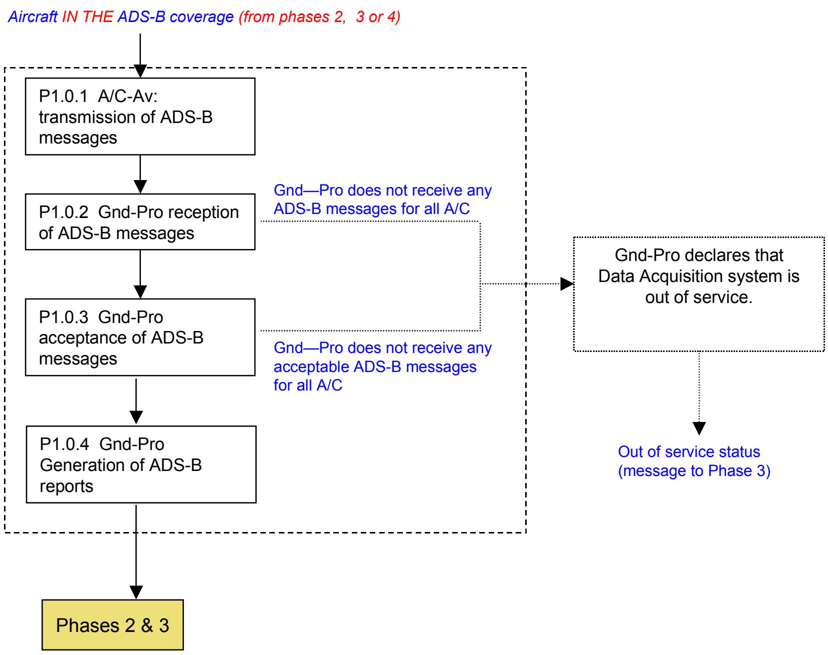
In order to derive safety objectives, it has been agreed by the SPR SG to allocate a maximum occurrence probability of 1E-8 per Flight Hour for severity 1 operational consequences. This figure has been derived assuming a maximum tolerable probability of ATM directly contributing to an accident of a Commercial Air Transport aircraft 2E-8 per Flight Hour, as agreed at RFG level and considering that in a NRA environment, ADS-B services may contribute to 50% of ATM operations.

ADS-B NRA modelling

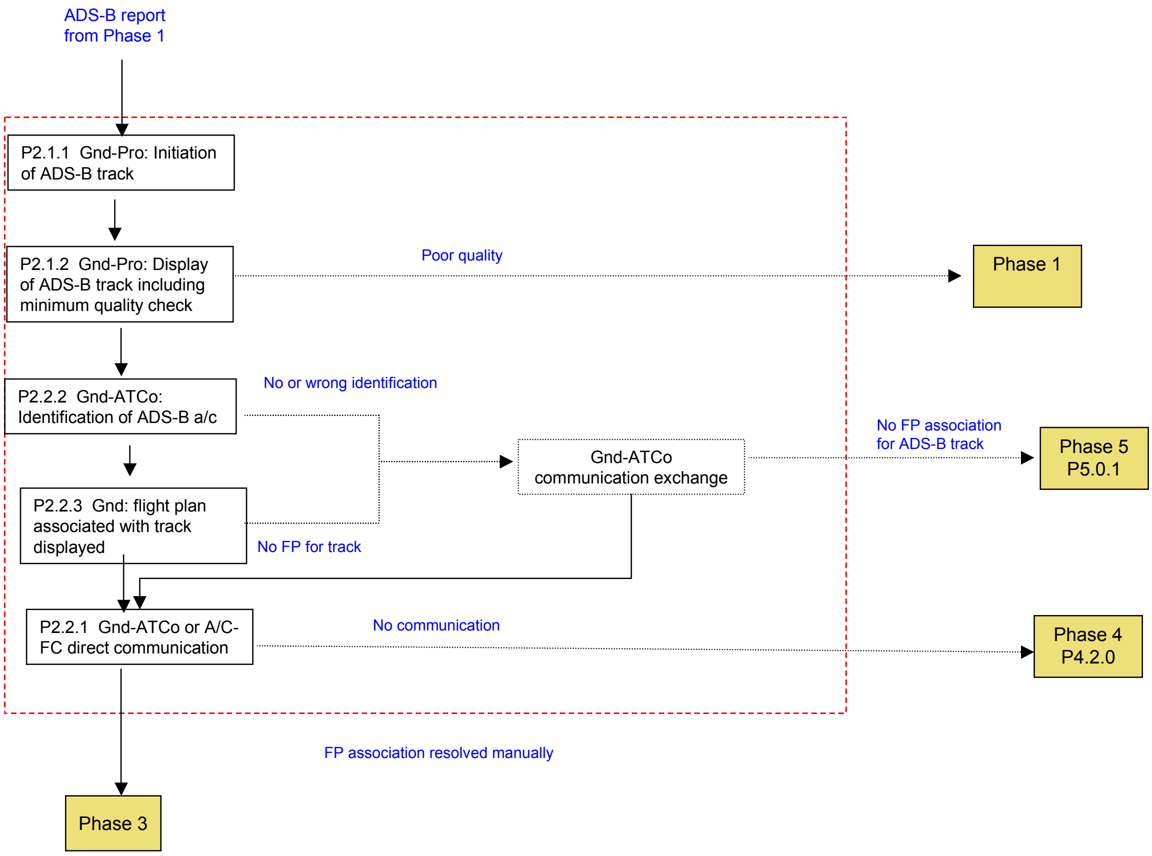
The NRA OHA is based on the following modelling



