OFA 01.01.01 GBAS CAT III L1 Safety Assessment Report

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Abstract

This document contains the Specimen Safety Assessment for a typical application of the OFA01.01.01 (LVPs using GBAS) relative to GBAS CAT II-III operations based on single GPS frequency (L1). This operational safety assessment addresses both CAT III approach & landing operations and Guided Take-Off in Low Visibility Conditions. This assessment was conducted considering the operational change (optimised operations) described in the GBAS CAT II/III Functional Description Report/OSED (06.08.05 D11) and the technical change described in the GBAS CONOPS including CAT II/III specificities (15.03.06 D20). The report presents the assurance that the identified Safety Requirements for the V1-V3 phases are complete, correct and realistic.

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Executive summary

This document contains the Specimen Safety Assessment for a typical application of the OFA01.01.01 (LVPs using GBAS) relative to GBAS CAT II-III operations based on single GPS frequency (L1) known as GAST-D (GBAS Approach Service Type D). The applicable Operational Improvement is AO-0505-A.

This operational safety assessment addresses both CAT III approach & landing operations and Guided Take-Off in Low Visibility Conditions. This assessment was conducted considering the operational change (optimised operations) described in the GBAS CAT II/III Functional Description Report/OSED (06.08.05 D11) and the technical change described in the GBAS CONOPS including CAT II/III specificities (15.03.06 D20).

This operational safety assessment does not address GBAS CAT II approach operations because there is no ICAO GAST-D requirements specific to CAT II. Furthermore GBAS CAT III approach and landing operations are considered to be more challenging and demanding than CAT II operations.

This operational safety assessment started by the identification of Safety Criteria describing what is acceptably safe for the operational concept supported by GAST-D. Then Safety Objectives were derived at operational level (OSED) to satisfy the Safety criteria in normal, abnormal and failure conditions. Finally when the high-level design architecture supporting the operational level was defined, Safety Requirements in normal/abnormal conditions and considering failure aspects were derived to satisfy the Safety Objectives. Safety Requirements were determined though the success and the failure approach as described by the SESAR Safety reference Material (SRM) developed by Project 16.06.01.

During this iterative process, safety validation objectives have been identified and have been addressed during Validation Exercises.

This report presents the assurance that the Safety Requirements for the V1-V3 phases are complete, correct and realistic. .

Furthermore, assumptions, issues, recommendations and limitations have been identified during the safety assessment.

- The main assumption not validated yet is relative to the GBAS CAT III obstacle clearance and should be addressed at the ICAO level (IFPP) to confirm that GBAS CAT III obstacle clearance is identical to ILS CAT III.

- The safety issue which remains open is relative to the phraseology to be used during GBAS operation (GBAS or GLS) and this issue shall be addressed at ICAO level.

- Several recommendations remains open in particular the one associated to naming and phraseology used for GBAS which recommends consistency between radiotelephony communications, charting information, ATC displayed information and flight deck indication.

It should be noted that this safety assessment will be revisited considering the new task T33 of SESAR Project 15.03.06.

1 Introduction

1.1 Background

The future concept for runway operations aims to increase capacity in terms of runway throughput and enhance predictability at the airport through improvements to all aspects of runway operations, from planning through to full exploitation of new technologies such as GBAS. This Safety Assessment Report addresses the Operational Improvement AO-0505-A Improved Low Visibility Runway Operations using GBAS CAT II/III for precision approaches based on GPS L1 addressed in Operational Focus Area (OFA) 01.01.01 LVP using GBAS.

The operations included in LVP using GBAS have minima lower than for CAT I approach operations (CAT II/III, Lower than Standard Cat I and Other than Standard CAT II) as well as low visibility take-off operations.

The use of GBAS removes the need to protect ILS CAT II/III Critical and Sensitive areas (currently penalizing ILS operations) and therefore the spacing between aircraft in GBAS should be reduced thus improving landing rates.

GBAS CAT II-III L1 is the initial GBAS CAT II-III solution called also ICAO-GAST-D[1] solution which is based on the GPS L1 single frequency. This safety assessment report uses the ICAO term GAST-D in lieu of GBAS CAT II-III L1 when technology is mentioned whereas it uses the term GBAS CAT III when CAT III approach and landing operations based on GAST-D are mentioned.

1.2 General Approach to Safety Assessment

1.2.1 A Broader approach

The safety assessment has been conducted in accordance with the SESAR Safety Reference Material (**[1]**) and associated Guidance (**[2]**). The SRM is based on a twofold approach:

- a new *success approach* which is concerned with the safety of CAT III approach and landing operations supported by GAST-D in the absence of failure; and
- a conventional *failure approach* which is concerned with the safety of CAT III approach and landing operations supported by GAST-D in the event of failure within the end-to-end System

These two approaches are applied to the derivation of safety properties at each stage of the development of CAT III approach and landing operations supported by GAST-D, as follows:

Safety specification at the OSED Level

This is defined as what the CAT III approach and landing operations supported by GAST-D has to achieve at the ATM operational level in order that the requirements of the airspace users are satisfied - *i.e.* it takes a “black-box” view of the CAT III approach and landing operations supported by GAST-D and includes what is “shared” between the users (aircraft) and the ATS Service Provider.

From a safety perspective, the users’ requirements are expressed in the form of Safety Criteria (see section **2.5** below) and the Specification is expressed in the form of Safety Objectives (functionality & performance and integrity/reliability properties), which are derived during the V1 and V2 phases of the development lifecycle. The purpose here is to check the completeness of the CONOPS and OSED (**[5][6]**), and, if relevant, inform the OSED with additional safety objectives and the validation plan **[7]** with additional V2 validation objectives that will be revealed by the safety analysis.

In addition to CAT III approach and Landing, guided take-off operations in LVC supported by GAST-D will be assessed.

The safety specification at OSED level could be summarized as follows:

[1] **G**BAS **A**pproach **S**ervice **T**ype D

- Safety Criteria (SAC) which are described in section 2.5 of this report
- Safety objectives (to satisfy Safety Criteria) which are defined at that stage and include:
    - Safety Objectives (functionality and performance) relative to normal conditions described in section 2.7 (supported by Appendix E)
    - Safety Objectives (functionality and performance) relative to abnormal conditions described in section 2.8
    - Safety Objectives (Integrity/reliability) relative to failure aspects described in section 2.9 (supported by Appendix F)

Safe Design at the SPR Level

This describes what the CAT III approach and landing operations supported by GAST-D itself is actually like internally and includes all those system properties that are not directly required by the users but are implicitly necessary in order to fulfil the specification and thereby satisfy the User requirements. Design is essentially an internal, or "white-box", view of the CAT III approach and landing operations supported by GAST-D. Herein, it takes the form of a SPR-level Model of the GAST-D System supporting the CAT III approach and landing operations in terms of human actors and machine-based elements that deliver the functionality.

It should be noted that no SPR document will be developed within the context of this project.

From a safety perspective, the Design is expressed in the form of Safety Requirements (sub-divided into functionality & performance and integrity/reliability properties), which are derived during the V2/V3 phase of the development lifecycle. The purpose here is to check the completeness and correctness of the High-level design to support the operations described at OSED level. Furthermore during this safety analysis additional V3 validation objectives might be identified and be included in the validation plan **[7]**.

In addition to CAT III approach and Landing, guided take-off operations in LVC supported by GAST-D will be assessed.

The Safe design at SPR level could be summarized as follows:

- A high-level design (SPR-level Model) is defined and described in section 3.2
- Safety Requirements (to satisfy Safety Objectives) are defined at that stage and include:
    - Safety Requirements relative to normal conditions described in section 3.2.3 and 3.3
    - Safety Requirements relative to abnormal conditions described in section 3.4
    - Safety Requirements relative to failure aspects described in section 3.5

1.3 Scope of the Safety Assessment

The safety assurance activities to be carried out during this safety assessment are specified in the Safety Plan [4]. This Safety Assessment Report covers only the V1, V2 and V3 stages of the lifecycle as described in section 1.2. It also presents the assurance that the Safety Requirements are complete, correct and (from a potential Implementation viewpoint) realistic.

The concept, which is the subject of this safety assessment, applies to:

- aircraft conducting CAT III approach and landing operations supported by GAST-D
    - With decision height lower than 100 ft or no decision height and runway visual range less than 200m but not less than 75 m.
    - from the interception of the final approach path to the vacation of the Runway Protected Area to Apron/Taxiway control function

  - by considering the transition between final approach and the missed approach
- aircraft conducting guided take-off operations in low visibility conditions
  - with RVR lower than 400 m but not less than 75 m
  - From the start of the take-off to main wheel lift-off.

This operational safety assessment does not address GBAS CAT II approach operations because there is no ICAO GAST-D requirements specific to CAT II. Furthermore GBAS CAT III approach and landing operations are considered to be more challenging and demanding compared to CAT II operations.

As per (**[5]**), the SESAR OI Step that falls within the scope of this safety assessment is:

> AO-0505-A: Use GBAS CAT II/III based on GPS L1 for precision approaches. The main benefit is the increased runway capacity in poor weather conditions as the glide path and azimuth signals will face hardly any interference from previous landing aircraft or other obstacles. More sustained accuracy in aircraft guidance on final approach.

1.4 Layout of the Document

- **Section 02** derives a specification for CAT III approach and landing and guided take-off operations supported by GAST-D, in the form of Safety Objectives, such that the Safety Criteria specified therein are achievable.
- **Section 03** describes an SPR-level Design of the CAT III approach and landing and guided take-off operations supported by GAST-D and derives Safety Requirements such that the Specification is satisfied by the Safety Requirements.
- **Section 4** is the conclusion section.
- **Appendix A** presents a consolidated list of all the Safety Objectives
- **Appendix B** presents a consolidated list of all the Safety Requirements
- **Appendix C** lists all the Assumptions, Safety Issues, Recommendations & Limitations that arose during safety assessment documented herein.
- **Appendix D** describes a general form of the relevant Accident-Incident Models that are used in the derivation of the Specification (in particular the Safety Criteria – see section 2.5).
- **Appendix E** presents the details for the derivation of Safety Objectives in normal conditions.
- **Appendix F** presents the details of the Operational Hazard derivation (OHA table)

1.5 Acronyms and Terminology

Term	Definition
A/C	Aircraft
ADS-B	Automatic Dependent Surveillance-Broadcast
AIM	Accident Incident Model
AIP	Aeronautical Information Publication
ANS	Air Navigation Service

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Term	Definition
ANSP	Air Navigation Service Provider
ARNS	Aeronautical Radio Navigation Service
A-SMGCS	Advanced Surface Movement Guidance and Control Systems
ATC	Air Traffic Control
ATCO	Air Traffic COntroller
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATS	Air Traffic Service
AU	Airspace Users
AWO	All Weather Operations
CAT	Category
C/A	Coarse/Acquisition
CDO	Continuous Descent Operation
CFIT	Controlled Flight Into Terrain
CFTT	Controlled Flight Toward Terrain
CONOPS	Concept for Operation
CRM	Collision Risk Model
CSA	Critical and Sensitive Area
DA	Decision Altitude
DH	Decision Height
Dmax	Maximum Use Distance
DOP	Dilution Of Precision
EANPG	European Air Navigation Planning Group
FAF	Final Approach Fix
FAP	Final Approach Point
FAS	Final Approach Segment

Term	Definition
FAST	Facility Approach Service Type
FHA	Functional Hazard Assessment
FTE	Flight Technical Error
FMEA	Failure Mode and effect Analysis
FMS	Flight Management System
FPLN	Flight Plan
GAEC	GBAS Airborne Equipment Classification
GAST	GBAS Approach Service Type
GAST C	GBAS Approach Service Type C
GAST D	GBAS Approach Service Type D
GBAS	Ground Based Augmentation System
GBAS GS	GBAS Ground Station
GFC	GBAS Facility Classification
GLS	GBAS Landing System
GNSS	Global Navigation Satellite System
GLI or GP	ILS Glide
GPA	Glide Path Angle
GPWS	Ground Proximity Warning System
GS	Ground Subsystem
HAL	Human Assurance Level
HAZID	HAZard IDentification
Hp	Pre-existing Hazard
IAF	Initial Approach Fix
ICAO	International Civil Aviation Organization
IFP	Instrument Flight Procedure
IFPP	Instrument Flight Procedure Panel of ICAO

Term	Definition
ILS	Instrument Landing System
LOC	ILS Localizer
LOCA	Local Object Consideration Area
LPV	Localizer Performance with Vertical guidance
LVC	Low Visibility Conditions
LVO	Low Visibility Operation
LVP	Low Visibility Procedures
MA	Missed Approach
MAC	Mid Air Collision
MMR	Multi Mode Receiver
MOPS	Minimum Operational Performance Specification
MSAW	Minimum Safe Altitude Warning
MSL	Mean Sea Level
NOTAM	NOtice To Air Men
NSA	National Supervisory Authority
NSE	Navigation System Error
NTZ	Non Transgression Zone
OAS	Obstacle Assessment Surface
OCA	Obstacle Clearance Altitude
OCH	Obstacle Clearance Height
OFA	Operational Focus Area
OFZ	Obstacle Free Zone
OSED	Operational Service and Environment Definition
PAL	Procedure Assurance Level
PANS ATM	Procedures for Air Navigation Services Air Traffic Management
PANS OPS	Procedures for Air Navigation Services OPerationS