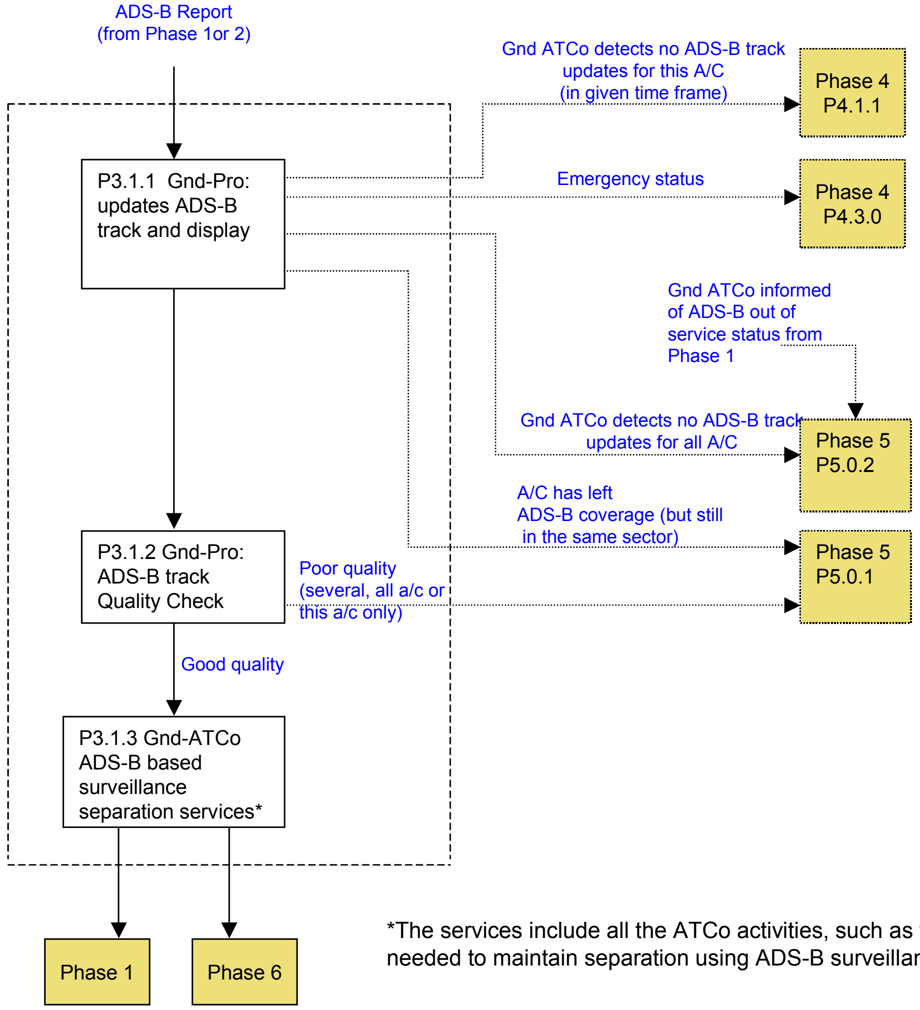
Phase 1 – ADS-B Data Acquisition



Phase 2 – Initiation of ADS-B based services

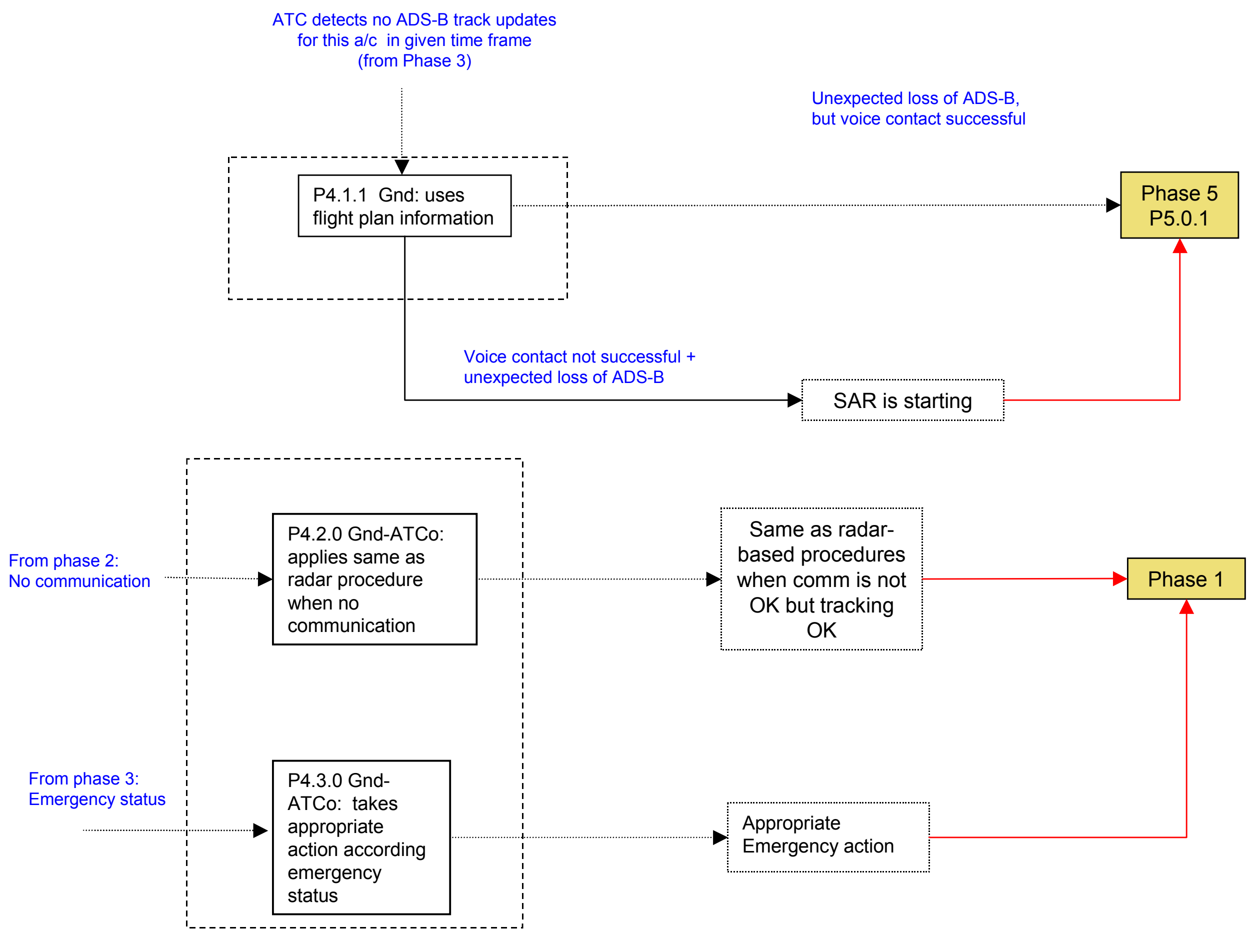


Phase 3 – Provision of ADS-B Based Services

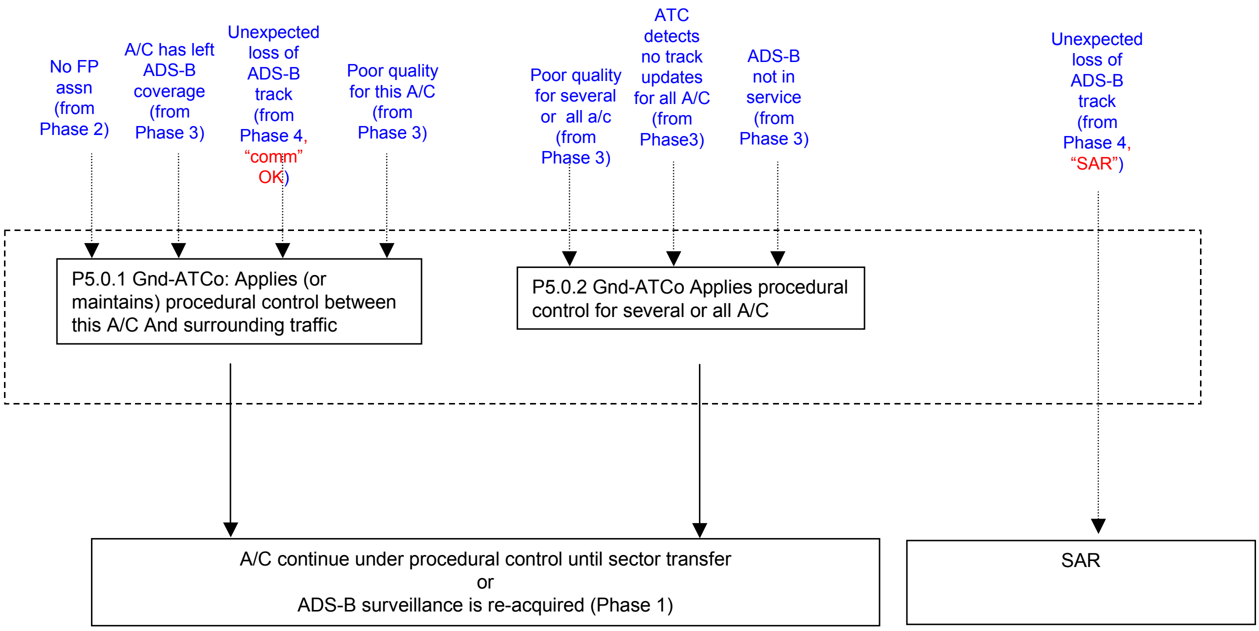


*The services include all the ATCo activities, such as vectoring and monitoring, needed to maintain separation using ADS-B surveillance in a similar way to radar

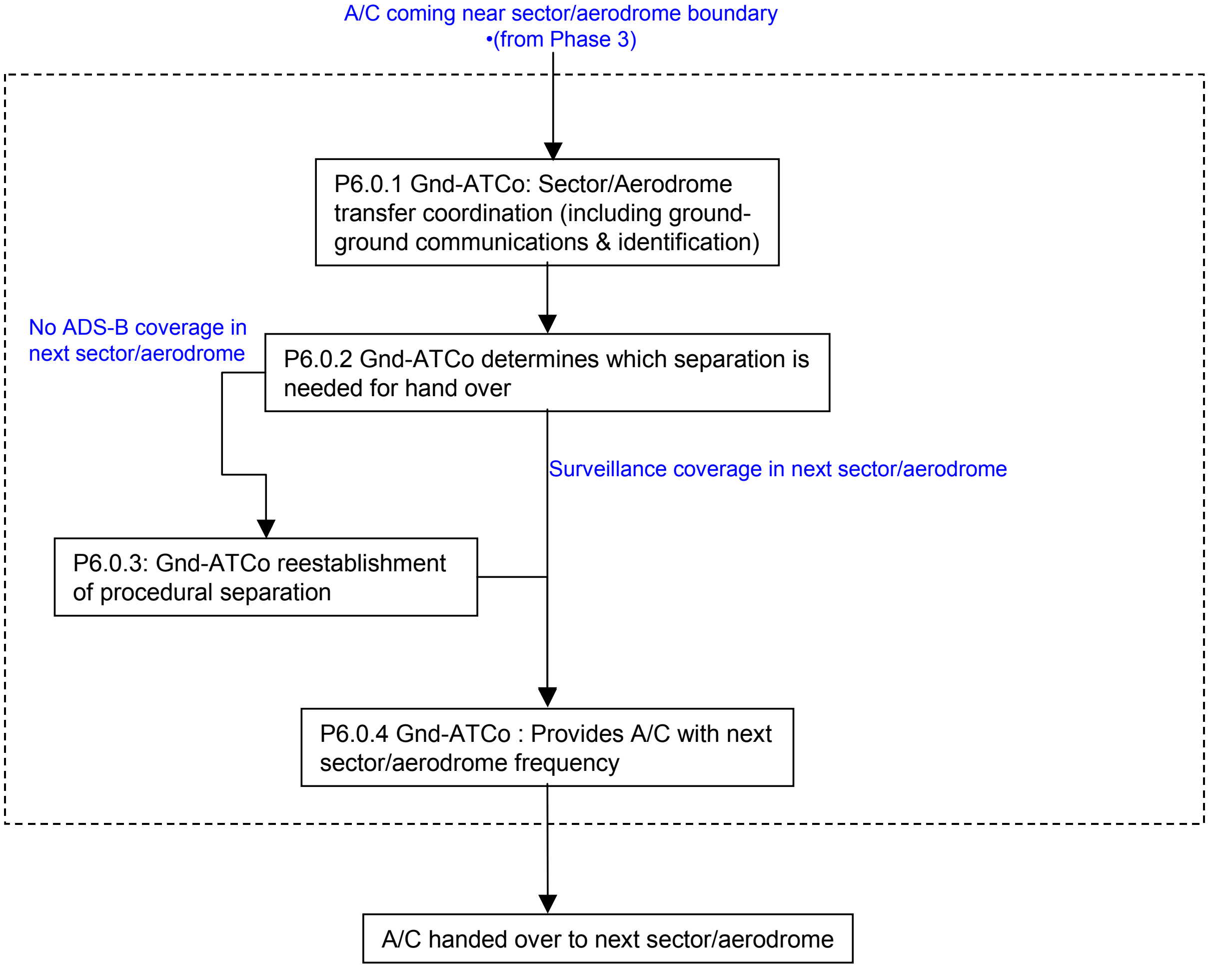
Phase 4 – Alerting



Phase 5 – Exceptional Termination of ADS-B Based Services



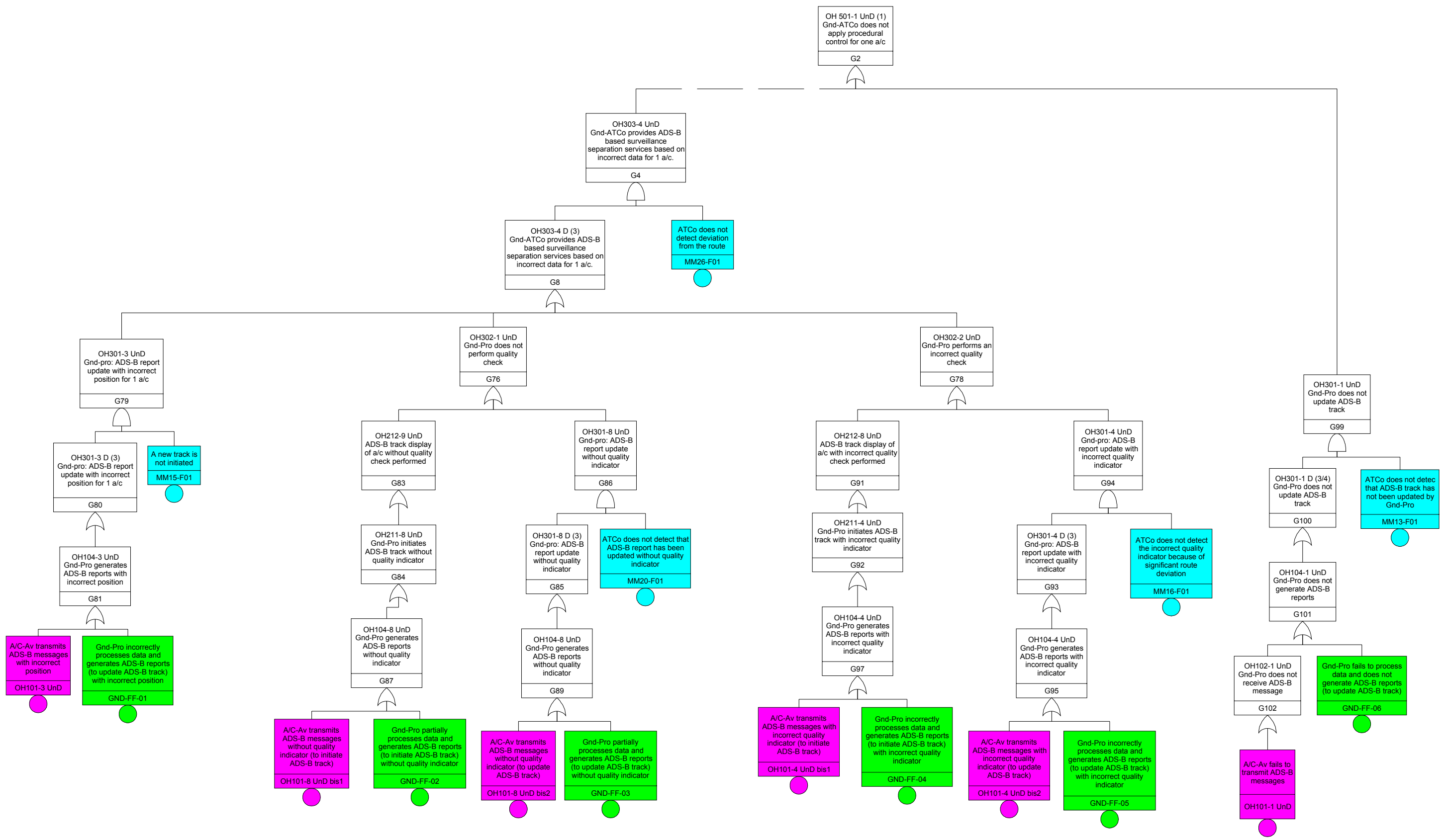
Phase 6 – Normal Termination of ADS-B Based Services through transfer

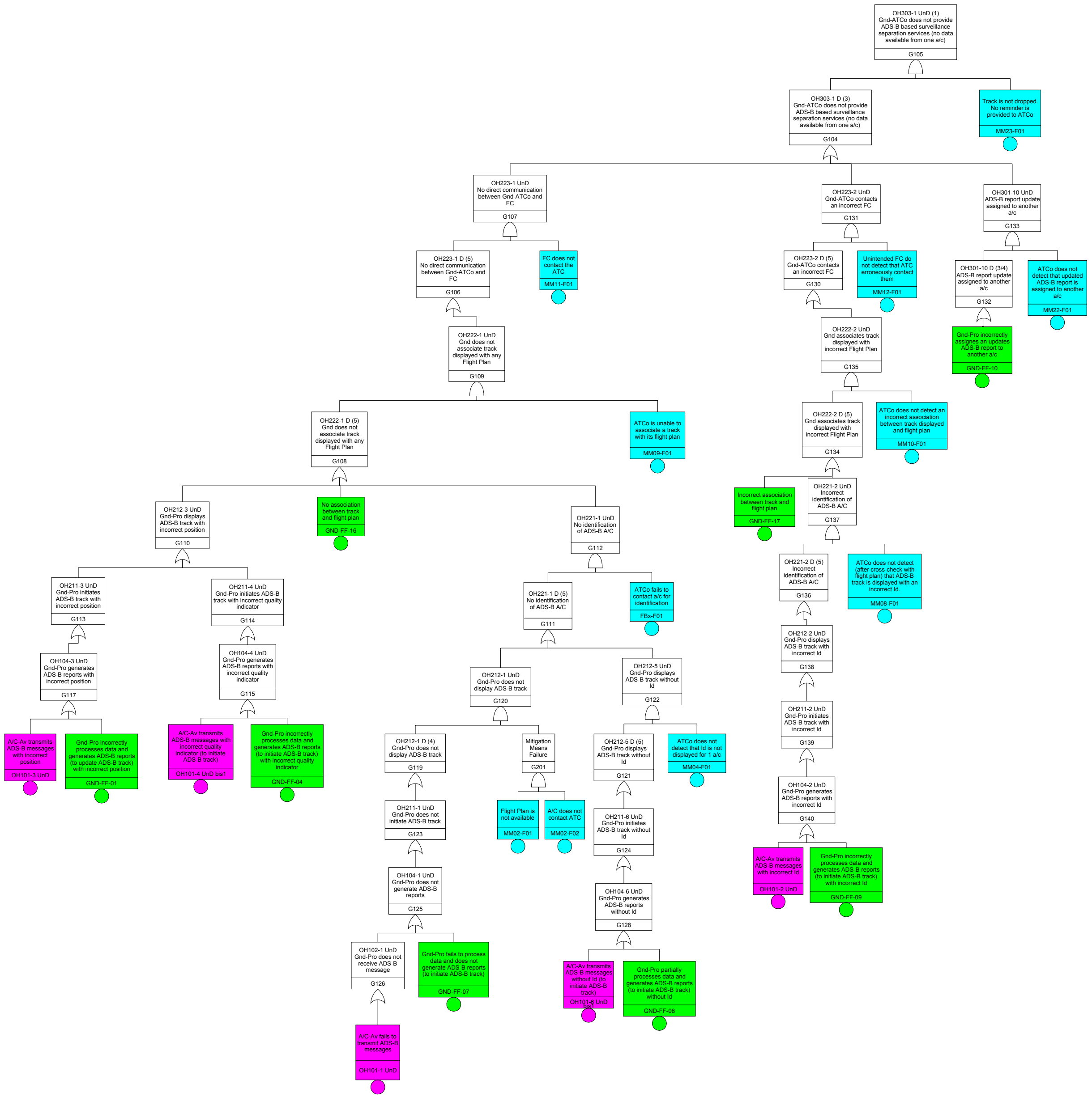


List of NRA Operational Hazards analysed in the frame of the ASOR

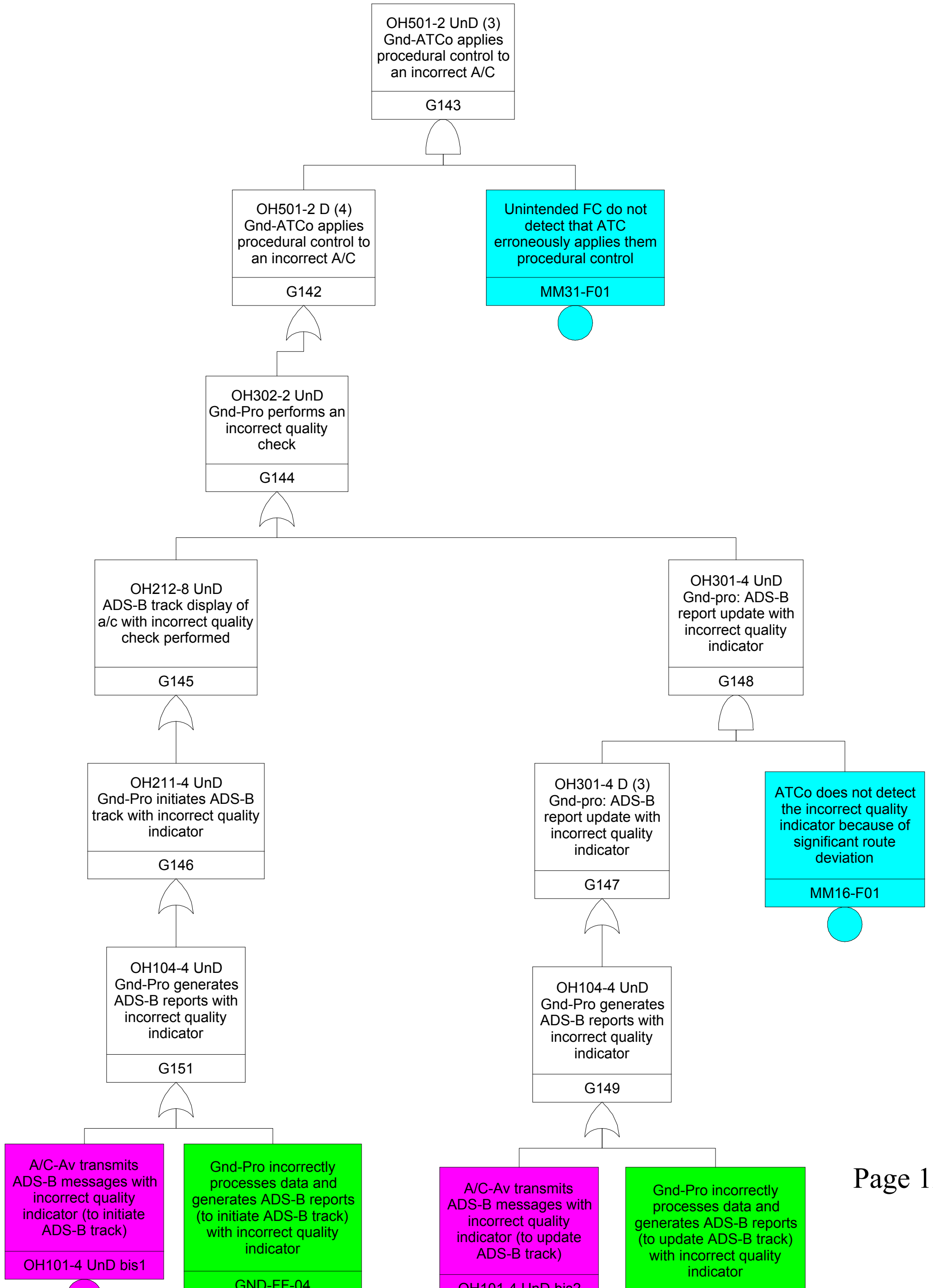
OH	**Severity if detected**	**Severity if not detected**
OH 2.1.2-1: Gnd-Pro does not display ADS-B track	One a/c: **4** Several a/c: **3**	
OH 2.1.2-6: Gnd-Pro displays ADS-B track without position	One a/c: **4** Several a/c: **3**	
OH 3.0.1-1: Gnd-Pro does not update ADS-B track	One a/c: **3/4** Several a/c: **2**	
OH 3.0.1-3: Gnd-pro: ADS-B report update with incorrect position	One a/c: **3** Several a/c: **2**	
OH 3.0.1-4: Gnd-pro: ADS-B report update with incorrect quality indicator	One a/c: **3** Several a/c: **2**	
OH 3.0.1-7: Gnd-pro: ADS-B report update without position	One a/c: **3** Several a/c: **2**	
OH 3.0.1-8: Gnd-pro: ADS-B report update without quality indicator	One a/c: **3** Several a/c: **2**	
OH 3.0.1-10: ADS-B report update assigned to another a/c	One a/c: **3/4** Several a/c: **3/4**	
OH 3.0.2-1: Gnd-Pro does not perform quality check	One a/c: **n/a** Several a/c: **2**	
OH 3.0.2-2: Gnd-Pro performs an incorrect quality check	One a/c: **n/a** Several a/c: **2**	
OH 3.0.3-1: Gnd-ATCo does not provide ADS-B based surveillance separation services (no data available from one a/c)	One a/c: **3** Several a/c: **n/a**	**1** n/a
OH 3.0.3-2: Gnd-ATCo does not provide ADS-B based surveillance separation services (no data available from all a/c)	One a/c: **n/a** Several a/c: **2**	n/a **1**
OH 3.0.3-3: Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect Id.	One a/c: **5** Several a/c: **4**	**3** **2**
OH 3.0.3-4: Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect position.	One a/c: **3** Several a/c: **2**	
OH 3.0.3-5: Gnd-ATCo provides ADS-B based surveillance separation	One a/c: **4/5**	**3**

services based on incorrect altitude.	Several a/c: **4/5**	**3**
OH 4.1.0-1: Gnd does not use flight plan information	One a/c: **n/a** Several a/c: **n/a**	**3** **3**
OH 4.1.0-2: Gnd uses an incorrect flight plan	One a/c: **4** Several a/c: **4**	**3** **3**
OH 5.0.1-1: Gnd-ATCo does not apply procedural control for one a/c	One a/c: **n/a** Several a/c: **n/a**	1 n/a
OH 5.0.1-2: Gnd-ATCo applies procedural control to an incorrect A/C	One a/c: **4** Several a/c: **n/a**	3 n/a
OH 5.0.2-1: Gnd-ATCo does not apply procedural control for all a/c	One a/c: **n/a** Several a/c: **2**	n/a 1
OH 6.0.3-1: Gnd-ATCo does not re-establish procedural separation	**4**	2/3
OH 6.0.3-2: Gnd-ATCo re-establishes incorrect separation	**4**	2/3