Term	Definition
PBN	Performance Based Navigation
PSSA	Preliminary System Safety Assessment
RC	Runway Collision
RCS	Risk Classification Scheme
RE	Runway Excursion
RFI	Radio Frequency Interference
RI	Runway Incursion
RNAV	aRea NAVigation
RNP	Required Navigation Performance
RNP APCH (LNAV, LNAV/VNAV, LPV)	RNP Approach (Lateral Navigation, Vertical Navigation, Localiser Performance with Vertical guidance)
RNP AR APCH	RNP Authorization Required Approach
ROT	Runway Occupancy Time
RVR	Runway Visual Range
S	Spacing
SAC	SAfety Criteria
SAM	Safety Assessment Methodology
SAR	Safety Assessment Report
SARPS	Standards And Recommended Practices
SC	Severity Condition
SESAR	Single European Sky ATM Research Programme
SESAR Programme	The programme which defines the Research and Development activities and Projects for the SJU.
SIS	Signal In Space
SJU	SESAR Joint Undertaking (Agency of the European Commission)
SJU Work Programme	The programme which addresses all activities of the SESAR Joint Undertaking Agency.
SMR	Surface Movement Radar

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Term	Definition
SO	Safety Objective
SPR	Safety and Performance Requirements
SR	Safety Requirement
SRM	SESAR Safety Reference Material
SSR	Secondary Surveillance Radar
STAR	STandard Instrument ARrival
SWAL	Software Assurance Level
TAWS	Terrain Awareness and Warning System
TCH	Threshold Crossing Height
THR	Threshold
T/O	Take Off
TS	Technical Specification
VAL	Validation
VDB	VHF Data Broadcast
VTF	Vector To Final
xLS	ILS, MLS and GLS Landing Systems

1.6 References

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[21].ICAO NSP, GBAS CAT II-III Development Baseline SARPS proposal 28/05/10

[22].EUROCONTROL Safety assessment of optimised operations in Low Visibility Conditions utilising landing clearance delivery position and/or landing clearance line concept Ed 1.5 dated 15 Dec 2010

[23].EASA CS AWO Decision 2003/6/RM 17 Oct 2003

[24].15.3.6 D03 High level performance allocation and split of responsibilities between air and ground

[25].15.3.6 D04 Ground architecture and airport installation

[26].15.3.6 D06 Vulnerability Report

[27].15.3.6 D16 System validation Plan

[28].ICAO-NSP Conceptual framework for the proposal for GBAS to support CAT III operations, version 6.5

[29].6.8.5 D45 Validation Plan Advanced procedure RNP to GLS concept for V3- Edition 00.01.000 dated 17 September 2013

[30]. 6.8.5 D46 Validation Report for advanced procedure (RNP to GLS concept) for V3

[31]. B4.1 D39 Updated performance validation target allocation for Concept Step 1 and 2- Edition 03.00.00 dated 05 November 2013

[32].ICAO-NSP October 14 WG1&2 / Flimsy 15 - Proposal for requirement changes supporting GBAS Guided Take-Off operation

2 Safety specifications at the OSED Level

2.1 Scope

This section addresses the following activities:

- description of the key properties of the Operational Environment that are relevant to the safety assessment – section **2.3**
- Setting of the Safety Criteria – sections **2.4** and **2.5**
- identification of the pre-existing hazards that affect traffic in approach/ landing and guided take-off operations in relevant operational environment (airspace) and the risks of which operational services provided by ATS System may reasonably be expected to mitigate to some degree and extent – section **2.6.**
- Comprehensive determination of the operational services that are provided for CAT III approach and landing and guided take-off operations supported by GAST-D to address the relevant pre-existing hazards and derivation of Safety Objectives (success approach) in order to mitigate the pre-existing risks under normal operational conditions – section **2.7**.
- assessment of the adequacy of the operational services provided for CAT III approach and landing and guided take-off operations supported by GAST-D under abnormal conditions of the Operational Environment – section **2.8**.
- assessment of the adequacy of the operational services provided for CAT III approach and landing and guided take-off operations supported by GAST-D in the case of internal failures and mitigation of the Operational hazards (derivation of Safety Objectives (failure approach)) – section **2.9**.
- impacts of CAT III approach and landing or guided take-off in LVC supported by GAST-D upon adjacent airspace – section **2.10**
- achievability of the Safety Criteria – section **2.11**
- validation & verification of the safety specification – section **2.12**

2.2 Overview of the Change

The change is twofold:

- A technological change by moving from ILS CAT III to GBAS CAT III (GAST-D)
- An operational change by introducing optimised operations in Low Visibility Conditions

2.2.1 A technological change: GBAS GAST-D Concept

GBAS Approach Service Types (GAST) is defined as the matched set of airborne and ground performance and functional requirements that are intended to be used in concert in order to provide approach guidance with quantifiable performance. GAST-D has been introduced to support landing operations in lower than CAT I visibility conditions including Category III operations.

With GAST-D concept, the ground station protects the aircraft in the range domain by monitoring each GPS measurement received on L1 frequency only against an acceptable error limit. It then transfers parameters through the VHF Data Broadcast (VDB) in order that the aircraft compute protection level to protect the aircraft in the position domain. The aircraft receives the integrity alerts with regard to exceeded protection levels, but the airborne receiver has now the responsibility to select a satellite geometry subset that is adapted to its performance – this is called geometry screening. The geometry screening is the process of satellite selection according to pre-defined criteria linked to aircraft capabilities. An overview of the GAST-D concept is provided in GBAS CAT II-III L1 CONOPS [6] while more details can be found in the ICAO GAST D concept paper [28], the ICAO SARPS GAST D baseline [21] as well as in the 15.3.6 D3 [24].

The change applies to a specimen aerodrome environment (baseline situation) currently supported by ILS CAT III operations for at least one runway end. Whereas one ILS System must be implemented per runway end, GAST-D could support CAT III operations for all runway ends of the aerodrome.

The aerodrome infrastructure and basic air traffic service provision requirements are unchanged compared to the baseline situation if GAST-D concept is used like ILS CAT III. However some operational aspects associated to the GBAS CAT III operation will be impacted (e.g. procedure design and publication, maintenance, controller and flight crew procedures).

The GAST-D concept replaces the ILS CAT III concept for approach and landing operations including the rollout phase (CAT III-B) and relies on:

- Ground Subsystem
- Aircraft Subsystem
- GNSS Satellites Subsystem based on GPS L1 frequency only

Furthermore for take-off in low visibility, the directional take-off guidance is now based on GAST-D instead of ILS (Localizer).

2.2.2 An operational change: The optimised operation

The future concept for runway operations aims to increase runway throughput and predictability of operations through improvements to all aspects of runway operations, from planning through to full exploitation of new technologies such as GBAS.

In current ILS operations, during low visibility conditions, the establishment of low visibility procedures by ATC ensure safe conduct of low visibility operations. In these conditions extra spacing margins between aircraft has to be provided in order to protect the ILS CAT II/III critical and sensitive areas. This results in a significant decrease of runway throughput during low visibility conditions.

In the same conditions using GBAS instead of ILS, the ILS CAT II/III sensitive or critical area does not need to be protected, so the spacing margins between aircraft may be reduced. This operational change is called optimised operation because runway throughput in LVC is increased compared to ILS operation. In such case a landing clearance line is defined to play the role of the holding position used in current ILS operations.

Optimised operations for CAT III approaches based only on GBAS is quite obvious but if the CAT III approach is supported by ILS and GBAS (mixed GBAS/ILS equipage operations), the optimised operation procedures shall protect the ILS CAT III critical and sensitive areas when an aircraft is conducting an ILS approach whereas it is not necessary during a GBAS landing.
Note: The term “mixed GBAS/ILS equipage operations” is used in this SAR and in [5] to describe an operation where the same runway end supports indifferently GBAS and ILS approaches. This operation is called sometimes “GBAS/ILS landing mixed mode of operations” but this term is not used to prevent any confusion with “mixed mode runway operations” relative to arrival and departures on the same runway.

The full operational concept description, including optimised operations, is described in GBAS CAT II-III OSED [5]

2.3 OFA Operational Environment and Key Properties

The operational safety assessment of GAST-D concept will address a specimen operational environment represented by an **airport with multiple runways independent or dependent**.

The main characteristics of that operational environment are recalled below and are referenced as Environment key properties (ENV).

2.3.1 Airspace Structure and Boundaries

ENV#001: TMA and approach structure includes Initial, Intermediate, Final and Missed approach segments. Within GAST-D context, the following segments will be addressed from a safety point of view:

-Intermediate segment but only in its latter part, which is flown using GBAS lateral guidance. Capture of the final segment by RF leg should be considered whenever necessary.

-Final segment (From FAP to DH) is supported by GAST-D and is an "ILS-like" straight-in segment. The glide path angle is comprised between 2.5° and 3° in accordance with ICAO PANS-OPS for CAT III approaches and with GAST D CONOPS [6].

-Missed approach could be conventional, RNAV or RNP (e.g. RNAV 1[2] or RNP APCH).

2.3.2 Types of Airspace – ICAO Classification

ENV#005: The airspace is classified so that all traffic (IFR and VFR) is controlled (ICAO Airspace Class A, B and C).

2.3.3 Types of Operations

ENV#010: GAST-D applies down to CAT IIIb Precision approaches with decision height lower than 100 ft or no decision height and runway visual range less than 200m but not less than 75 m.

ENV#015: Guided Take-Off in Low Visibility Conditions (LVC) supported by GAST-D applies to take-off with RVR lower than 400 m but not less than 75 m

2.3.4 Airspace Users – Flight Rules

ENV#020: GAST-D Concept applies to all airspace users conducting CAT III approach operations or guided take-off in LVC
ENV#021: Airspace Users of CAT III approaches are operating mainline and business aircraft.
ENV#022: Airspace users apply operational procedures promulgated for CAT III approaches in accordance with their applicable regulation (e.g. ICAO Annex 6, EU OPS, IR OPS)

2.3.5 Runway usage/ Runway Layout

ENV#025: The runways may be configured in segregated mode (landings on specific runway(s) take-off on specific runway(s)), or in mixed mode (interlaced landings and take-offs on the same runway).

ENV#030: For airport with parallel runways, these runways may be used for dependent or independent parallel approaches

ENV#035: The airport may have converging/crossing runways.

ENV#040: Runway end is used in optimised operation using GBAS only or mixed GBAS/ILS equipage

ENV#050: The possibility of having several GBAS approaches for one runway end is not considered for this typical implementation proposal. This will be considered when addressing the GBAS advanced concept where multiple approaches for the same runway end could be possible e.g. with different glide path angles.

2.3.6 Separation Minima

ENV#060: Already existing minimum Radar Separation and/or wake turbulence separations apply on final approach considering the different aircraft categories (J, H, M, L).

ENV#065: Considering that it is not necessary to protect the ILS CAT IIII sensitive area during GBAS approaches, a reduction of separation may apply during final approach

[2] RNAV 1 can only be used after the initial climb of a missed approach phase (ICAO PBN manual [19]Table II-A-1-1)

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2.3.7 Traffic density

ENV#070: Currently, in Low Visibility Procedures (LVP) the number of arrivals and departures is reduced in order to maintain the safety level at the aerodrome. However with GAST-D, the longitudinal spacing between aircraft during the approach could be reduced which lead to an increase of runway throughput in LVP. Therefore GAST-D is an enabler for the airport operation traffic increase rate of 14% specified for SESAR Step 1 [9] even if this quantitative figure of 14% cannot be applied for Low Visibility Conditions.

2.3.8 Aerodrome Service

ENV#075: The aerodrome is suitable for Low Visibility Operations and visual aids (Marking, lighting) are suitable for CAT III operations with decision height lower than 100 ft or no decision height and runway visual range less than 200m but not less than 75 m (see ICAO Annex 14 [15] , EU-OPS [13] and EASA-OPS[17]).

ENV#080: The ability to enable or disable a specific GBAS approach during the operation might be provided by the ATC interface depending on local decision

ENV#081: Automatic Terminal Information Service (ATIS) is available and broadcast inter alia the active runways and the available approaches.

2.3.9 Meteorological Service

ENV#085: Runway Visual Range (RVR) are assessed on all runways intended for CAT III approach or for guided Take-off in LVC

2.3.10GBAS Coverage

ENV#090: GBAS CAT III approaches are conducted within the GBAS coverage defined for the approach service in accordance with ICAO ([20] and [21]). Final approach interception is made inside the GBAS coverage.