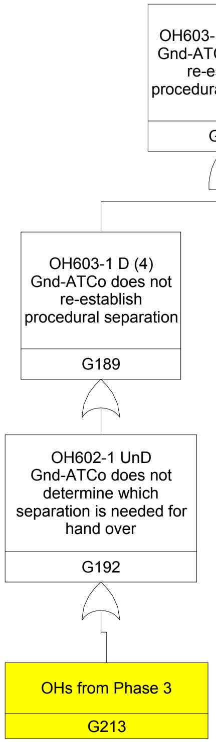

OH 501-1 UnD (1) Gnd-ATCo does not apply procedural control for one a/c
G2
OH303-4 UnD Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect data for 1 a/c.
G4
OH303-4 D (3) Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect data for 1 a/c.
G8
ATCo does not detect deviation from the route
MM26-F01
OH301-3 UnD Gnd-pro: ADS-B report update with incorrect position for 1 a/c
G79
OH301-3 D (3) Gnd-pro: ADS-B report update with incorrect position for 1 a/c
G80
A new track is not initiated
MM15-F01
OH104-3 UnD Gnd-Pro generates ADS-B reports with incorrect position
G81
A/C-Av transmits ADS-B messages with incorrect position
OH101-3 UnD
Gnd-Pro incorrectly processes data and generates ADS-B reports (to update ADS-B track) with incorrect position
GND-FF-01
OH302-1 UnD Gnd-Pro does not perform quality check
G76
OH212-9 UnD ADS-B track display of a/c without quality check performed
G83
OH211-8 UnD Gnd-Pro initiates ADS-B track without quality indicator
G84
OH104-8 UnD Gnd-Pro generates ADS-B reports without quality indicator
G87
A/C-Av transmits ADS-B messages without quality indicator (to initiate ADS-B track)
OH101-8 UnD bis1
Gnd-Pro partially processes data and generates ADS-B reports (to initiate ADS-B track) without quality indicator
GND-FF-02
OH301-8 UnD Gnd-pro: ADS-B report update without quality indicator
G86
OH301-8 D (3) Gnd-pro: ADS-B report update without quality indicator
G85
ATCo does not detect that ADS-B report has been updated without quality indicator
MM20-F01
OH104-8 UnD Gnd-Pro generates ADS-B reports without quality indicator
G89
A/C-Av transmits ADS-B messages without quality indicator (to update ADS-B track)
OH101-8 UnD bis2
Gnd-Pro partially processes data and generates ADS-B reports (to update ADS-B track) without quality indicator
GND-FF-03
OH302-2 UnD Gnd-Pro performs an incorrect quality check
G78
OH212-8 UnD ADS-B track display of a/c with incorrect quality check performed
G91
OH211-4 UnD Gnd-Pro initiates ADS-B track with incorrect quality indicator
G92
OH104-4 UnD Gnd-Pro generates ADS-B reports with incorrect quality indicator
G97
A/C-Av transmits ADS-B messages with incorrect quality indicator (to initiate ADS-B track)
OH101-4 UnD bis1
Gnd-Pro incorrectly processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect quality indicator
GND-FF-04
OH301-4 UnD Gnd-pro: ADS-B report update with incorrect quality indicator
G94
OH301-4 D (3) Gnd-pro: ADS-B report update with incorrect quality indicator
G93
ATCo does not detect the incorrect quality indicator because of significant route deviation
MM16-F01
OH104-4 UnD Gnd-Pro generates ADS-B reports with incorrect quality indicator
G95
A/C-Av transmits ADS-B messages with incorrect quality indicator (to update ADS-B track)
OH101-4 UnD bis2
Gnd-Pro incorrectly processes data and generates ADS-B reports (to update ADS-B track) with incorrect quality indicator
GND-FF-05
OH301-1 UnD Gnd-Pro does not update ADS-B track
G99
OH301-1 D (3/4) Gnd-Pro does not update ADS-B track
G100
ATCo does not detec that ADS-B track has not been updated by Gnd-Pro
MM13-F01
OH104-1 UnD Gnd-Pro does not generate ADS-B reports
G101
OH102-1 UnD Gnd-Pro does not receive ADS-B message
G102
Gnd-Pro fails to process data and does not generate ADS-B reports (to update ADS-B track)
GND-FF-06
A/C-Av fails to transmit ADS-B messages
OH101-1 UnD

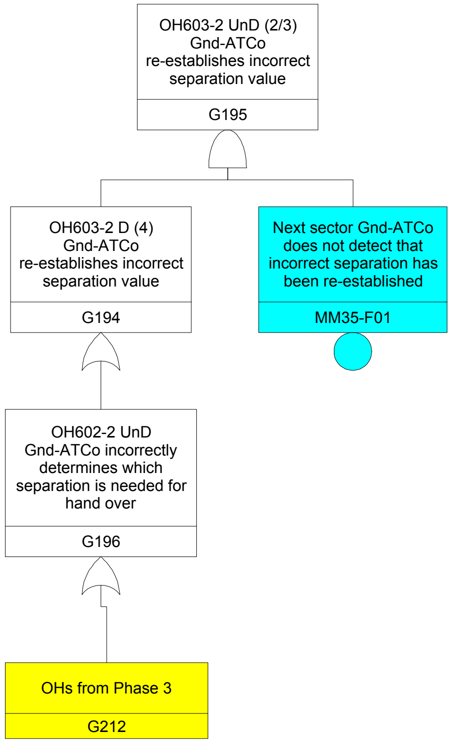


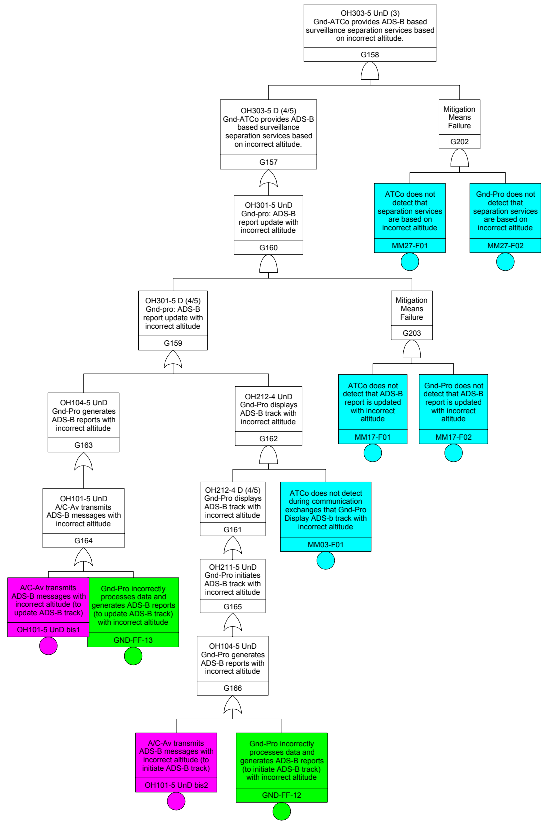
OH303-1 UnD (1) Gnd-ATCo does not provide ADS-B based surveillance separation services (no data available from one a/c)
G105
OH303-1 D (3) Gnd-ATCo does not provide ADS-B based surveillance separation services (no data available from one a/c)
G104
Track is not dropped. No reminder is provided to ATCo
MM23-F01
OH223-1 UnD No direct communication between Gnd-ATCo and FC
G107
OH223-1 D (5) No direct communication between Gnd-ATCo and FC
G106
FC does not contact the ATC
MM11-F01
OH222-1 UnD Gnd does not associate track displayed with any Flight Plan
G109
OH222-1 D (5) Gnd does not associate track displayed with any Flight Plan
G108
ATCo is unable to associate a track with its flight plan
MM09-F01
OH212-3 UnD Gnd-Pro displays ADS-B track with incorrect position
G110
No association between track and flight plan
GND-FF-16
OH221-1 UnD No identification of ADS-B A/C
G112
OH211-3 UnD Gnd-Pro initiates ADS-B track with incorrect position
G113
OH211-4 UnD Gnd-Pro initiates ADS-B track with incorrect quality indicator
G114
OH104-3 UnD Gnd-Pro generates ADS-B reports with incorrect position
G117
OH104-4 UnD Gnd-Pro generates ADS-B reports with incorrect quality indicator
G115
A/C-Av transmits ADS-B messages with incorrect position
OH101-3 UnD
Gnd-Pro incorrectly processes data and generates ADS-B reports (to update ADS-B track) with incorrect position
GND-FF-01
A/C-Av transmits ADS-B messages with incorrect quality indicator (to initiate ADS-B track)
OH101-4 UnD bis1
Gnd-Pro incorrectly processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect quality indicator
GND-FF-04
OH221-1 D (5) No identification of ADS-B A/C
G111
ATCo fails to contact a/c for identification
FBx-F01
OH212-1 UnD Gnd-Pro does not display ADS-B track
G120
OH212-5 UnD Gnd-Pro displays ADS-B track without Id
G122
OH212-1 D (4) Gnd-Pro does not display ADS-B track
G119
Mitigation Means Failure
G201
OH212-5 D (5) Gnd-Pro displays ADS-B track without Id
G121
ATCo does not detect that Id is not displayed for 1 a/c
MM04-F01
OH211-1 UnD Gnd-Pro does not initiate ADS-B track
G123
Flight Plan is not available
MM02-F01
A/C does not contact ATC
MM02-F02
OH211-6 UnD Gnd-Pro initiates ADS-B track without Id
G124
OH104-1 UnD Gnd-Pro does not generate ADS-B reports
G125
OH104-6 UnD Gnd-Pro generates ADS-B reports without Id
G128
OH102-1 UnD Gnd-Pro does not receive ADS-B message
G126
Gnd-Pro fails to process data and does not generate ADS-B reports (to initiate ADS-B track)
GND-FF-07
A/C-Av transmits ADS-B messages without Id (to initiate ADS-B track)
OH101-6 UnD bis1
Gnd-Pro partially processes data and generates ADS-B reports (to initiate ADS-B track) without Id
GND-FF-08
A/C-Av fails to transmit ADS-B messages
OH101-1 UnD
OH223-2 UnD Gnd-ATCo contacts an incorrect FC
G131
OH301-10 UnD ADS-B report update assigned to another a/c
G133
OH223-2 D (5) Gnd-ATCo contacts an incorrect FC
G130
Unintended FC do not detect that ATC erroneously contact them
MM12-F01
OH301-10 D (3/4) ADS-B report update assigned to another a/c
G132
ATCo does not detect that updated ADS-B report is assigned to another a/c
MM22-F01
Gnd-Pro incorrectly assignes an updates ADS-B report to another a/c
GND-FF-10
OH222-2 UnD Gnd associates track displayed with incorrect Flight Plan
G135
OH222-2 D (5) Gnd associates track displayed with incorrect Flight Plan
G134
ATCo does not detect an incorrect association between track displayed and flight plan
MM10-F01
Incorrect association between track and flight plan
GND-FF-17
OH221-2 UnD Incorrect identification of ADS-B A/C
G137
OH221-2 D (5) Incorrect identification of ADS-B A/C
G136
ATCo does not detect (after cross-check with flight plan) that ADS-B track is displayed with an incorrect Id.
MM08-F01
OH212-2 UnD Gnd-Pro displays ADS-B track with incorrect Id
G138
OH211-2 UnD Gnd-Pro initiates ADS-B track with incorrect Id
G139
OH104-2 UnD Gnd-Pro generates ADS-B reports with incorrect Id
G140
A/C-Av transmits ADS-B messages with incorrect Id
OH101-2 UnD
Gnd-Pro incorrectly processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect Id
GND-FF-09

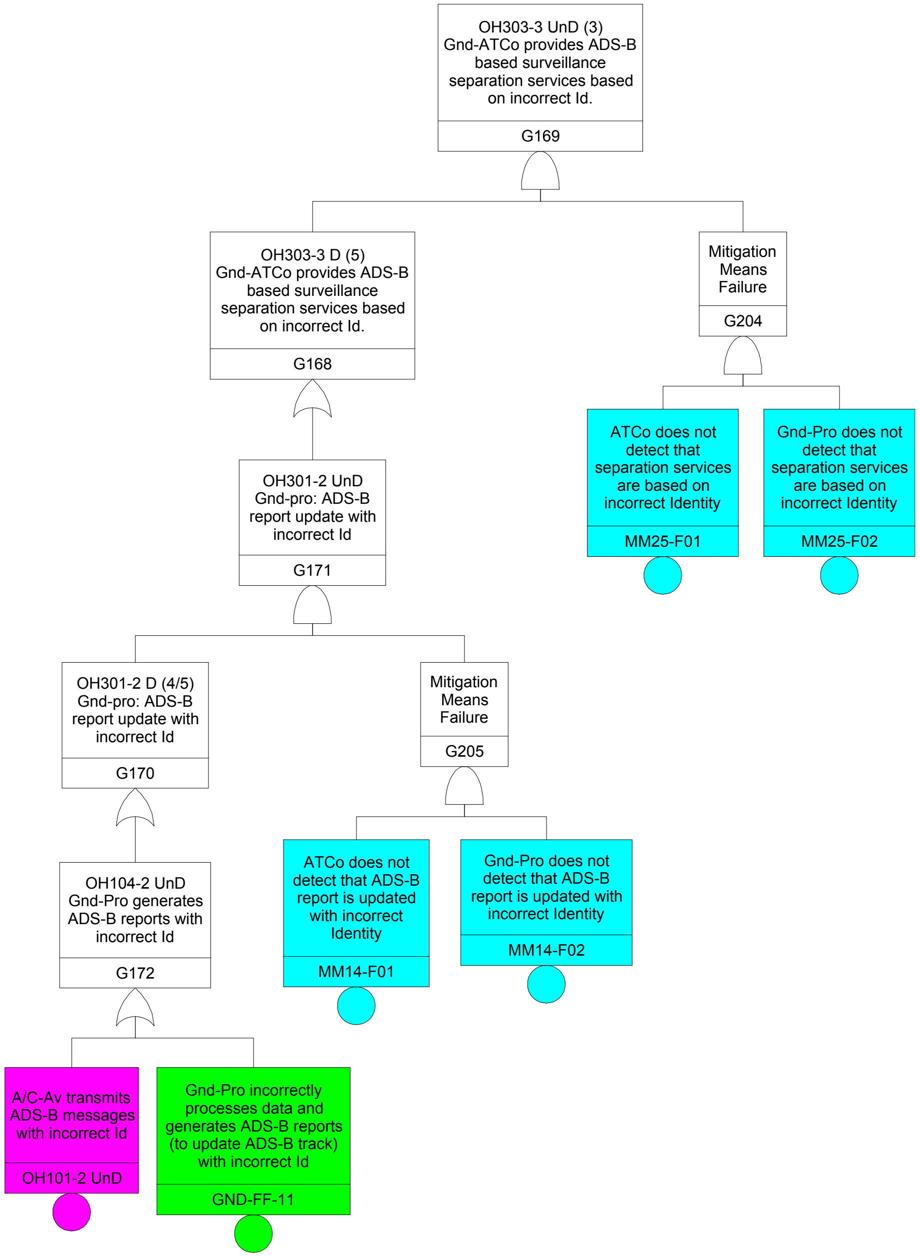


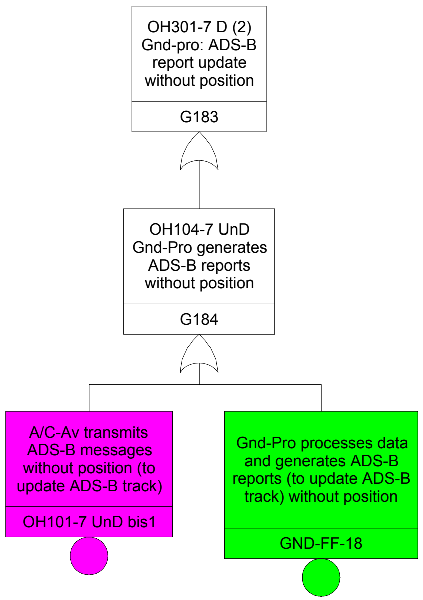
OH501-2 UnD (3) Gnd-ATCo applies procedural control to an incorrect A/C
G143
OH501-2 D (4) Gnd-ATCo applies procedural control to an incorrect A/C
G142
Unintended FC do not detect that ATC erroneously applies them procedural control
MM31-F01
OH302-2 UnD Gnd-Pro performs an incorrect quality check
G144
OH212-8 UnD ADS-B track display of a/c with incorrect quality check performed
G145
OH301-4 UnD Gnd-pro: ADS-B report update with incorrect quality indicator
G148
OH211-4 UnD Gnd-Pro initiates ADS-B track with incorrect quality indicator
G146
OH301-4 D (3) Gnd-pro: ADS-B report update with incorrect quality indicator
G147
ATCo does not detect the incorrect quality indicator because of significant route deviation
MM16-F01
OH104-4 UnD Gnd-Pro generates ADS-B reports with incorrect quality indicator
G151
OH104-4 UnD Gnd-Pro generates ADS-B reports with incorrect quality indicator
G149
A/C-Av transmits ADS-B messages with incorrect quality indicator (to initiate ADS-B track)
OH101-4 UnD bis1
Gnd-Pro incorrectly processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect quality indicator
A/C-Av transmits ADS-B messages with incorrect quality indicator (to update ADS-B track)
Gnd-Pro incorrectly processes data and generates ADS-B reports (to update ADS-B track) with incorrect quality indicator

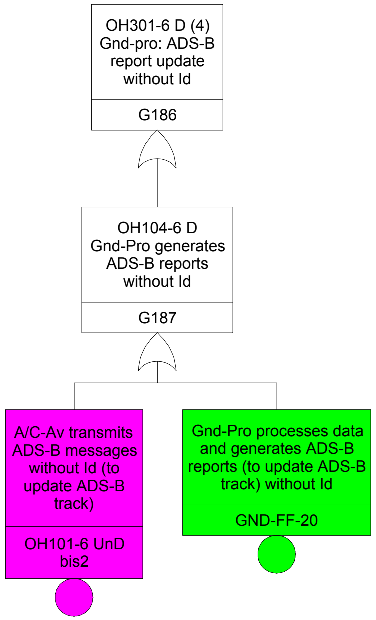

OH603-1 UnD (2/3)
Gnd-ATCo does not re-establish procedural separation
G190
OH603-1 D (4)
Gnd-ATCo does not re-establish procedural separation
G189
Next sector Gnd-ATCo does not detect that procedural separation has not been re-established
MM34-F01
OH602-1 UnD
Gnd-ATCo does not determine which separation is needed for hand over
G192
OHs from Phase 3
G213

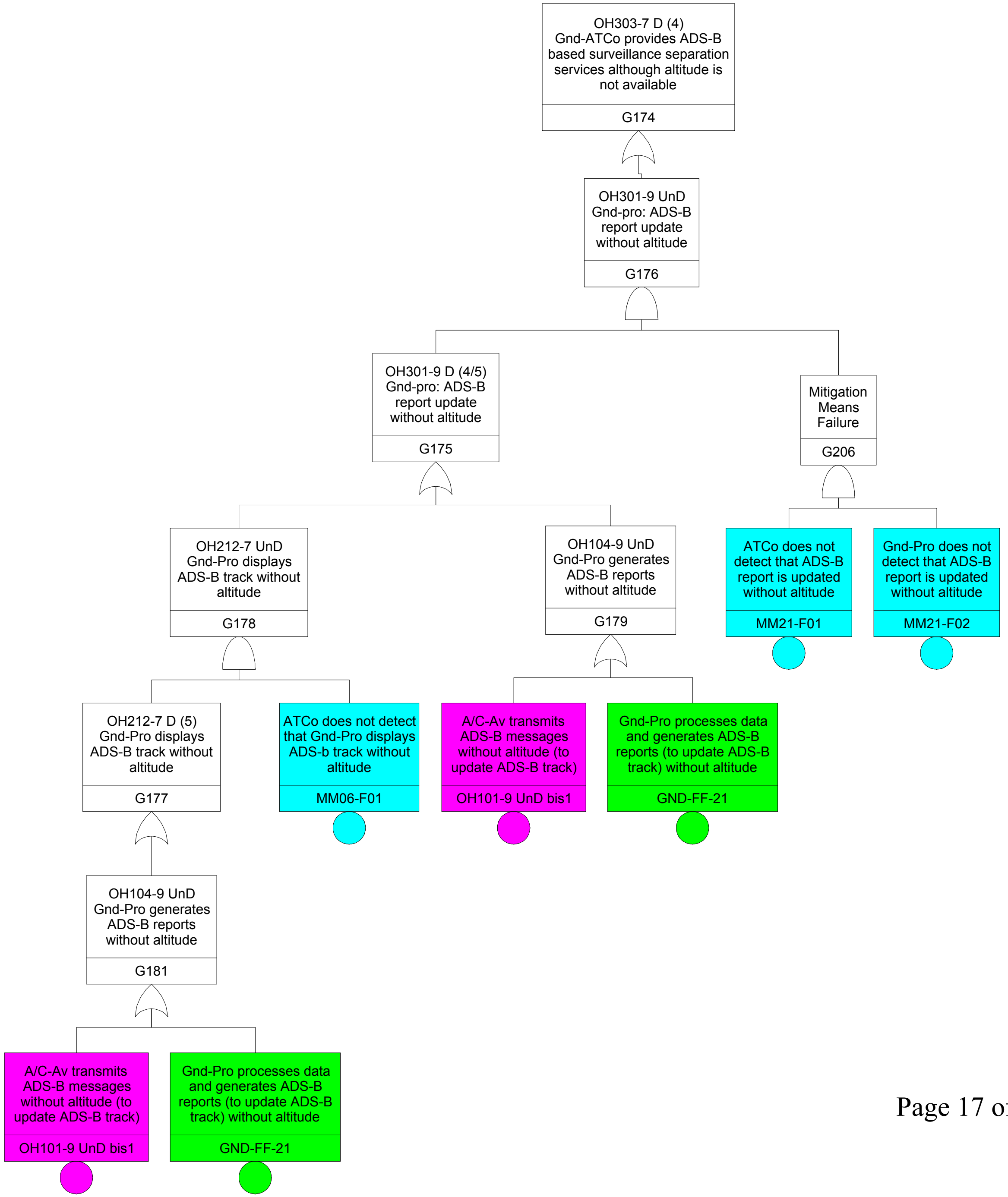

OH603-2 UnD (2/3)
Gnd-ATCo re-establishes incorrect separation value
G195
OH603-2 D (4)
Gnd-ATCo re-establishes incorrect separation value
G194
Next sector Gnd-ATCo does not detect that incorrect separation has been re-established
MM35-F01
OH602-2 UnD
Gnd-ATCo incorrectly determines which separation is needed for hand over
G196
OHs from Phase 3
G212