2.3.11ATM capabilities

ENV#100: Communication: VHF voice between ATC and aircraft

ENV#105: Surveillance:

- Approach surveillance coverage (SSR, Mode S, ADS-B RAD) as used for ILS approaches (baseline situation)
- Surface surveillance coverage (A-SMGCS, SMR,..) as used in LVP (baseline situation)

ENV#110: Navigation:

- Ground Navaid coverage as required to support navigation on the initial, intermediate and missed approach segments
- Aircraft navigation equipage as required to support navigation on the initial, intermediate and missed approach segments

ENV#115: Approach and landing:

- Facility Approach Service Type: FAST D compliant ground subsystem
  - One GBAS Ground Station might serve all/multiple runway ends of an airport or only one runway end
- GBAS Airborne Equipment Classification: GAEC D compliant aircraft subsystem

2.4 Airspace Users Requirements

Non-nominal weather conditions reduce runway throughput, therefore airport capacity. Landing rate resilience suffers from weather conditions, particularly in low-visibility conditions. In addition, protection areas for ILS create reduced capacity in low-visibility operations.
The objectives of LVP using GBAS include:

- Increase runway throughput under Low Visibility Conditions
- Maintain and if possible improve safety in Low Visibility Conditions
- Reduction of fuel and noise footprint

The safety strategy is to show that GBAS CAT III approach and landing operations (including rollout) and guided take-off supported by GAST-D are safe i.e. allows to meet Safety Criteria in principle (pre-implementation). It is assumed that CAT III operations and guided take-off based on ILS CAT III are currently safe. This is further translated in a set of Safety Criteria (SAC) below.

2.5 Safety Criteria

2.5.1 Introduction

The ***Safety Criteria*** (SAC) define what is considered acceptably safe for the change being introduced by operations within the scope of the OFA.

Safety Criteria will drive the safety-related objectives for both Validation exercises and operational safety assessment.

Considering the nature of GBAS CAT III operations and the relevant pre-existing Hazards (see 2.6) to be mitigated by ATM services, Figure 1 and Figure 2 below respectively addressing CAT III approach and landing and guided take-off in LVC, depict the safety risks for such operations. Based on this, the CFIT, the Runway Collision and the Mid Air Collision (MAC) Accident-Incident Models (AIM) were used to set up Safety Criteria. An outline of simplified CFIT, Runway Collision and MAC models are provided in Appendix D. For Runway Excursion, there is currently no AIM model available.

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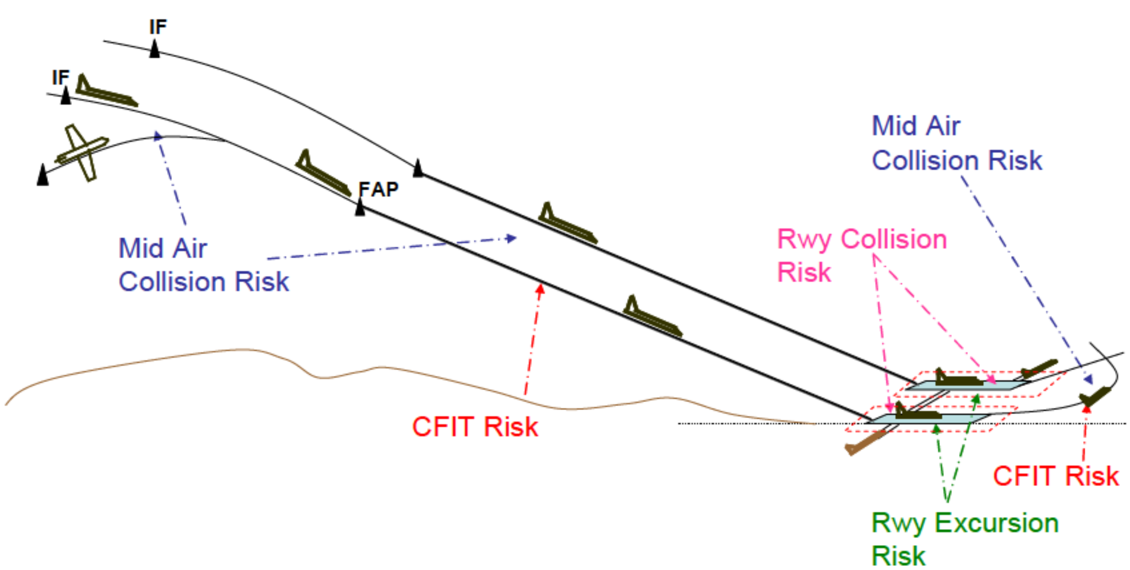

Figure 1: Risk to be considered for CAT III approach and landing operations

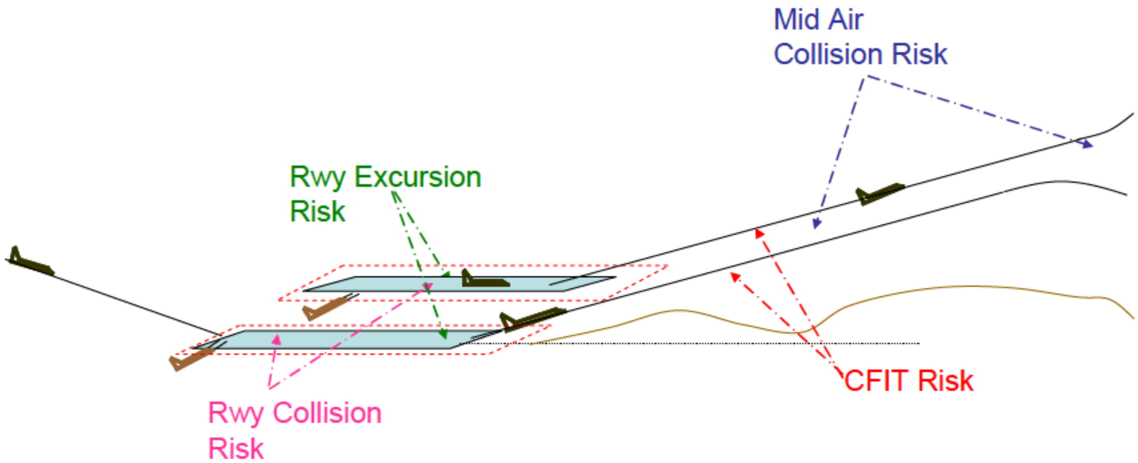

Figure 2: Risk to be considered for Guided Take-off operations

Initially the safety validation target allocation for Step 1[9] and for this OFA was requesting a CFIT reduction of 0.8% compared to the defined baseline (2005) which was unrealistic considering the new concept and the current safety level of ILS CAT III operations. An update of this report was done [31] indicating that safety impact shall be at least neutral when considering GAST-D (no safety improvement required).

2.5.2 Impact of the change on the CFIT Accident Barrier Model and SAC setting

The simplified AIM Model provided in Appendix D section D.1 is used to support the SAC setting for CFIT accident. The change is affecting the CFIT barrier model only for approach and landing operations (not for guided take-off considering that such operation stops at the main wheel lift-off).

GAST-D System guides the aircraft during the final approach, the landing and the rollout in accordance with the defined approach. Therefore CFIT risk should be assessed during the final approach segment however in addition it shall be shown that no additional risks arise from the entry and exit transitions (from the intermediate approach to final approach (GBAS capture) and from final approach to missed approach (Go Around)).

The obstacle clearance during a GBAS CAT III approach is the same compared to ILS CAT III (Assumption A#0035).

The impact of the GAST-D concept on the CFIT AIM Model (see Appendix D section D.1 for barrier and precursor illustration) is clearly at the level of the “Flight Towards Terrain Commanded” accident precursor and more precisely at the levels of the:

- “Flight Towards Terrain Commanded by Systems” (CF6) because such precursor is directly associated with the performance of the aircraft System trajectory management barrier (B6) which is supported by the position computation (including SIS), the flight path processing and the flight guidance functions

- "Flight Towards Terrain Commanded by ANS" (CF8) because such precursor is directly associated with the performance of the route/procedure design barrier (B8) which is supported by procedure design and procedure publication functions

It is assumed that the performance of the pilot trajectory management barrier (B5) and the ATC trajectory management barrier (B7) are not significantly affected considering the ILS look-alike principle. Indeed for the pilot, lateral and vertical guidance will be presented in a similar way and for the ATCo vectoring to the final approach (when required) will be similar compared to ILS operations.

The other barriers preventing CFIT are unchanged compared to ILS CAT III operations: Flight crew monitoring (B4), ATC CFIT avoidance (B3) and Aircraft CFIT avoidance (B1/B2).

Consequently the following Safety Criteria (SAC) have been defined for the CFIT risk during final approach:

SAC#01: The likelihood per approach of "Flight Towards Terrain Commanded" on final approach segment shall not increase during GBAS CAT III operations based on GAST-D compared to ILS CAT III operations.

2.5.3 Impact of the change on the Mid Air Collision Barrier Model and SAC setting

The simplified AIM Model provided in Appendix D section D.2 is used to support the SAC setting for MAC. The change is affecting the MAC barrier model only for approach and landing operations (not for guided take-off considering that such operation stops at the main wheel lift-off).

The arrival separation service sits with the Tactical Conflict Management barrier within the MAC AIM model. This barrier represents the ATC capability to monitor for potential conflicts, to detect and resolve them before they result in imminent infringement that in turn could lead to loss of separation.

The separation minima and the transition from intermediate approach to final are unchanged compared to ILS CAT III operations therefore the risk of mid Air Collision during final approach should be unchanged. Since GAST-D can support multiple runways with a single system, loss of the broadcast signal or other interruption to normal services could affect multiple aircraft at various stages of approach and landing. This could theoretically result in go-around by every aircraft currently on approach, it should be shown that risk of mid air collision does not increase in such situation.
The main objective is to maintain the performance of this barrier during final approach despite that GBAS ground station serves multiple runways.
Note: Project 6.8.3 is working on the separation minima reduction during approach and is responsible to demonstrate that such reduction is acceptably safe in particular with regards to the risk of Mid Air Collision.

Consequently the following Safety Criteria (SAC) has been defined for the risk of Mid Air Collision during final approach:

SAC#02: The likelihood per approach of separation minima infringement between aircraft during GBAS CAT III operations based on GAST-D shall not increase compared to ILS CAT III operations.

2.5.4 Impact of the change on the Runway Accident Barrier Model and SAC setting

The simplified AIM Model provided in Appendix D section D.3 is used to support the SAC setting for Runway Incursion. The change is affecting the Runway Incursion barrier model for approach and landing operations and for guided take-off operations.

The landing management (B7) and the Take-off management (B8) barriers might be affected by GAST-D. Indeed if the runway throughput increases, it might lead to more ATC Operational Error (OE) or more aircraft landing without clearance.

Note: Project 6.8.3 is working on the separation minima reduction during approach and is responsible to demonstrate that such reduction is acceptably safe in particular with regards to the risk of Runway Collision.

Consequently the following Safety Criteria (SAC) have been defined for the risk of Runway Incursion:

SAC#03a: The likelihood of landing runway incursion due to Pilot or ATC during GBAS CAT III landing operations based on GAST-D shall not increase compared to ILS CAT III despite the foreseen landing rate increase

SAC#03b: The likelihood of take-off runway incursion due to Pilot or ATC during take-off operations based on GAST-D shall not increase compared to ILS CAT III

Furthermore the risk of runway collision during the guided-take-off, landing and rollout phase due to another aircraft located in the Obstacle Free Zone (OFZ) should be addressed.

The procedures for the OFZ protection by controlling ground traffic is unchanged compared to ILS operations therefore it is assumed that with GBAS operations there will be no more OFZ penetrations compared to ILS operations. However for ILS CAT III operation the ILS CAT III sensitive area is larger than the OFZ area meaning that protecting by procedure the ILS sensitive areas protects de facto the OFZ area. Therefore it should be shown that during GBAS CAT III operations and despite that ILS CAT III sensitive area does not need to be protected, the aerodrome control procedure for OFZ is effective.

Consequently no Safety Criteria are derived but instead the following Safety Assumption has been defined for the risk of Runway Incursion:

SAC_Assumption#01: Aerodrome control procedures for OFZ protection during GBAS CAT III operations based on GAST-D are effective despite that ILS CAT III sensitive areas does not need to be protected and despite the foreseen landing rate increase

It is recalled that a safety assessment [22] has been carried out for the MLS/GBAS CAT II/III Anticipated Landing Clearance which provide requirements to be implemented at ATC level in order to maintain the OFZ clear of traffic by the time the landing aircraft is crossing the threshold. Implementation of such requirements participates to the validation of SAC_Assumption#01.

2.5.5 Impact of the change on the Runway excursion and SAC setting

There is no SESAR AIM model addressing Runway Excursion but a simplified Barrier Model is proposed in Appendix D section D.4. The change is affecting the risk of Runway excursion which is relevant for approach and landing operations and for guided take-off operations.

For CAT III operations, the aircraft automatic landing system controls the aircraft to touchdown (CAT III-A) and through rollout to a safe taxi speed (CAT III-B). For guided take-off in low visibility, the aircraft take-off guidance system provides directional guidance information to the pilot from the start of the take-off to the main wheel lift-off.

The GAST-D concept could impact the performance of the aircraft automatic landing system and guided take-off system. Such impact could affect the risk of runway excursions: runway overrun, runway undershoot and runway veer-off. Consequently the following Safety Criteria (SAC) has been defined for the risk of Runway Excursion:

SAC#04: The likelihood per approach of "Runway excursion" during GBAS CAT III operations based on GAST-D (landing, rollout or guided take-off) shall not increase compared to ILS CAT III operations. Runway excursions are characterised by incident/accident relative to runway overrun, runway undershoot and runway veer-off

Note1: Runway undershoot are also addressed by SAC#01 relative to Controlled Flight Into Terrain.