OH303-5 UnD (3)
Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect altitude.
G158
OH303-5 D (4/5)
Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect altitude.
G157
Mitigation Means Failure
G202
ATCo does not detect that separation services are based on incorrect altitude
MM27-F01
Gnd-Pro does not detect that separation services are based on incorrect altitude
MM27-F02
OH301-5 UnD
Gnd-pro: ADS-B report update with incorrect altitude
G160
OH301-5 D (4/5)
Gnd-pro: ADS-B report update with incorrect altitude
G159
Mitigation Means Failure
G203
ATCo does not detect that ADS-B report is updated with incorrect altitude
MM17-F01
Gnd-Pro does not detect that ADS-B report is updated with incorrect altitude
MM17-F02
OH104-5 UnD
Gnd-Pro generates ADS-B reports with incorrect altitude
G163
OH212-4 UnD
Gnd-Pro displays ADS-B track with incorrect altitude
G162
OH212-4 D (4/5)
Gnd-Pro displays ADS-B track with incorrect altitude
G161
ATCo does not detect during communication exchanges that Gnd-Pro Display ADS-b track with incorrect altitude
MM03-F01
OH101-5 UnD
A/C-Av transmits ADS-B messages with incorrect altitude
G164
A/C-Av transmits ADS-B messages with incorrect altitude (to update ADS-B track)
OH101-5 UnD bis1
Gnd-Pro incorrectly processes data and generates ADS-B reports (to update ADS-B track) with incorrect altitude
GND-FF-13
OH211-5 UnD
Gnd-Pro initiates ADS-B track with incorrect altitude
G165
OH104-5 UnD
Gnd-Pro generates ADS-B reports with incorrect altitude
G166
A/C-Av transmits ADS-B messages with incorrect altitude (to initiate ADS-B track)
OH101-5 UnD bis2
Gnd-Pro incorrectly processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect altitude
GND-FF-12

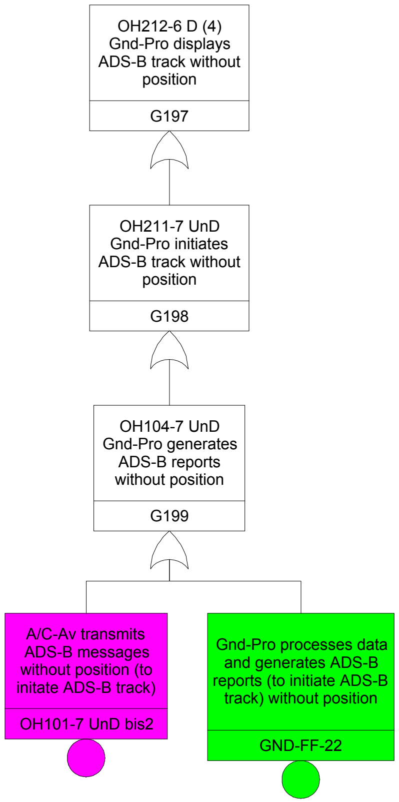

OH303-3 UnD (3)
Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect Id.
G169
OH303-3 D (5)
Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect Id.
G168
Mitigation Means Failure
G204
ATCo does not detect that separation services are based on incorrect Identity
MM25-F01
Gnd-Pro does not detect that separation services are based on incorrect Identity
MM25-F02
OH301-2 UnD
Gnd-pro: ADS-B report update with incorrect Id
G171
OH301-2 D (4/5)
Gnd-pro: ADS-B report update with incorrect Id
G170
Mitigation Means Failure
G205
ATCo does not detect that ADS-B report is updated with incorrect Identity
MM14-F01
Gnd-Pro does not detect that ADS-B report is updated with incorrect Identity
MM14-F02
OH104-2 UnD
Gnd-Pro generates ADS-B reports with incorrect Id
G172
A/C-Av transmits ADS-B messages with incorrect Id
OH101-2 UnD
Gnd-Pro incorrectly processes data and generates ADS-B reports (to update ADS-B track) with incorrect Id
GND-FF-11

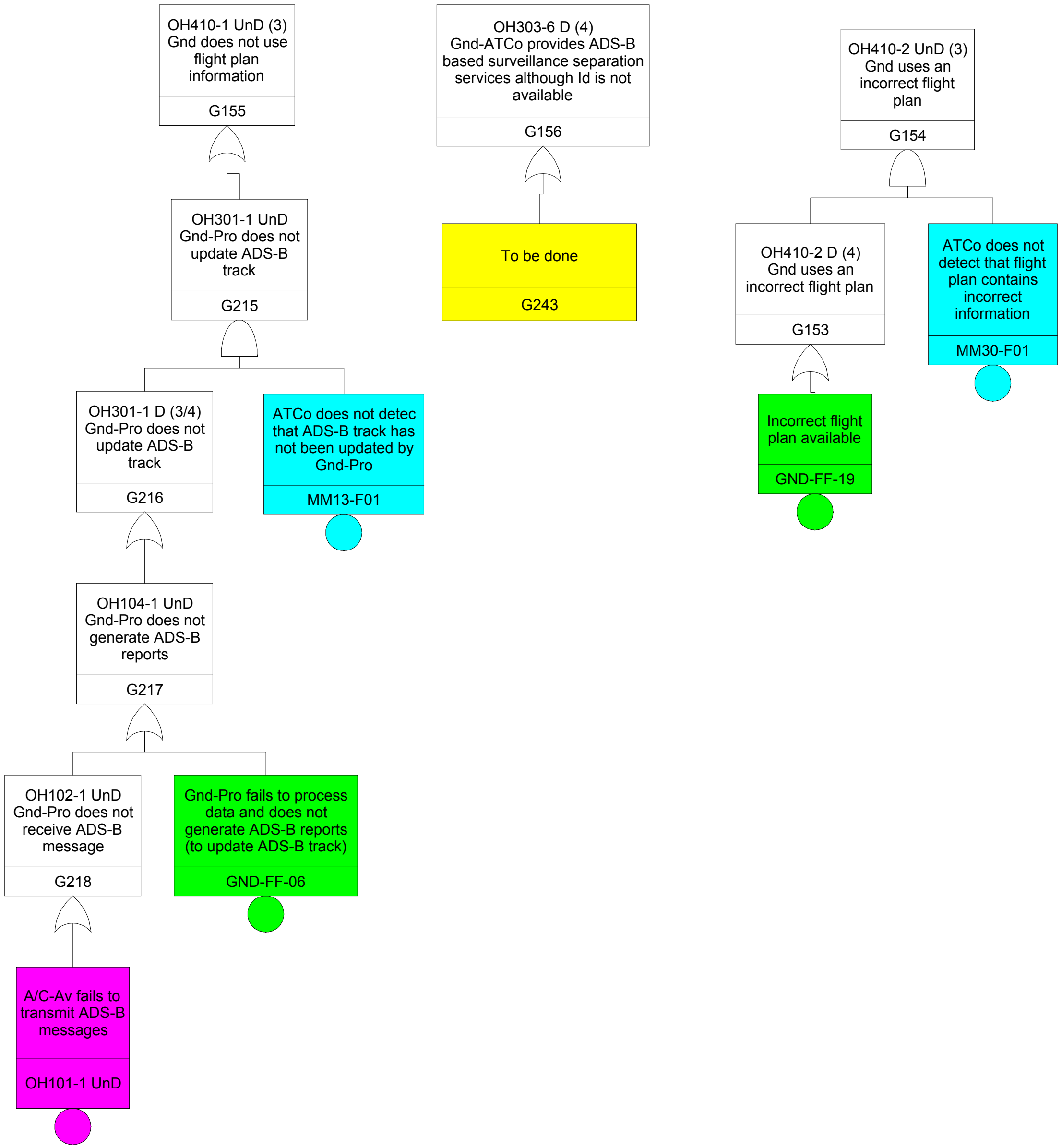

OH301-7 D (2) Gnd-pro: ADS-B report update without position
G183
OH104-7 UnD Gnd-Pro generates ADS-B reports without position
G184
A/C-Av transmits ADS-B messages without position (to update ADS-B track)
OH101-7 UnD bis1
Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without position
GND-FF-18


OH301-6 D (4)
Gnd-pro: ADS-B report update without Id
G186
OH104-6 D
Gnd-Pro generates ADS-B reports without Id
G187
A/C-Av transmits ADS-B messages without Id (to update ADS-B track)
OH101-6 UnD bis2
Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without Id
GND-FF-20