Note2: EASA CS AWO [23] specifies the performance to be demonstrated for the automatic landing system, for the automatic ground roll-control and for the take-off guidance system. Because such demonstration shall consider GBAS characteristics, the risk of runway excursion due to GBAS will be assessed by the CS-AWO demonstration and will show compliance against this SAC. Furthermore it is crucial to define a GBAS model to be considered during the autoland demonstrations which characterise GBAS performances (accuracy, continuity, integrity,…). CS-AWO certification requirements are used in absence of a Runway Excursion AIM model however a simplified model is proposed in Appendix D section D.4 for qualitative analysis

2.6 Relevant Pre-existing Hazards

A number of pre-existing hazards (extracted from [2] SRM Guidance, §F2.2) associated to CAT III approach and landing and guided take-off operations have been identified. These pre-existing hazards are associated with a pre-existing risk, which is the risk that would be associated with them in the absence of any ATM service. The reason for identifying these hazards is that the Approach/Runway control services are designed to control or mitigate at least some of these hazards, and it is important to demonstrate that all relevant hazards are indeed controlled and mitigated by those services.

The pre-existing hazards that the ATM Services / Systems associated to GAST-D have to mitigate are as follows:

Hp#1. "Situation in which the intended trajectory of an aircraft is in conflict with terrain or an obstacle during an approach"

Hp#2a. "Situation in which the aircraft veer off, undershoot or overrun off the runway surface during landing"

Hp#2b. "Situation in which the aircraft veer off or overrun off the runway surface during take-off"

Hp#3. "Situation in which the intended trajectories of two or more aircraft are in conflict during the approach (including missed approach)"

Hp#4. "Another aircraft or vehicle inside landing aid protection area during approach or take-off"

Hp#5. "Another aircraft or vehicle inside OFZ during a CAT II/III approach or guided take-off"

Hp#6. "Situation in which the intended trajectories of two or more aircraft on the runway are in conflict during landing or take-off"

The ATM Services mitigating Hp#1 and Hp#3 are the approach control service (before Final Approach Point (FAP)) and the aerodrome control service (after FAP)). The other pre-existing risks (Hp#2a,b, Hp#4, Hp#5 and Hp#6) are mitigated by the aerodrome control service.

By definition, these hazards exist in the Operational Environment before any form of de-confliction has taken place. It is, therefore, the primary purpose of the above ATM operational service to mitigate those hazards such that the Safety Criteria defined in section 2.5 are satisfied.

2.7 Mitigation of the Pre-existing Risks – Normal Operations

2.7.1 Operational Services to Address the Pre-existing Hazards

The following ATM/ANS Services are provided to aircraft for approach and landing and for guided Take-off to address the above pre-existing aviation hazards sufficiently to satisfy the Safety Criteria. They are detailed in Table 1 below.

Services in grey colour are not directly relevant for final approach and landing or Guided take-off in LVC supported by GAST-D but are listed in the table to identify services supporting the different transitions (e.g. transition from approach to missed approach).

ID[3]	Air Navigation Service Objective	Pre existing Hazard
Approach and Landing		
SAD	Establish separation between arrival flows and departing flows (including missed approach situation) in the considered environment	**Hp#3** (MAC risk)
SP1	Maintain arrival flow separation	**Hp#3** (MAC risk)
SPT1	Separate aircraft from terrain/obstacles during the initial/intermediate approach	**Hp#1** (CFIT risk)
FCF	Facilitate capture of the Final approach	**Hp#1** (CFIT risk) **Hp#3** (MAC risk)
SPT2	Separate aircraft from terrain/obstacles during the final approach	**Hp#1** (CFIT risk) **Hp#4** (S.A/C.A infringement risk)
SP2a	Maintain separation between aircraft on the same final approach	**Hp#3** (MAC risk)
SP2b	Monitor separation between aircraft on parallel approaches	**Hp#3** (MAC risk)
FLD	Facilitate landing and deceleration on the runway	**Hp#2a** (RE risk) **Hp#4** (S.A/C.A infringement risk) **Hp#5** (OFZ infringement risk)
SP3	Maintain aircraft separation on the Runway Protected Area (RPA)	**Hp#6** (Rw collision risk)
SPT3	Separate aircraft from terrain/obstacles during the missed approach	**Hp#1** (CFIT risk)
SP4	Establish and maintain separation between aircraft during missed approach	Hp#3 (MAC risk)
Guided Take-Off		
FTA	Facilitate take-off roll on the runway	**Hp#2b** (RE risk)

[3] SAD= Separate Arrival Departure; SP= SeParate aircraft with other aircraft; SPT= SeParate aircraft with Terrain; FCF= Facilitate Capture of the Final approach; FLD= Facilitate Landing & Deceleration; FTA= Facilitate Take-off & Acceleration

		Hp#4 (S.A/C.A infringement risk) **Hp#5** (OFZ infringement risk)
SP3	Maintain aircraft separation on the Runway Protected Area (RPA)	**Hp#6** (Rw collision risk)
SPT4	Separate aircraft from terrain/obstacles during the climb phase	**Hp#1** (CFIT risk)
SP5	Establish and maintain separation between aircraft during climb	Hp#3 (MAC risk)

Table 1: ATM/ANS services and Pre-existing Hazards

2.7.2 Derivation of Safety Objectives (Functionality & Performance – success approach) for Normal Operations

This section define the safety objectives (functionality and performance) in order to mitigate the pre-existing risks under normal operations, i.e. those conditions that are expected to occur on a day to day basis. This is done first by considering in sections 2.7.2.1 and 2.7.2.2 a description of respectively CAT III approach and landing operations and guided take-off in LVC.

The delivery of the above ATM/ANS services (Table 1) can be described in relation to the AIM Barrier Model of the ATM system when considering risk of CFIT, MAC and Runway Accident. This is done in Appendix E Table E.1 for approach and landing and in Appendix E Table E.2 for guided take-off. These Tables show each of the ANS/ATM Services, the Barriers which provide them and the means by which the service objective is achieved **by deriving the necessary Success-case Safety Objectives**.

Finally Section 2.7.2.3 provides a summary table of the Success-case Safety Objectives derived in Appendix E.

2.7.2.1 Analysis of the Concept for a Typical CAT III approach and landing operations

The OSED [5] describes in detail the operational environment to be considered.

Figure 3 below gives an overview of the operational context to be considered during the safety assessment. This operational context is addressing CAT III approach and landing operation based only on GBAS or on mixed GBAS/ILS equipage. Furthermore segregated runway operations (arrival only), mixed mode runway operations (departure and arrival on the same runway) and parallel runways should be considered.

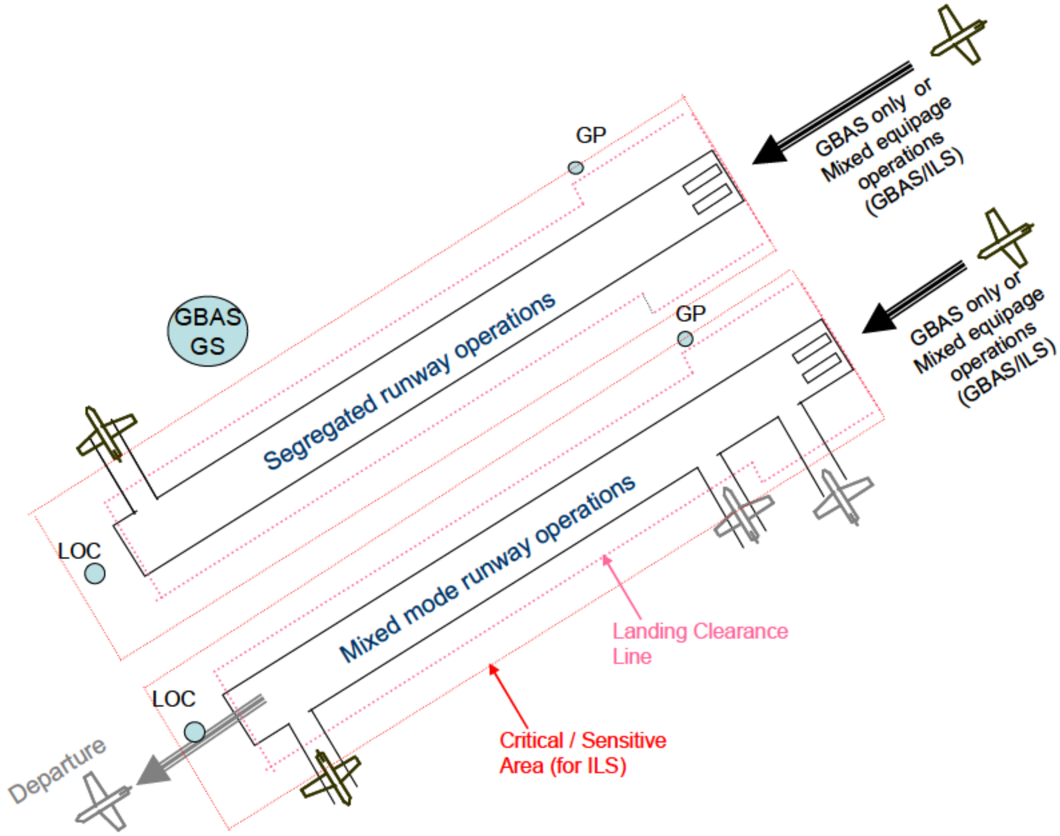

Figure 3: Operational context overview for CAT III approach and landing operations

The capacity of a runway in Low Visibility Procedures is currently limited by the position of the holding points. The holding points are positioned to protect the larger of the sensitive areas of the supporting navigation aid or the Obstacle Free Zone (OFZ). To date, the sensitive areas have generally been larger than the OFZ and by default the OFZ has been protected.
The introduction of new technology such as GBAS leads to smaller sensitive area which could provide capacity benefit at an airport. Where the sensitive area is smaller than the OFZ the capacity benefit is limited by the OFZ dimensions.
With such optimised operation, the landing clearance line plays the role of the holding position in the current operations for aircraft/vehicle vacating the runway. The Landing Clearance Line is the point that an aircraft or vehicle vacating the runway must have reached before the controller can issue landing clearance to an approaching aircraft.

Safety Objectives in Normal Conditions are derived in Appendix E section E.1 and summarized in 2.7.2.3 considering the ATM/ANS services to be delivered during the different sub-phases of the approach and the applicable operational context (mixed GBAS/ILS equipage or not, segregated runway operations or mixed mode, parallel runways or not,…).

These Safety Objectives (functional and performance) are objectives to be satisfied from ATC and aircraft point of view for a safe CAT III approach and landing.

These safety objectives have been derived considering the operational scenario described in Figure 4 and the relevant applicable Safety Criteria.

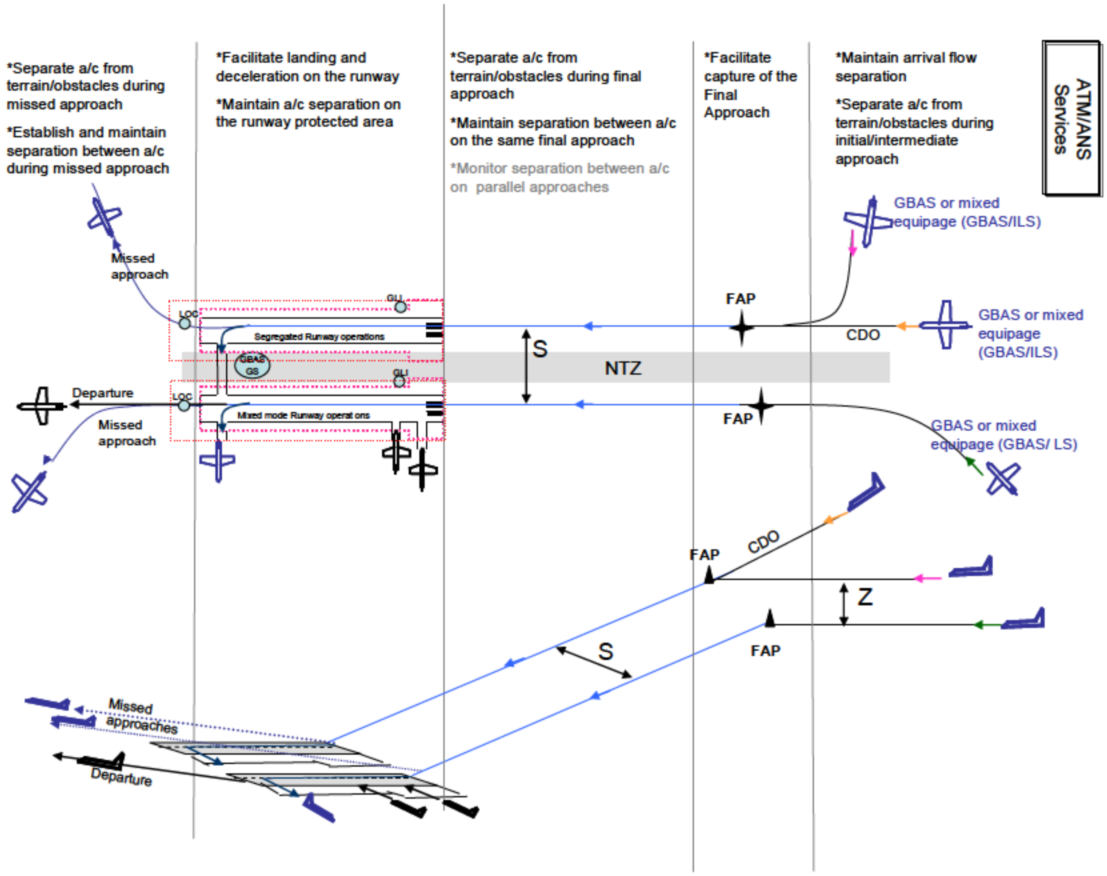

Figure 4: Operational Scenario and ATM/ANS services to be considered for CAT III approach and landing

2.7.2.2 Analysis of the Concept for a Typical Guided Take-Off operations in LVC

The OSED [5] describes in detail the operational environment to be considered.