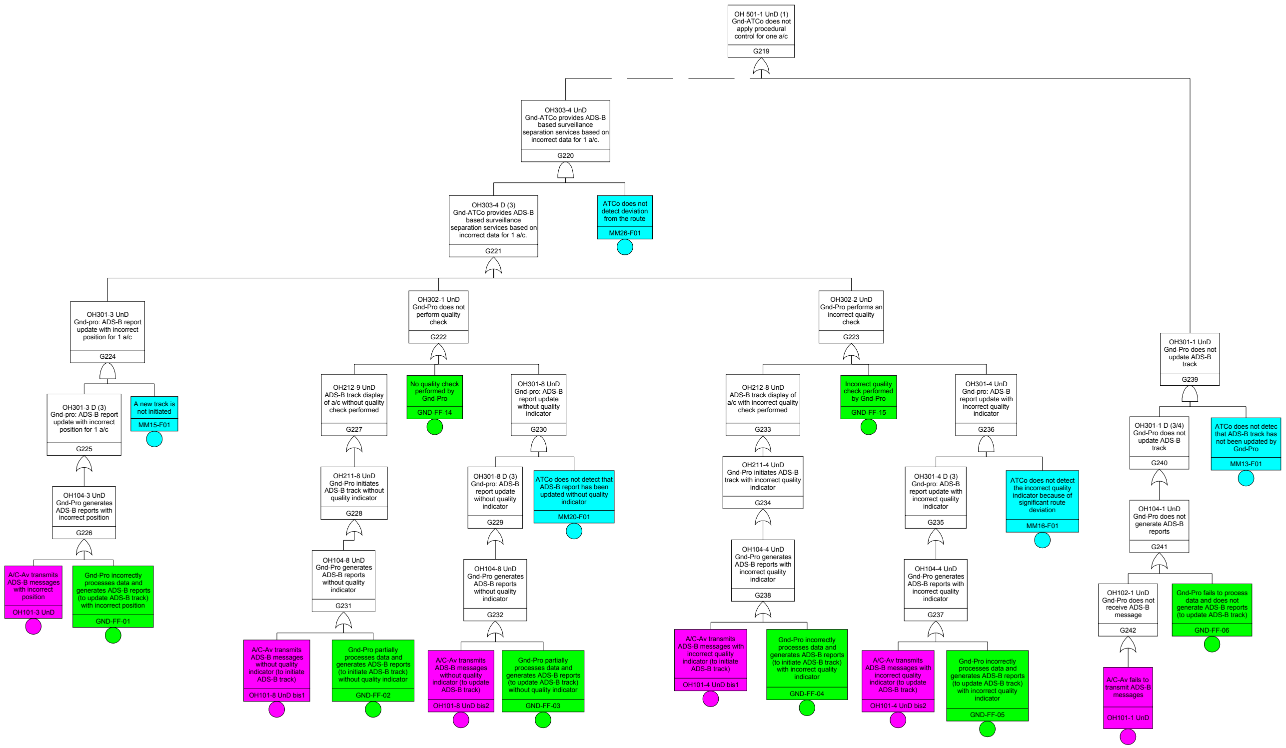
OH303-7 D (4) Gnd-ATCo provides ADS-B based surveillance separation services although altitude is not available
G174
OH301-9 UnD Gnd-pro: ADS-B report update without altitude
G176
OH301-9 D (4/5) Gnd-pro: ADS-B report update without altitude
G175
Mitigation Means Failure
G206
OH212-7 UnD Gnd-Pro displays ADS-B track without altitude
G178
OH104-9 UnD Gnd-Pro generates ADS-B reports without altitude
G179
ATCo does not detect that ADS-B report is updated without altitude
MM21-F01
Gnd-Pro does not detect that ADS-B report is updated without altitude
MM21-F02
OH212-7 D (5) Gnd-Pro displays ADS-B track without altitude
G177
ATCo does not detect that Gnd-Pro displays ADS-b track without altitude
MM06-F01
A/C-Av transmits ADS-B messages without altitude (to update ADS-B track)
OH101-9 UnD bis1
Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without altitude
GND-FF-21
OH104-9 UnD Gnd-Pro generates ADS-B reports without altitude
G181
A/C-Av transmits ADS-B messages without altitude (to update ADS-B track)
OH101-9 UnD bis1
Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without altitude
GND-FF-21


OH212-6 D (4)
Gnd-Pro displays ADS-B track without position
G197
OH211-7 UnD
Gnd-Pro initiates ADS-B track without position
G198
OH104-7 UnD
Gnd-Pro generates ADS-B reports without position
G199
A/C-Av transmits ADS-B messages without position (to initate ADS-B track)
OH101-7 UnD bis2
Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) without position
GND-FF-22


OH410-1 UnD (3)
Gnd does not use flight plan information
G155
OH301-1 UnD
Gnd-Pro does not update ADS-B track
G215
OH301-1 D (3/4)
Gnd-Pro does not update ADS-B track
G216
ATCo does not detec that ADS-B track has not been updated by Gnd-Pro
MM13-F01
OH104-1 UnD
Gnd-Pro does not generate ADS-B reports
G217
OH102-1 UnD
Gnd-Pro does not receive ADS-B message
G218
Gnd-Pro fails to process data and does not generate ADS-B reports (to update ADS-B track)
GND-FF-06
A/C-Av fails to transmit ADS-B messages
OH101-1 UnD
OH303-6 D (4)
Gnd-ATCo provides ADS-B based surveillance separation services although Id is not available
G156
To be done
G243
OH410-2 UnD (3)
Gnd uses an incorrect flight plan
G154
OH410-2 D (4)
Gnd uses an incorrect flight plan
G153
ATCo does not detect that flight plan contains incorrect information
MM30-F01
Incorrect flight plan available
GND-FF-19

Version 0.1a: based on OHA v0.7 results

Version 0.1b: Modifications based on discussion with PhC
03/02/04


OH 501-1 UnD (1)
Gnd-ATCo does not apply procedural control for one a/c
G219
OH303-4 UnD
Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect data for 1 a/c.
G220
OH303-4 D (3)
Gnd-ATCo provides ADS-B based surveillance separation services based on incorrect data for 1 a/c.
G221
ATCo does not detect deviation from the route
MM26-F01
OH301-3 UnD
Gnd-pro: ADS-B report update with incorrect position for 1 a/c
G224
OH301-3 D (3)
Gnd-pro: ADS-B report update with incorrect position for 1 a/c
G225
A new track is not initiated
MM15-F01
OH104-3 UnD
Gnd-Pro generates ADS-B reports with incorrect position
G226
A/C-Av transmits ADS-B messages with incorrect position
OH101-3 UnD
Gnd-Pro incorrectly processes data and generates ADS-B reports (to update ADS-B track) with incorrect position
GND-FF-01
OH302-1 UnD
Gnd-Pro does not perform quality check
G222
OH212-9 UnD
ADS-B track display of a/c without quality check performed
G227
No quality check performed by Gnd-Pro
GND-FF-14
OH301-8 UnD
Gnd-pro: ADS-B report update without quality indicator
G230
OH211-8 UnD
Gnd-Pro initiates ADS-B track without quality indicator
G228
OH104-8 UnD
Gnd-Pro generates ADS-B reports without quality indicator
G231
A/C-Av transmits ADS-B messages without quality indicator (to initiate ADS-B track)
OH101-8 UnD bis1
Gnd-Pro partially processes data and generates ADS-B reports (to initiate ADS-B track) without quality indicator
GND-FF-02
OH301-8 D (3)
Gnd-pro: ADS-B report update without quality indicator
G229
ATCo does not detect that ADS-B report has been updated without quality indicator
MM20-F01
OH104-8 UnD
Gnd-Pro generates ADS-B reports without quality indicator
G232
A/C-Av transmits ADS-B messages without quality indicator (to update ADS-B track)
OH101-8 UnD bis2
Gnd-Pro partially processes data and generates ADS-B reports (to update ADS-B track) without quality indicator
GND-FF-03
OH302-2 UnD
Gnd-Pro performs an incorrect quality check
G223
OH212-8 UnD
ADS-B track display of a/c with incorrect quality check performed
G233
Incorrect quality check performed by Gnd-Pro
GND-FF-15
OH301-4 UnD
Gnd-pro: ADS-B report update with incorrect quality indicator
G236
OH211-4 UnD
Gnd-Pro initiates ADS-B track with incorrect quality indicator
G234
OH104-4 UnD
Gnd-Pro generates ADS-B reports with incorrect quality indicator
G238
A/C-Av transmits ADS-B messages with incorrect quality indicator (to initiate ADS-B track)
OH101-4 UnD bis1
Gnd-Pro incorrectly processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect quality indicator
GND-FF-04
OH301-4 D (3)
Gnd-pro: ADS-B report update with incorrect quality indicator
G235
ATCo does not detect the incorrect quality indicator because of significant route deviation
MM16-F01
OH104-4 UnD
Gnd-Pro generates ADS-B reports with incorrect quality indicator
G237
A/C-Av transmits ADS-B messages with incorrect quality indicator (to update ADS-B track)
OH101-4 UnD bis2
Gnd-Pro incorrectly processes data and generates ADS-B reports (to update ADS-B track) with incorrect quality indicator
GND-FF-05
OH301-1 UnD
Gnd-Pro does not update ADS-B track
G239
OH301-1 D (3/4)
Gnd-Pro does not update ADS-B track
G240
ATCo does not detec that ADS-B track has not been updated by Gnd-Pro
MM13-F01
OH104-1 UnD
Gnd-Pro does not generate ADS-B reports
G241
OH102-1 UnD
Gnd-Pro does not receive ADS-B message
G242
Gnd-Pro fails to process data and does not generate ADS-B reports (to update ADS-B track)
GND-FF-06
A/C-Av fails to transmit ADS-B messages
OH101-1 UnD

Elementary Causes and Mitigation means

The following Elementary causes have been identified when developing the fault trees

Elementary Causes Reference	Elementary Causes description
GROUND DOMAIN	
FBx-F01	ATCo fails to contact a/c for identification
GND-FF-01	Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) with incorrect position
GND-FF-02	Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) without quality indicator
GND-FF-03	Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without quality indicator
GND-FF-04	Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect quality indicator
GND-FF-05	Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) with incorrect quality indicator
GND-FF-06	Gnd-Pro fails to process data and does not generate ADS-B reports (to update ADS-B track)
GND-FF-07	Gnd-Pro fails to process data and does not generate ADS-B reports (to initiate ADS-B track)
GND-FF-08	Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) without Id
GND-FF-09	Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect Id
GND-FF-10	Gnd-Pro incorrectly assignes an updates ADS-B report to another a/c
GND-FF-11	Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) with incorrect Id
GND-FF-12	Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect altitude
GND-FF-13	Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) with incorrect altitude
GND-FF-14	No quality check performed by Gnd-Pro
GND-FF-15	Incorrect quality check performed by Gnd-Pro
GND-FF-16	No association between track and flight plan
GND-FF-17	Incorrect association between track and flight plan
GND-FF-18	Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track)

	without position
GND-FF-19	Incorrect flight plan available
GND-FF-20	Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without Id
GND-FF-21	Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without altitude
GND-FF-22	Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) without position
AIRBORNE DOMAIN	
OH101-1 UnD	A/C-Av fails to transmit ADS-B messages
OH101-2 UnD	A/C-Av transmits ADS-B messages with incorrect Id
OH101-3 UnD	A/C-Av transmits ADS-B messages with incorrect position
OH101-4 UnD bis1	A/C-Av transmits ADS-B messages with incorrect quality indicator (to initiate ADS-B track)
OH101-4 UnD bis2	A/C-Av transmits ADS-B messages with incorrect quality indicator (to update ADS-B track)
OH101-5 UnD bis1	A/C-Av transmits ADS-B messages with incorrect altitude (to update ADS-B track)
OH101-5 UnD bis2	A/C-Av transmits ADS-B messages with incorrect altitude (to initiate ADS-B track)
OH101-6 UnD bis1	A/C-Av transmits ADS-B messages without Id (to initiate ADS-B track)
OH101-6 UnD bis2	A/C-Av transmits ADS-B messages without Id (to update ADS-B track)
OH101-7 UnD bis1	A/C-Av transmits ADS-B messages without position (to update ADS-B track)
OH101-7 UnD bis2	A/C-Av transmits ADS-B messages without position (to initate ADS-B track)
OH101-8 UnD bis1	A/C-Av transmits ADS-B messages without quality indicator (to initiate ADS-B track)
OH101-8 UnD bis2	A/C-Av transmits ADS-B messages without quality indicator (to update ADS-B track)
OH101-9 UnD bis1	A/C-Av transmits ADS-B messages without altitude (to update ADS-B track)