Figure 5 below gives an overview of the operational context to be considered during the safety assessment. This operational context is addressing Guided Take-Off in LVC based only on GBAS or on mixed GBAS/ILS equipage. Furthermore segregated runway operations (departure only), mixed mode runway operations (departure and arrival on the same runway) and parallel runways departures should be considered.

It should be clarified if optimised operation for guided take-off in LVC is required (Safety Issue#001)

Details on ILS critical/sensitive area and landing clearance line could be found in 2.7.2.1 above.

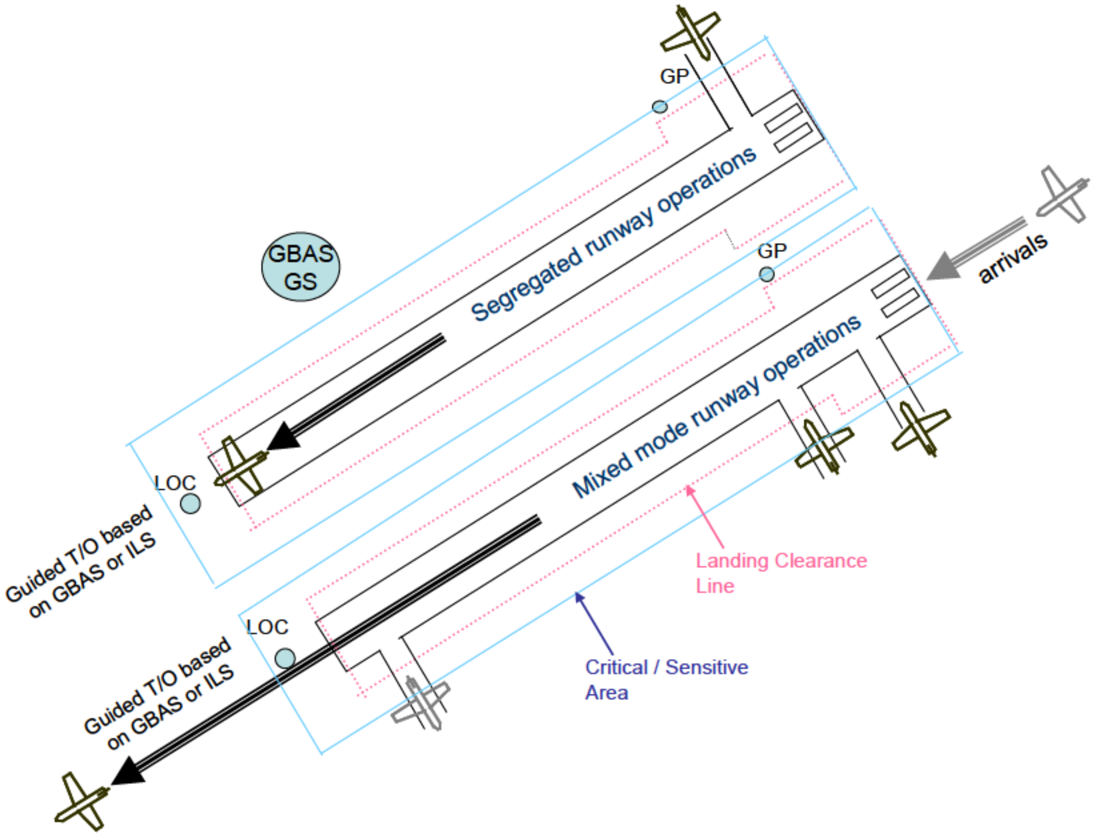

Figure 5: Operational context overview for Guided Take-Off operations

Safety Objectives in Normal Conditions are identified in Appendix E section E.2 and summarized in 2.7.2.3 considering the ATM/ANS services to be delivered and the applicable operational context (mixed GBAS/ILS equipage or not, segregated runway operations or mixed mode, parallel runways or not,…).

These Safety objectives (functional and performance) are objectives to be satisfied from ATC and aircraft point of view for a safe guided Take-Off operations.

These Safety Objectives have been derived considering the operational scenario described in Figure 6 and the relevant applicable Safety Criteria.

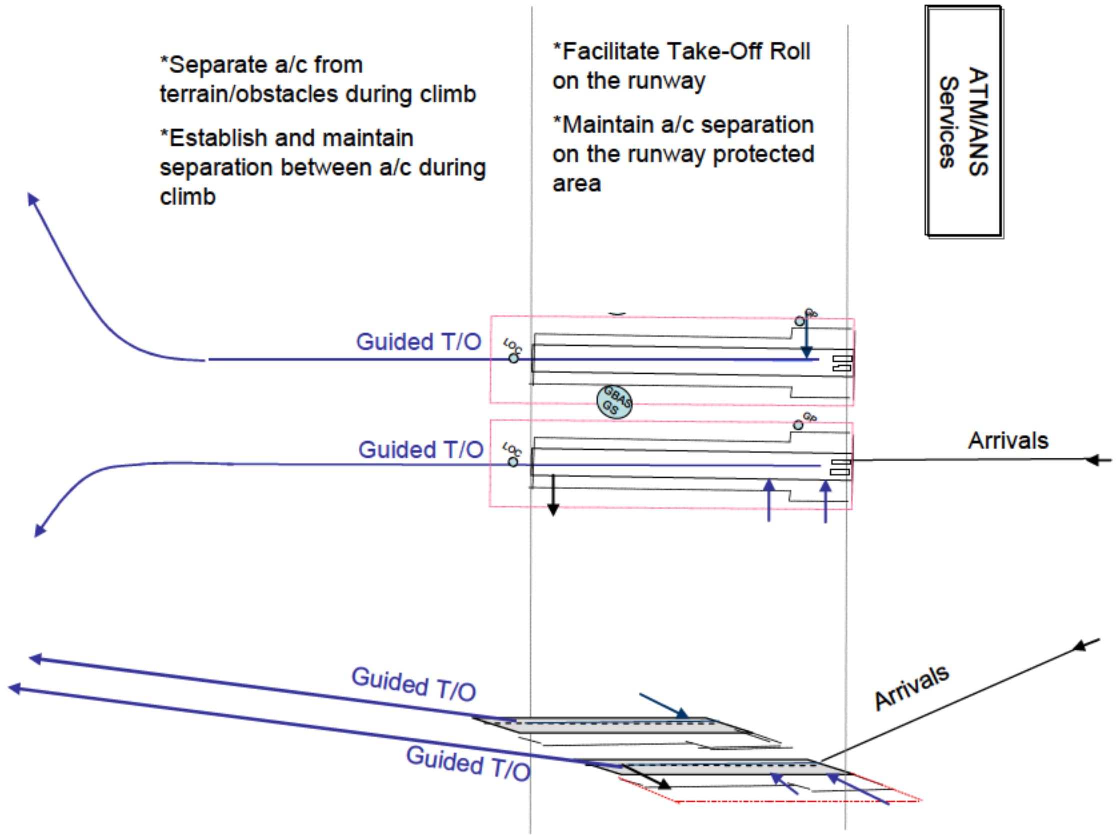

Figure 6: Operational Scenario to be considered for Guided Take-Off operations

2.7.2.3 Consolidated list of Safety Objectives (Functionality & Performance – success approach) for Normal Operations

Table 2 for CAT III approach and landing and Table 3 for Guided take-off in LVC identify the Safety Objectives for normal operations per relevant phase of flight/ATM service, provide traceability towards Safety Criteria (SAC) and make a comparison with current operation based on ILS. Furthermore these tables identify whenever necessary Assumption (A#xx), Recommendation (REC#xx), Limitation (LIM#xx), Issue (I#xx) and Item to be considered during validation (VAL#xx).

Note: SO in italics characters in the following tables indicate that such element has been already derived for another phase of flight/ATM services.

CAT III approach and landing based on GBAS			
Phase of Flight/ATM service	**Achieved by/ Success-case Safety Objective (SO#n):**	**SAC**	**Comparison with ILS CAT III**
Arrival/ Establish separation between	SO# 0005: ATIS shall inform arriving aircraft of the landing procedures available for the runway in use (ILS and GBAS or GBAS only) and indicate that LVP are in place SO# 0010: Approach clearance shall be provided to	SAC#02 (MAC)	-SO#0005 and SO#0010 are equivalent for ILS approaches SO#0011 is specific to

CAT III approach and landing based on GBAS			
Phase of Flight/ATM service	**Achieved by/ Success-case Safety Objective (SO#n):**	**SAC**	**Comparison with ILS CAT III**
arrival flows and departing flows (SAD)	arriving aircraft which indicate the expected approach to be flown SO# 0011: For optimised operations conducted in mixed GBAS/ILS equipage, aircraft shall inform ATC about the approach that will be flown: GBAS or ILS.		GBAS
Initial approach/ Facilitate capture of final approach (FCF)	• **General:** SO#0015: Before Final Approach Point, the aircraft shall capture the GBAS Lateral path before the GBAS vertical path to conduct stabilised approach REC#0001: It is recommended that the aircraft guidance remains coupled to the FMS/RNAV system for the capture of the GBAS approach path if ATC vectoring is not provided by ATC • **In lateral:** SO#0020: Aircraft shall respect the lateral performance of the published approach intermediate segment which might include an RF leg during a final approach capture supported by RNAV/RNP. VAL#001: It should be validated that the capture of the final approach supported by RNP is safe and efficient (with respect to the RNP corridor) SO#0025: Aircraft shall respect ATC vectoring instructions for the final approach capture. • **In Vertical:** SO# 0030: Aircraft shall respect the vertical altitude constraint at FAP during a final approach capture by transitioning properly from Baro-altitude to GBAS vertical path (xLS). SO# 0035/VAL#0008: For non CDO operations, a 2Nm (or 30 sec) straight and level flight segment prior to final approach track intercept shall be the flown to conduct stabilised approach SO# 0040: ATC shall not provide vectoring for aircraft conducting CDO when aircraft cannot conduct a fully optimised CDO with vectoring • **For parallel runways operation:** LIM#0001: Independent parallel runway operations with different GBAS glide path angle could be implemented at the airport but the optimum glide path angle remains 3°. LIM#0002: PANS-OPS (para. 6.7.3.2.1.f) requires the use of vectoring to intercept the final approach track for parallel runway operations REC#0002: For GBAS parallel approaches, the Final Approach Point(FAP) could be located at different position/altitude to establish strategic separation between the two approaches flows	SAC#01 (CFIT): -SO#0015 -SO#0020 -SO#0030 -SO#0035 -SO#0040 SAC#02 (MAC): -SO#0020 -SO#0025 -SO#0030 -SO#0040	-SO#0015 is equivalent for ILS approaches -SO#0020 and SO#0030 are equivalent for ILS approaches if RNP to ILS transition is used for ILS operations. -SO#0025, SO#0035 and SO#0040 are equivalent for ILS operations -VAL#001 is a specific item to be validated because beyond a certain distance from the threshold the angular deviation could be truncated and become linear Therefore it should be validated that capture of the final approach path is safe and efficient in such condition -Lim#0001 is not per say different from ILS but it is easier with GBAS to modify the glide path angle however from a pilot's point of view the 3° GPA remains the optimum approach angle. -Lim#0002 is applicable to ILS operation -REC#0001and REC#0002 could be implemented with ILS but are not currently so common and anyway could be more easily implemented with GBAS. -VAL#008 is identified to validate if a 2Nm level off segment is really necessary for non-CDO operations
Final approach/ Separate aircraft from terrain/obstacles during the final	SO#0045: The GBAS CAT III approach is designed and promulgated to prevent loss of separation with terrain/obstacle SO#0050: Aircraft shall respect the lateral and vertical path of the published GBAS approach	SAC#01 (CFIT)	SO#0045, SO#0050 and SO#0055 are equivalent for ILS operations SO#0060 is specific to GBAS