The following mitigations means have been used in the fault trees

MM02	Flight Plan is available
MM02	A/C contact ATC
MM03	ATCo detect during communication exchanges that Gnd-Pro Display ADS-b track with incorrect altitude
MM04	ATCo detect that Id is not displayed for 1 a/c
MM06	ATCo detect that Gnd-Pro displays ADS-b track without altitude
MM08	ATCo detect (after cross-check with flight plan) that ADS-B track is displayed with an incorrect Id.
MM09	ATCo associate a track with its flight plan
MM10	ATCo detect an incorrect association between track displayed and flight plan
MM11	FC contact the ATC
MM12	Unintended FC detect that ATC erroneously contact them
MM13	ATCo detec that ADS-B track has not been updated by Gnd-Pro
MM14_1	ATCo detect that ADS-B report is updated with incorrect Identity
MM14_2	Gnd-Pro detect that ADS-B report is updated with incorrect Identity
MM15	A new track is initiated
MM16	ATCo detect the incorrect quality indicator because of significant route deviation
MM17_1	ATCo detect that ADS-B report is updated with incorrect altitude
MM17_2	Gnd-Pro detect that ADS-B report is updated with incorrect altitude
MM20	ATCo detect that ADS-B report has been updated without quality indicator
MM21_1	ATCo detect that ADS-B report is updated without altitude
MM21_2	Gnd-Pro detect that ADS-B report is updated without altitude
MM22	ATCo detect that updated ADS-B report is assigned to another a/c
MM23	Track is dropped. Reminder is provided to ATCo
MM25_1	ATCo detect that separation services are based on incorrect Identity
MM25_2	Gnd-Pro detect that separation services are based on incorrect Identity
MM26	ATCo detect deviation from the route
MM27_1	ATCo detect that separation services are based on incorrect altitude
MM27_2	Gnd-Pro detect that separation services are based on incorrect altitude
MM30	ATCo detect that flight plan contains incorrect information
MM31	Unintended FC detect that ATC erroneously applies them procedural control
MM34	Next sector Gnd-ATCo detect that procedural separation has not been re-established
MM35	Next sector Gnd-ATCo detect that incorrect separation has been re-established

Safety Objectives at ground domain level

SO – Gnd 1: The likelihood that ATCo fails to contact a/c for identification shall be less than 1E-2 per FH

SO – Gnd 2: Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) with incorrect position shall be less than 1E-4 per FH

SO – Gnd 3: Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) without quality indicator shall be less than 1E-7 per FH

SO – Gnd 4: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without quality indicator shall be less than 1E-4 per FH

SO – Gnd 5: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect quality indicator shall be less than 1E-6 per FH

SO – Gnd 6: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) with incorrect quality indicator shall be less than1E-4 per FH

SO – Gnd 7: The likelihood that Gnd-Pro fails to process data and does not generate ADS-B reports (to update ADS-B track) shall be less than 1E-6 per FH

SO – Gnd 8: The likelihood that Gnd-Pro fails to process data and does not generate ADS-B reports (to initiate ADS-B track) shall be less than 1E-2 per FH

SO – Gnd 9: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) without Id shall be less than 1E-2 per FH

SO – Gnd 10: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect Id shall be less than 1E-2 per FH

SO – Gnd 11: The likelihood that Gnd-Pro incorrectly assigned an updates ADS-B report to another a/c shall be less than 1E-4 per FH

SO – Gnd 12: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) with incorrect Id shall be less than 1E-2 per FH

SO – Gnd 13: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) with incorrect altitude shall be less than 1E-2 per FH

SO – Gnd 14: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) with incorrect altitude shall be less than shall be less than 1E-2 per FH

SO – Gnd 15: The likelihood that No quality check performed by Gnd-Pro shall be less than 1E-6 per FH

SO – Gnd 16: The likelihood that Incorrect quality check performed by Gnd-Pro shall be less than 1E-6 per FH

SO – Gnd 17: The likelihood that No association between track and flight plan shall be less than 1E-2 per FH

SO – Gnd 18: The likelihood that Incorrect association between track and flight plan shall be less than 1E-2 per FH

SO – Gnd 19: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without position shall be less than 1E-6 per FH

SO – Gnd 20: The likelihood that Incorrect flight plan available shall be less than 1E-2 per FH

SO – Gnd 21: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without Id shall be less than 1E-2 per FH

SO – Gnd 22: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to update ADS-B track) without altitude shall be less than 1E-4 per FH

SO – Gnd 23: The likelihood that Gnd-Pro processes data and generates ADS-B reports (to initiate ADS-B track) without position shall be less than 1E-6 per FH

Safety Objectives at airborne domain level

SO-AC 1: The likelihood that A/C-Av fails to transmit ADS-B messages shall be less than 1E-7 per FH

SO-AC 2: The likelihood that A/C-Av transmits ADS-B messages with incorrect Id shall be less than 1E-3 per FH

SO-AC 3: The likelihood that A/C-Av transmits ADS-B messages with incorrect position shall be less than 1E-5 per FH

SO-AC 4: The likelihood that A/C-Av transmits ADS-B messages with incorrect quality indicator (to initiate ADS-B track) shall be less than 1E-7 per FH

SO-AC 5: The likelihood that A/C-Av transmits ADS-B messages with incorrect quality indicator (to update ADS-B track) shall be less than 1E-5 per FH

SO-AC 6: The likelihood that A/C-Av transmits ADS-B messages with incorrect altitude (to update ADS-B track) shall be less than 1E-3 per FH

SO-AC 7: The likelihood that A/C-Av transmits ADS-B messages with incorrect altitude (to initiate ADS-B track) shall be less than 1E-3 per FH

SO-AC 8: The likelihood that A/C-Av transmits ADS-B messages without Id (to initiate ADS-B track) shall be less than 1E-3 per FH

SO-AC 9: The likelihood that A/C-Av transmits ADS-B messages without Id (to update ADS-B track) shall be less than 1E-3 per FH

SO-AC 10: The likelihood that A/C-Av transmits ADS-B messages without position (to update ADS-B track) shall be less than 1E-7 per FH

SO-AC 11: The likelihood that A/C-Av transmits ADS-B messages without position (to initiate ADS-B track) shall be less than 1E-7 per FH

SO-AC 12: The likelihood that A/C-Av transmits ADS-B messages without quality indicator (to initiate ADS-B track) shall be less than 1E-7 per FH

SO-AC 13: The likelihood that A/C-Av transmits ADS-B messages without quality indicator (to update ADS-B track) shall be less than 1E-5 per FH

SO-AC 14: The likelihood that A/C-Av transmits ADS-B messages without altitude (to update ADS-B track) shall be less than 1E-3 per FH

Safety Objectives at Mitigation Means level

SO-MM 1: The likelihood that Flight Plan is not available shall be less than 1E-2 per FH

SO-MM 2: The likelihood that A/C does not contact ATC shall be less than 1E-2 per FH

SO-MM 3: The likelihood that ATCo does not detect during communication exchanges that Gnd-Pro Display ADS-b track with incorrect altitude shall be less than 1E-2 per FH

SO-MM 4: The likelihood that ATCo does not detect that Id is not displayed for 1 a/c shall be less than 1E-2 per FH

SO-MM 5: The likelihood that ATCo does not detect that Gnd-Pro displays ADS-b track without altitude shall be less than 1E-2 per FH

SO-MM 6: The likelihood that ATCo does not detect (after cross-check with flight plan) that ADS-B track is displayed with an incorrect Id. shall be less than 1E-2 per FH

SO-MM 7: The likelihood that ATCo is unable to associate a track with its flight plan shall be less than 1E-2 per FH

SO-MM 8: The likelihood that ATCo does not detect an incorrect association between track displayed and flight plan shall be less than 1E-2 per FH

SO-MM 9: The likelihood that FC does not contact the ATC shall be less than 1E-2 per FH

SO-MM 10: The likelihood that Unintended FC do not detect that ATC erroneously contact them shall be less than 1E-2 per FH

SO-MM 11: The likelihood that ATCo does not detec that ADS-B track has not been updated by Gnd-Pro shall be less than 1E-2 per FH

SO-MM 12: The likelihood that ATCo does not detect that ADS-B report is updated with incorrect Identity shall be less than 1E-2 per FH

SO-MM 13: The likelihood that Gnd-Pro does not detect that ADS-B report is updated with incorrect Identity shall be less than 1E-2 per FH

SO-MM 14: The likelihood that A new track is not initiated shall be less than 1E-2 per FH

SO-MM 15: The likelihood that ATCo does not detect the incorrect quality indicator because of significant route deviation shall be less than 1E-2 per FH

SO-MM 16: The likelihood that ATCo does not detect that ADS-B report is updated with incorrect altitude shall be less than 1E-2 per FH

SO-MM 17: The likelihood that Gnd-Pro does not detect that ADS-B report is updated with incorrect altitude shall be less than 1E-2 per FH

SO-MM 18: The likelihood that ATCo does not detect that ADS-B report has been updated without quality indicator shall be less than 1E-2 per FH

SO-MM 19: The likelihood that ATCo does not detect that ADS-B report is updated without altitude shall be less than 1E-2 per FH

SO-MM 20: The likelihood that Gnd-Pro does not detect that ADS-B report is updated without altitude shall be less than 1E-2 per FH

SO-MM 21: The likelihood that ATCo does not detect that updated ADS-B report is assigned to another a/c shall be less than 1E-2 per FH

SO-MM 22: The likelihood that Track is not dropped. No reminder is provided to ATCo shall be less than 1E-2 per FH

SO-MM 23: The likelihood that ATCo does not detect that separation services are based on incorrect Identity shall be less than 1E-2 per FH

SO-MM 24: The likelihood that Gnd-Pro does not detect that separation services are based on incorrect Identity shall be less than 1E-2 per FH

SO-MM 25: The likelihood that ATCo does not detect deviation from the route shall be less than 1E-2 per FH

SO-MM 26: The likelihood that ATCo does not detect that separation services are based on incorrect altitude shall be less than 1E-2 per FH

SO-MM 27: The likelihood that Gnd-Pro does not detect that separation services are based on incorrect altitude shall be less than 1E-2 per FH

SO-MM 28: The likelihood that ATCo does not detect that flight plan contains incorrect information shall be less than 1E-2 per FH

SO-MM 29: The likelihood that Unintended FC do not detect that ATC erroneously applies them procedural control shall be less than 1E-2 per FH

SO-MM 30: The likelihood that Next sector Gnd-ATCo does not detect that procedural separation has not been re-established shall be less than 1E-2 per FH

SO-MM 31: The likelihood that Next sector Gnd-ATCo does not detect that incorrect separation has been re-established shall be less than 1E-2 per FH

Safety Requirement

SR – GND1 : If call sign is missing in the ADS-B report, 24-bit address shall be used.

SR- GND2: A/C without position shall remain under procedural control.

SR- GND3: A/C without quality indicator shall remain under procedural control.

SR – AC1: An Ident button shall be provided at the ADS-B out equipment level.