CAT III approach and landing based on GBAS			
Phase of Flight/ATM service	**Achieved by/ Success-case Safety Objective (SO#n):**	**SAC**	**Comparison with ILS CAT III**
approach (SPT2)	SO#0055: For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside the ILS CAT III critical and sensitive areas during an ILS approach SO#0060: The aircraft GBAS Total System error (TSE) shall be equivalent or better than ILS CAT III TSE A#0001: For GBAS only operation, ILS CAT III critical and sensitive areas do not need to be protected VAL#009: To prevent any detrimental impact on GAST-D operations, it should be determined if ATC measures are necessary in LVP to control the access of GBAS areas on the ground based on LOCA (Local Object Consideration Areas)		Assumption#01 is specific to GBAS and a specific validation item (VAL#009) is defined to determine if GBAS areas need to be controlled on the ground
Final approach/ Maintain separation between aircraft on the same final approach (SP2a)	SO#0065: Aircraft shall respect accurately speeds, which have been defined for the CAT III approach, during the approach and landing *SO#0050: Aircraft shall respect the lateral and vertical path of the published GBAS approach* SO#0070: ATC procedures shall support the mixed GBAS/ILS equipage operations by providing appropriate spacing between the different aircraft pairs (GBAS-ILS; GBAS-GBAS and ILS-GBAS) VAL#0002: In CAT III approach mixed GBAS/ILS equipage operation, appropriate spacing between aircraft pairs (GBAS-ILS; GBAS-GBAS and ILS-GBAS) should be validated to prevent ILS CAT III sensitive area infringement by a preceding aircraft during an ILS landing SO#0072: For CAT III optimised operations, the reduced spacing between aircraft shall consider the necessary Runway Occupancy Time (ROT) in Low Vis bility Conditions and not only that ILS CAT III critical/sensitive area does not need to be protected.	SAC#02 (MAC)	SO#0065 and SO#0050 are equivalent for ILS SO#0070 and SO#0072 are specific to GBAS -VAL#0002 and 0003 are specific items to be validated
Final approach/ Monitor separation between aircraft on parallel approaches (SP2b)	*SO#0050: Aircraft shall respect the lateral and vertical path of the published GBAS approach* SO#0075: For parallel approaches, the infringement rate of the Non Transgression Zone (NTZ) shall not be greater with GBAS (GBAS only operation or mixed GBAS/ILS equipage operation) compared to ILS *LIM#0001: Independent parallel runway operations with different GBAS glide path angle could be implemented at the airport but the optimum glide path angle remains 3°.* *REC#0002: For GBAS parallel approaches, the Final Approach Point(FAP) could be located at different position/altitude to establish strategic separation between the two approaches flows*	SAC#02 (MAC)	SO#0050 is equivalent for ILS SO#0075 is specific to GBAS *-Lim#0001 -see above.* *-REC#0002 – see above.*
Landing/ Facilitate landing and deceleration on the runway (FLD)	• **General** *SO#0050: Aircraft shall respect the lateral and vertical path of the published GBAS approach* *SO#0065: Aircraft shall respect accurately the approach speed* SO#0080: During GBAS CAT III operation, aircraft shall	SAC#01 (CFIT): -SO#0050 -SO#0055 -SO#0060 -A#0001 SAC#04 (R.E):	SO#0050, SO#055, SO#0065, SO#0080 and SO#0085 are equivalent for ILS SO#0060 is specific to GBAS Assumption#01 is specific

CAT III approach and landing based on GBAS			
Phase of Flight/ATM service	**Achieved by/ Success-case Safety Objective (SO#n):**	**SAC**	**Comparison with ILS CAT III**
	land in the prescribed touch down zone SO#0085: During GBAS CAT III operation, aircraft shall respect the runway centre-line during the landing rollout and decelerates to a safe taxi speed *SO#0055: For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside the ILS CAT III critical and sensitive areas during an ILS approach* *SO#0060: The aircraft GBAS Guidance quality (accuracy, noise,…) shall be equivalent or better than ILS* *A#0001: For GBAS only operation, ILS CAT III critical and sensitive areas do not need to be protected* *VAL#009: To prevent any detrimental impact on GAST-D operations, it should be determined if ATC measures are necessary in LVP to control the access of GBAS areas on the ground based on LOCA (Local Object Consideration Areas)*	-SO#0065 -SO#0080 -SO#0085 -SO#0055 -SO#0060 -A#0001	to GBAS and a specific validation item (VAL#009) is defined to determine if GBAS areas need to be controlled on the ground
Landing/ Maintain aircraft separation on the runway protected area (SP3)	• **General** SO#0090: Landing Clearance (and associated read back) shall be provided to the aircraft to ensure proper separation with other aircraft or vehicles on the runway SO#0095/VAL#0004: For optimised operations, the late landing Clearance shall be provided at a distance to the runway threshold which does not impair the aircraft ability to prepare the landing SO#0100: All aircraft on the ground shall remain outside the Obstacle Free Zone (OFZ) during a landing SO#0105: The landed aircraft shall vacate the runway at the cleared exit point SO#0110: The landed aircraft shall report when he has vacated the runway indicating that aircraft tail has left the runway SO#0115: ATC shall provide when necessary additional information to facilitate aircraft runway vacation REC#0003: It is recommended that aircraft displays the distance to runway-end after passing the runway threshold to ease ROT reduction. Other means are also poss ble, for instance brake-to vacate or "countdown" lights before a runway exit or specific guidance lights towards the suitable exits. SO#0120: Runway Incursion safety net (e.g. RIMCAS) shall be suitable for optimised operations. An aircraft holding inside ILS CAT III Critical and Sensitive Area (CSA) during an ILS landing is considered a Runway Incursion whereas an aircraft holding at the same position during a GBAS landing is not. VAL#0005: It should be validated if Runway safety nets are suitable for optimised operations and mixed GBAS/ILS equipage operation or if they should be modified. • **Specific to Segregated runway operation (arrival)** SO#0125: For segregated runway operation (arrival only) with GBAS optimised operations, ATC shall provide the landing clearance to the next arrival when the preceding	SAC#03a (R.C): -SO#0090 -SO#0095 -SO#0105 -SO#0110 -SO#0115 -SO#0120 -SO#0125 -SO#0130 -SO#0135 -SO#0140 -SO#0145 SAC_Assumption #01 (OFZ protection): -SO#0100 -A#0002	SO#0090, SO#0100, SO#0105, SO#110, SO#115 are equivalent for ILS but are impacted by optimised operations SO#0095, SO#0120, SO#0125, SO#0130 SO#0135, SO#0140 and SO#0145 are specific to optimised operations -REC#0003 is specific to optimised operations. -VAL#0004,0005 and 0006 are specific items to be validated -A#0002 is applicable to ILS

CAT III approach and landing based on GBAS			
Phase of Flight/ATM service	Achieved by/ Success-case Safety Objective (SO#n):	SAC	Comparison with ILS CAT III
	arrival has passed the landing clearance line SO#0130: For segregated runway operation(arrival) with mixed GBAS/ILS equipage optimised operations, ATC shall provide the landing clearance to the: *next GBAS arrival when the preceding arrival has passed the landing clearance line * next ILS arrival when the preceding arrival has vacated the ILS CAT III sensitive area • **Specific to mixed mode runway (arrival/departure)** SO#0135: For mixed mode runway operation (arrival/departure) with GBAS optimised operations, departing aircraft shall hold at the landing clearance line SO#0140: For mixed mode runway operation (arrival/departure) with mixed GBAS/ILS equipage optimised operations, departing aircraft shall hold: *at the landing clearance line during a GBAS landing *at the CAT III holding point during an ILS landing A#0002: For mixed mode runway operation (arrival/departure), the Obstacle Free Zone (OFZ) shall be protected when a departing aircraft holds the CAT I holding position, if holding 900 meters or more down the runway • **Specific to landing clearance line** SO#0145: For optimised operations, the landing clearance line shall be positioned where: *the risk of collision between the landing aircraft and obstacles (aircraft/vehicle) on the runway is shown to be acceptable. *wing tip clearance of the landing aircraft is provided from touchdown to end of roll out along the runway VAL#0006:The landing clearance line concept should be validated for: *segregated runway operation (arrival) with GBAS optimised operations *segregated runway operation (arrival) with mixed GBAS/ILS equipage operations *mixed mode runway operation (arrival/departure) with GBAS optimised operations *mixed mode runway operation (arrival/departure) with mixed GBAS/ILS equipage optimised operations		
Missed Approach/ Separate aircraft from terrain/obstacles during missed approach (SPT3)	• **CAT III missed approach initiation:** SO#0150: Aircraft shall monitor operational conditions and technical capabilities at the Decision Height (DH) or at the Alert Height (for operations conducted with no DH) to decide if CAT III approach can be continued SO#0155: For CAT III approach conducted with DH, aircraft shall execute a missed approach at DH if visual references not acquired SO#0160: For CAT III approach conducted with no DH, aircraft shall execute a missed approach at or below the Alert Height in case of aircraft capability and/or performance degradation impacting the CAT III landing and visual references not acquired • **CAT III missed approach procedure:** SO#0165: The Missed approach segment of a GBAS CAT III approach shall be designed to prevent loss of	SAC#01 (CFIT) SAC#01 (CFIT)	SO#0150, SO#0155, SO#0160, SO#0165 and SO#0166 are equivalent for ILS -REC#0004 could be implemented with ILS but is not currently so common because ILS missed approach are in most cases based on conventional navaids and therefore not RNAV

CAT III approach and landing based on GBAS			
Phase of Flight/ATM service	**Achieved by/ Success-case Safety Objective (SO#n):**	**SAC**	**Comparison with ILS CAT III**
	separation with terrain/obstacle and shall not rely on GBAS REC#0004: It is recommended that the aircraft guidance remains coupled to the FMS/RNAV system during the missed approach procedure if the missed approach is based on RNAV/RNP. • **CAT III missed approach procedure for parallel runways operation:** SO#0166: For independent parallel runway operations, the Missed approach track for one approach diverges by at least 30 degrees from the missed approach track of the adjacent approach (PANS-ATM)	SAC#02 (MAC)	
Missed Approach/ Establish and maintain separation between aircraft during missed approach (SP4)	SO#0170/VAL#0007: During optimised operations, the go-around rate (without considering failure) shall not be greater than in ILS CAT III only operations (without considering failure) in similar operational environment and weather conditions.	SAC#02 (MAC)	SO#0170/VAL#0007 is specific to optimised operations

Table 2: List of Safety Objectives (success approach) for CAT III approach and landing/ Normal Operations

Guided Take-Off in LVC based on GBAS			
Phase of Flight/ATM service	**Achieved by/ Success-case Safety Objective (SO#n):**	**SAC**	**Comparison with ILS CAT III**
Take-Off / Facilitate Take-Off roll on the runway (FTA)	SO#0200: Aircraft shall respect the GBAS lateral path for the guided take-off from the start of the take-off roll to the main wheel lift-off SO#0060: The aircraft GBAS Guidance quality (accuracy, noise,…) shall be equivalent or better than ILS SO#0055: For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside the ILS CAT III critical and sensitive areas during an ILS approach/take-off A#0001: For GBAS only operation, ILS CAT III critical and sensitive areas do not need to be protected VAL#009: To prevent any detrimental impact on GAST-D operations, it should be determined if ATC measures are necessary in LVP to control the access of GBAS areas on the ground based on LOCA (Local Object Consideration Areas) A#0005: Back course take-off is not used with GBAS	SAC#04 (R.E) SAC_Assumption #01 (OFZ protection)	SO#0200 is equivalent for ILS operations but guidance is GBAS and not LOC SO#0055 is equivalent to guided take-off based on LOC SO#0060 is specific to GBAS A#0001 and A#0005 are specific to GBAS Validation item (VAL#009) is defined to determine if GBAS areas need to be controlled on the ground
Take-Off / Maintain aircraft separation on	SO#0205: Take-Off Clearance (and associated read back) shall be provided to the aircraft to ensure appropriate separation with other aircraft and vehicles on the runway	SAC#03b (R.C)	SO#0200 is equivalent for ILS operations but guidance is GBAS and not

Guided Take-Off in LVC based on GBAS			
Phase of Flight/ATM service	Achieved by/ Success-case Safety Objective (SO#n):	SAC	Comparison with ILS CAT III
the Runway Protected Area (RPA) (SP3)	*SO#0200: Aircraft shall respect the GBAS lateral path for the guided take-off from the start of the take-off roll to the main wheel lift-off* *SO#0060: The aircraft GBAS Guidance quality (accuracy, noise,…) shall be equivalent or better than ILS* SO#0210: All aircraft on the ground shall remain outside the Obstacle Free Zone (OFZ) during a take-off REC#0005: : It is recommended that aircraft displays the distance to runway-end to enhance situational awareness during guided take-off in LVC		LOC SO#0205 and SO#0210 are equivalent for ILS operations SO#0060 is specific to GBAS -REC#0005 is based on REC#0003 which has been recommended for optimised CAT III operations and could be easily extended to guided take-off

Table 3: List of Safety Objectives (success approach) for Guided Take-Off in LVC/ Normal Operations

2.8 Operations under Abnormal Conditions

The purpose of this section is to assess the ability of operations based on GAST-D (CAT III approach and guided Take-Off) to work through (robustness), or at least recover easily from (resilience), any abnormal conditions, external to it, that might be encountered relatively infrequently.

Such conditions cover both:

- failures (human or technical) external to the GBAS functional system (or ILS for mixed GBAS/ILS equipage operation) but affecting it; and
- other significant, but infrequent events in the operational environment of the GBAS.

2.8.1 Identification of Abnormal Conditions

The following have been identified as abnormal conditions relevant to CAT III approach and guided take-off in LVC operations supported by GAST-D:

- Severe Ionospheric disturbances
- Unintentional Interference.
  Note: The Intentional interference aspect is a security threat which is not addressed by a safety assessment
- Severe weather conditions (heavy snow, ice , heavy rain,…)
- Over flight disruption of GBAS ground subsystem (Signal blockage)
- Excessive Multipath affecting GNSS at ground level
- Wrong Arrival Sequence Manager sequencing for optimised operation conducted in mixed GBAS/ILS equipage
- Local weather phenomena like thunderstorm
- GPS constellation failure/degradation leading to GPS SIS loss

2.8.2 Potential Mitigations of Abnormal Conditions

Table 4 below shows, for each abnormal condition:

- the assessed immediate operational effect, and
- the possible mitigations of the safety consequence of the operational effect with a reference to existing Safety Objectives or to new Safety Objectives [thus] described in Table 5 below.

Ref	Abnormal Conditions	Operational Effect	Mitigation of Effects / [SO xx] incl. SAC traceability
1	Severe Ionospheric disturbances →specific to GBAS	The aircraft might deviate from the nominal path during the approach or the guided take-off	Preventive Mitigations: a) The proposal for mitigating the effects of the ionospheric anomalies should rely on a combination of: • Monitoring in the ground subsystem, • Monitoring in the airborne segment, • Siting restriction on the ground subsystem, and • A standard threat space which defines the range of ionospheric anomalies to which the user will be exposed. See [24] and [26]. Above preventive mitigations will be captured in SAR section 3 b) For GBAS CAT III approach and landing: → Aircraft respects the lateral and vertical path of the published GBAS approach when ionospheric disturbances are encountered or aircraft executes a safe go-around (SO#0300/ SAC#01) → Aircraft lands in the prescribed touch down zone when ionospheric disturbances are encountered or aircraft executes a safe go-around (SO#0305/ SAC#04) →Successful Aircraft GBAS landing rollout when ionospheric disturbances are encountered or aircraft executes a safe go-around (SO#0310/ SAC#04)). c) For GBAS guided Take-Off: → Aircraft respects the lateral path for the guided take-off from the start of the take-off roll to the main wheel lift-off when ionospheric disturbances are encountered or aircraft aborts safely the take-off. (SO#0400/ SAC#04).
2	Unintentional Interference (impacting GNSS and/or VDB) →specific to GBAS	The aircraft might loss the GBAS guidance (continuity event) during the approach when encountering the interference	Preventive Mitigations: a) The proposal for mitigating the effects of the interference should rely on a combination of: • Siting restriction on the ground subsystem • State spectrum regulation, frequency management and enforcement of these regulation • Specific maintenance procedure as a prerequisite • making GNSS receivers (ground and airborne) robust against interference, See [24] and [26].

			• Above preventive mitigations will be captured in SAR section 3 b) For GBAS CAT III approach and landing: → Aircraft respects the lateral and vertical path of the published GBAS approach when interference signals are encountered or aircraft executes a safe go-around (SO#0315/ SAC#01) →Aircraft lands in the prescribed touch down zone when interference signals are encountered or aircraft executes a safe go-around (SO#0320/ SAC#04) → Successful Aircraft GBAS landing rollout when interference signals are encountered or aircraft executes a safe go-around (SO#0325/ SAC#04) c) For GBAS guided Take-Off: → Aircraft respects the lateral path for the guided take-off from the start of the take-off roll to the main wheel lift-off when interference signals are encountered or aircraft aborts safely the take-off. (SO#0405/ SAC#04). <u>Corrective Mitigations:</u> → Aircraft executes a missed approach in case of loss of GBAS continuity during a GBAS CAT III approach. The missed approach can be executed with the autopilot still engaged or manually. (SO#330/ SAC#01 and SAC#04). → Aircraft aborts the guided take-off in LVC in case of loss of GBAS continuity and impossibility to continue to monitor external visual cues (centerline lights) (SO#410/ SAC#04).
3	Severe weather conditions (heavy snow, ice , heavy rain,…) →specific to GBAS	GBAS CAT III operation continuity might be impacted	<u>Preventive Mitigations:</u> -Design of ground antennas avoiding build-up of snow and ice - Procedure for snow removal - Siting measures (ie. drainage in case of heavy rain) Above preventive mitigations will be captured in SAR section 3 → No SO relative to the operation (CAT III approach/ Guided Take-Off) have been derived.
4	Over flight disruption of ground subsystem (Signal blockage) →Specific to GBAS	GBAS CAT III operation continuity might be impacted	<u>Preventive Mitigations:</u> • Siting restriction on the ground subsystem preventing masking of GBAS reference receivers antennas • regular co-ordination with airport/ authorities to avoid new buildings blocking signals. Above preventive mitigations will be captured in SAR section 3.

			→ No SO relative to the operation (CAT III approach/ Guided Take-Off) have been derived.
5	Excessive Multipath affecting GNSS at ground level →Specific to GBAS	GBAS CAT III operation continuity might be impacted	Preventive Mitigations: • GBAS reference receiver/antenna technology • Eliminate reflecting surfaces in the vicinity of the GBAS reference receivers antennas Above preventive mitigations will be captured in SAR section 3 → No SO relative to the operation (CAT III approach/ Guided Take-Off) have been derived but an assumption is defined: A#0003: GBAS siting on the aerodrome prevents detrimental impact on GAST D operations in particular the prevention of correlated multipath effects when mobiles (aircraft or vehicles) circulate on the aerodrome surface.
6	When fitted, wrong Arrival Sequence Manager sequencing for optimised operation conducted in mixed GBAS/ILS equipage →Specific to CAT III optimised operation	GBAS-ILS pairs are not correctly spaced. This could lead to an ILS landing aircraft deviation from its path due to wrong ILS guidance during landing and rollout because preceding GBAS landing is still in the ILS CAT III sensitive area	If an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations, the arrival manager shall allocate a greater spacing between a GBAS-ILS pair, than that between ILS-GBAS or GBAS-GBAS pairs in order to have an ILS CAT III sensitive area clear of obstacles during the ILS landing. (SO#335/ SAC#01 and SAC#04).
7	Local weather phenomena like thunderstorm, volcanic ash, fire or sand clouds,…	Could impact CAT III operations if GBAS SIS is impacted	→ No SO derived considering that GPS L1 Signal or VDB signal cannot be affected by such abnormal condition however aircraft operations are affected (re-routing, capacity decrease,…) but not due to GBAS impact.
8	GPS constellation failure/degradation leading to GPS SIS loss	Operations based on GPS are lost affecting Enroute, TMA and approaches. GBAS CAT III operation continuity is impacted	Preventive Mitigations: • GBAS missed approach procedure is based on conventional navigational aid or a safe aircraft extraction is possible when GPS is lost considering the airport environment (terrain, other arrivals and departure,…) (SO#340/ SAC#01 and SAC#02). and • Approach based on conventional means is at least available at the alternate aerodrome (SO#345/ SAC#01).

Table 4: Additional Safety Objectives (success approach) for Abnormal Conditions

ID	Description	SAC traceability

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CAT III approach and landing		
SO#0300	Aircraft shall respect the lateral and vertical path of the published GBAS approach when ionospheric disturbances are encountered or aircraft executes a safe go-around	SAC#01
SO#0305	Aircraft shall land in the prescribed touch down zone when ionospheric disturbances are encountered or aircraft executes a safe go-around	SAC#04
SO#0310	Aircraft shall conduct a successful GBAS landing rollout when ionospheric disturbances are encountered or aircraft executes a safe go-around	SAC#04
SO#0315	Aircraft shall respect the lateral and vertical path of the published GBAS approach when interference are encountered or aircraft executes a safe go-around	SAC#01
SO#0320	Aircraft shall land in the prescribed touch down zone when interference are encountered or aircraft executes a safe go-around	SAC#04
SO#0325	Aircraft shall conduct a successful GBAS landing rollout when interference are encountered or aircraft executes a safe go-around	SAC#04
SO#0330[4]	Aircraft shall execute a missed approach in case of loss of GBAS continuity during a GBAS CAT III approach	SAC#01 and SAC#04
SO#0335	When an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations, the Arrival Sequence Manager shall allocate a greater spacing between a GBAS-ILS pair, than that between ILS-GBAS or GBAS-GBAS pairs, to guarantee that a preceding landed aircraft has vacated the ILS CAT III sensitive area during an ILS landing	SAC#04
SO#0340	To mitigate GPS loss events, the GBAS missed approach procedure shall be either: *based on conventional navigational aid or *allows the flight crew to conduct a safe aircraft extraction using raw data (e.g. heading, altitude) when GPS is lost considering the airport environment (terrain, other arrivals and departure,…)	SAC#01
SO#0345	To mitigate GPS loss events, at least one approach based on conventional means is available at the alternate aerodrome	SAC#01
For Guided take-off in LVC		
SO#0400	Aircraft shall respect the lateral path of the guided take-off from the start of the take-off roll to the main wheel lift-off when ionospheric disturbances are encountered or aircraft aborts safely the take-off	SAC#04
SO#0405	Aircraft shall respect the lateral path of the guided take-off from the start of the take-off roll to the main wheel lift-off when interference signals are encountered or aircraft aborts safely the take-off	SAC#04

[4] SO#0330 is a corrective mitigation following an abnormal condition (e.g. interference) but SO#0330 cannot be considered as a Safety Objectives (success approach) for Abnormal Operations. Indeed loss of GBAS continuity is a failure condition which is more relevant for the failure analysis and therefore SO#0330 is transferred to section 2.9.1.

SO#0410[5]	Aircraft shall abort the guided take-off in LVC in case of loss of GBAS continuity and loss of external visual cues (centerline lights)	SAC#04

Table 5: List of Safety Objectives (success approach) for Abnormal Operations

2.9 Mitigation of System-generated Risks (failure approach)

This section concerns CAT III approach and guided take-off in LVC operations in the case of internal failures. Before any conclusion can be reached concerning the adequacy of the safety specification of these operations, at the OSED level, it is necessary to assess the possible adverse effects that failures internal to the end-to-end System might have upon the provision of the relevant operations and to derive safety objectives (failure approach) to mitigate against these effects.

2.9.1 Identification and Analysis of Operational Hazards

From the analysis of the above description of the operational services and by considering, for each safety objective (from the success approach in Table 2and Table 3 above), what would happen if the objectives were not satisfied (*i.e.* negate the safety objectives derived for normal conditions) complemented by a safety workshop held with pilot and controllers, the following system-generated hazards together with (…):

- the assessed immediate operational effect,
- the possible mitigations of the safety consequence of the operational effect with a reference to existing safety objectives (functionality and performance) or to safety objectives (functionality and performance) described in Table 7 below, and
- the assessed severity of the most probable effect from hazard occurrence as per the relevant Severity Classification Scheme(s) from Guidance E.2 of Reference [2]

(…) are documented in **Appendix F (F.1** for CAT III approach and landing and **F.2** for guided take-off in LVC**)**.

Table 6 below summarizes the results of **Appendix F** by identifying Operational Hazards, severity and making a comparison with ILS CAT III.

Furthermore the safety assessment led to the identification of Runway Excursion operational effects whereas there is no Accident Incident Model (AIM) for such accident but only a simplified Barrier Model not quantified. Without such AIM, there is no RCS available and it has been decided to rely on EASA Certification Specification for all weather operations CS-AWO [11] and CS 25 in this specific case.

Operational Hazard	Phase of flight/ ATM services/ Relevant SAC	Severity (most probable effect)	Comparison with ILS CAT III
CAT III approach and Landing			
No Hazard	TMA	NA	NA

[5] SO#0410 is a corrective mitigation following an abnormal condition (e.g. interference) but SO#0410 cannot be considered as a Safety Objectives (success approach) for Abnormal Operations. Indeed loss of GBAS continuity is a failure condition which is more relevant for the failure analysis and therefore SO#0410 is transferred to section 2.9.1.

Operational Hazard	Phase of flight/ ATM services/ Relevant SAC	Severity (most probable effect)	Comparison with ILS CAT III
CAT III approach and Landing			
Hz 002: Failure to transition laterally and/or vertically from RNP or radar vectoring to GBAS CAT III approach	Intermediate Approach Facilitate capture of Final Approach (FCF) SAC#01 (CFIT) and SAC#02 (Mid Air Collision)	*CFIT-SC3b / Flight Toward Terrain Commanded. → It corresponds to a situation where a controlled flight towards terrain was prevented by flight crew monitoring	When considering single approach operation, Hz 002 is applicable to current ILS operation for radar vectoring interception but not applicable for the transition from RNP to xLS because not currently implemented with ILS
		*MAC-SC4a/Tactical conflict (crew/aircraft induced). → It corresponds to a situation where an imminent infringement coming from crew/aircraft induced conflict was prevented by tactical conflict management	When considering parallel approach operation, Hz 002 is partially applicable to ILS however the GBAS ground station might serve the two approaches whereas for ILS , two ILS ground stations must be installed
Hz 003: Failure to follow the correct final approach path in GBAS CAT III	Final Approach Separate aircraft from terrain/obstacle during the final approach (SPT2) SAC#01 (CFIT)	*CFIT-SC1 / CFIT accident → It corresponds to a situation where aircraft collides with terrain/water/obstacle.	Hz 003 is applicable to current ILS CAT III operations. However a GBAS ground station failure may affect simultaneously multiple runway-ends at the airport.
Hz 004: Failure to maintain spacing between aircraft within the same final approach for optimised operations conducted in mixed GBAS/ILS equipage operations during CAT III approach	Final Approach Maintain separation between aircraft on the same final approach (SP2a) SAC#01(CFIT) and SAC#04 (Runway Excursion)	CAT IIII ILS Final approach *CFIT-SC2b / Imminent CFIT. → It corresponds to a situation where a near CFIT was prevented by pilot/airborne avoidance (e.g. Visual warning/TAWS) CAT IIII ILS Landing and Roll-out: *Imminent Runway excursion/ RE-SC 2b → It corresponds to a situation where a near Runway Excursion was mitigated by pilot avoidance (e.g. Late Go around or urgent manual take-over during rollout)	Hz 004 is applicable to current ILS CAT III operations but optimised and mixed GBAS/ILS equipage operations are new.
Hz 005: Failure to maintain the separation between aircraft on adjacent CAT III approach operations	Final Approach Monitor separation between aircraft on parallel approaches (SP2b) SAC#02 (Mid Air Collision)	*MAC-SC4a/Tactical conflict (crew/aircraft induced). → It corresponds to a situation where an imminent infringement coming from crew/aircraft induced conflict was prevented by tactical conflict management	Hz 005 is applicable to current ILS CAT III operations. However a GBAS Ground Station failure could affect simultaneously the two final approach tracks.
Hz 006: Failure to land in the prescribed touch-down zone in GBAS CAT III approach	Landing Facilitate landing and deceleration on the runway (FLD) SAC#04 (Runway	*RE- SC1 /R.E accident → It corresponds to Runway Excursion with fatalities/injuries or where the a/c sustains damage or structural failure which affects the structural	Hz 006 is applicable to current ILS CAT III operations. However a GBAS ground station failure may affect simultaneously multiple runway-ends at the airport.

Operational Hazard	Phase of flight/ ATM services/ Relevant SAC	Severity (most probable effect)	Comparison with ILS CAT III
CAT III approach and Landing			
	Excursion)	strength.	
Hz 007: Failure to maintain the A/C on the runway centreline during the CAT III GBAS landing rollout		*RE-SC 2b/ Imminent Runway Excursion → It correspond to a situation where a near Runway Excursion was mitigated by pilot avoidance (e.g. urgent manual take-over during rollout)	Hz 007 is applicable to current ILS CAT III operations. However a GBAS ground station failure may affect simultaneously multiple runway-ends at the airport.
Hz 008: Failure to maintain aircraft longitudinal spacing on the runway during CAT III approaches in optimised operation	Landing Maintain aircraft separation on the runway protected area (SP3) SAC#03a (Runway Collision)	*RInc-SC 3/ Runway conflict → It corresponds to a runway incursion due to a premature landing concurrent with a conflicting aircraft on the runway (preceding landing) or approaching the runway (departure)	Hz 008 is applicable to current ILS CAT III operations but is impacted by optimised operations. Indeed reduced ROT could be implemented thanks to the suppression of ILS CAT III sensitive area for GBAS landing.

Operational Hazard	Phase of flight/ ATM services	Severity (most probable effect)	Comparison with ILS CAT III
Guided Take-Off in LVC			
Hz 020: Failure to maintain the A/C on the runway centreline during the Guided Take-off in LVC based on GBAS	Take-Off Facilitate Take-Off roll on the runway (FTA) SAC#04 (Runway excursion)	*RE-SC 2b/ Imminent Runway Excursion → It correspond to a situation where a near Runway Excursion was mitigated by pilot avoidance (e.g Aborted Take-Off)	Hz 020 is applicable to Guided take-off based on ILS. However a GBAS ground station failure may affect simultaneously multiple take-off at the airport.
Hz 021: Failure to maintain the A/C on the runway centreline during the Guided Take-off in LVC based on ILS in mixed GBAS/ILS equipage operations			Hz 021 is relative to ILS but could be impacted by mixed GBAS/ILS equipage operation where the ILS CAT III sensitive area is not always protected (e.g. for GBAS departure)
Hz 022: Failure to maintain aircraft longitudinal spacing on the runway during guided take-off in LVC	Take-Off Maintain aircraft separation on the runway protected area (SP3) SAC#03b (Runway Collision)	*RInc-SC 3/ Runway conflict → It corresponds to a runway incursion due to a premature take-off concurrent with a conflicting aircraft on the runway (preceding departure) or approaching the runway (arrival)	Hz 022 is applicable also to guided take-off operations based on ILS but is impacted by the poss ble reduced ROT due to the suppression of ILS CAT III sensitive area for GBAS departure.

Table 6: Operational Hazards and Severity

Table 7 below identifies the required mitigations (additional Safety Objectives (functionality and performance)) derived in **Appendix F.**

ID	Description	Operational Hazard/ SAC traceability
	CAT III approach and Landing	
SO#0500	For CAT III optimised operations conducted in mixed GBAS/ILS equipage and before starting the final approach, an aircraft shall confirm that he is conducting an ILS approach (not required for GBAS approach)	Hz 004 SAC#01;SAC#04
SO#0501	During the initial approach, aircraft shall verify that GBAS CAT III approach can be conducted. If not the aircraft might revert to another GBAS approach or to an ILS approach (only for mixed GBAS/ILS equipage operations). GBAS capability indication might be different between aircraft and ATC.	Hz 004 SAC#01
SO#0505	In CAT III mixed GBAS/ILS equipage operations, if an aircraft informs ATC before starting the approach that he will conduct an ILS approach whereas ATC foresees a GBAS approach, either ATC verify that ILS CAT III sensitive area will be clear of obstacle or ask the aircraft to initiate a go-around	Hz 004 SAC#01;SAC#04
SO#0510	For CAT III parallel approaches and when final approach track intercept are not supported by radar vectoring, the two approach flows shall be strategically separated by an adequate FAP positioning for the two approaches (different position/altitude)	Hz 002 SAC#02
SO#0520	Aircraft shall execute a missed approach if excessive lateral and/or vertical deviation are detected during a GBAS CAT III approach	Hz 003; Hz 004 SAC#01;SAC#04
SO#0530	In case of GBAS system performance degradation leading to an aircraft capability downgrade from CAT III to CAT I during a CAT III approach, aircraft might continue the approach to CAT I minima or shall execute a missed approach	Hz 003 SAC#01
SO#0330[6]	Aircraft shall execute a missed approach in case of loss of GBAS continuity during a GBAS CAT III approach	Hz 003 Hz 004; Hz 006 and Hz 007 SAC#01;SAC#04
A#0010	For CAT III parallel approaches, ATC uses radar surveillance to monitor the interception of the parallel final approaches (PANS-ATM)	Hz 002 SAC#02
A#0015	Despite the CAT III optimised operations and the possible reduction of aircraft spacing in LVC, ATC still applies minimum radar separation and wake turbulence separation on the final approach	Hz 004 SAC#02
A#0020	ATC uses radar surveillance to monitor separation between aircraft flying CAT III parallel approaches (PANS-ATM)	Hz 005

[6] SO#0330 was derived through the analysis under abnormal condition failure (see section 2.8.2) but is considered as a mitigation following a failure. Indeed within the scope of this safety assessment loss of GPS is considered as an abnormal condition whereas loss of GBAS is considered as a failure condition.

		SAC#02
A#0025	For CAT III parallel approaches and when an aircraft is observed penetrating the NTZ, the aircraft on the adjacent final approach track shall be instructed by ATC to immediately climb and turn to the assigned altitude/height and heading in order to avoid the deviating aircraft (PANS-ATM).	Hz 005 SAC#02
A#0030	For CAT III optimised operations, ATC uses an airport surveillance system for the runway conflict prevention(e.g. A-SMGCS level 1)	Hz 008 SAC#03a
Guided Take-Off in LVC		
SO#0550	Aircraft aborts the guided take-off in LVC if excessive lateral deviation is detected and manual take over impossible due to loss of external visual cues (centerline lights)	Hz 020; Hz 021 SAC#04
SO#0410[7]	Aircraft shall abort the guided take-off in LVC in case of loss of GBAS continuity and loss of external visual cues (centerline lights)	Hz 020; Hz 021 SAC#04
A#0040	For guided Take-Off operations in LVC, ATC uses an airport surveillance system for the runway conflict prevention (e.g. A-SMGCS level 1)	Hz 022 SAC#03b

Table 7: Additional Safety Objectives (functionality and performance) in the case of internal failures

2.9.2 Derivation of Safety Objectives (integrity/reliability)

Safety Objectives (addressing integrity/reliability) listed in Table 8 limit the frequency with which the above Operational hazards could be allowed to occur using the relevant Risk Classification Scheme.

For CAT III approach and landing:

- SO 1001, 1005, 1010, 1015, 1020 and 1035 (relative to respectively Hz 004, Hz 002, Hz 002, Hz 003, Hz 005 and Hz 008) have been derived based on the Risk Classification Schemes (RCS) for the CFIT, Mid-Air Collision and Runway Collision and the formula proposed to derive the safety objectives in Guidance E in ([2]).For more details see also Appendix F.3.
- SO 1002, 1025 and SO 1030 (relative to respectively Hz 004, Hz 006 and Hz 007) have been derived based on EASA CS AWO and CS 25. For more details see also Appendix F.3. It should be noted that no CAT III approach accident due to ILS failure occurred so far but on the other hand number of CAT III operations are rather limited compared to e.g. CAT I approaches.

For Guided take-off in LVC:

- SO 2010 (relative to Hz 022) has been derived based on the Risk Classification Schemes (RCS) for the Runway Collision and the formula proposed to derive the safety objectives in Guidance E in ([2]). For more details see also Appendix F.3.
- SO 2000 and SO 2005 (relative to Hz 020 and Hz 021) have been derived based on EASA CS AWO and CS 25. For more details see also Appendix F.3.

[7] SO#0410 was derived through the analysis under abnormal condition (see section 2.8.2) but is considered as a mitigation following a failure. Indeed within the scope of this safety assessment loss of GPS is considered as an abnormal condition whereas loss of GBAS is considered as a failure condition.

SO ref	Safety Objectives (integrity/reliability)	Traceability Hz/ SAC
	CAT III approach and landing	
SO#1001	During CAT III optimised operations conducted in mixed GBAS/ILS equipage, the frequency of occurrence of an aircraft deviating laterally and/or vertically from the approach path due to an obstructed ILS CAT III sensitive/Critical area shall not be greater than **2x10-7 per approach**	Hz004 SAC#01
SO#1002	During CAT III optimised operations conducted in mixed GBAS/ILS equipage and during the rollout, the frequency of occurrence of an aircraft deviating due to an obstructed ILS CAT III sensitive/Critical area to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7per approach/Extremely Remote	Hz004 SAC#04
SO#1005	The frequency of occurrence of an aircraft erroneous capture of the GBAS CAT III final approach path leading to a flight towards terrain shall not be greater than **2x10-7 per approach**	Hz 002 SAC#01
SO#1010	During parallel approaches, the frequency of occurrence of aircraft erroneous capture of GBAS CAT III final approach paths leading possibly to separation infringement between the two arrival flows shall not be greater than **4x10-5 per flight hour**	Hz 002 SAC#02
SO#1015	The frequency of occurrence of an aircraft deviating laterally and/or vertically from the approach path due to GBAS failure leading to flight towards terrain during a CAT III approach shall not be greater than **2x10-9 per approach**	Hz 003 SAC#01
SO#1020	During parallel approaches, the frequency of occurrence of an aircraft deviating from the approach path due to GBAS failure, leading possibly to separation infringement between the two arrival flows shall not be greater than **4x10-5 per flight hour**	Hz 005 SAC#02
SO#1025	During GBAS CAT III landing, the frequency of occurrence of an aircraft which does not land in the prescribed touch down zone due to GBAS failure shall not be greater than 1x10-9 per approach/Extremely Improbable	Hz 006 SAC#04
SO#1030	During GBAS CAT III rollout, the frequency of occurrence of an aircraft deviating due to GBAS failure to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7per approach/Extremely Remote	Hz 007 SAC#04
SO#1035	During CAT III approach optimised operations, the frequency of occurrence of a longitudinal spacing infringement on the runway leading to runway conflict shall not be greater than **5x10-7 per movement**	Hz 008 SAC#03a
	For Guided take-off in LVC	

SO#2000	During Guided Take-Off in LVC based on GBAS, the frequency of occurrence of an aircraft deviating due to GBAS failure to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7per approach/Remote	Hz 020 SAC#04
SO#2005	During Guided Take-Off in LVC conducted in mixed GBAS/ILS equipage, the frequency of occurrence of an ILS aircraft deviating due to an obstructed ILS CAT III sensitive/Critical area to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Remote	Hz 021 SAC#04
SO#2010	During Guided Take-Off optimised operations, the frequency of occurrence of a longitudinal spacing infringement on the runway leading to a runway conflict shall not be greater than **5x10-7 per movement**	Hz 022 SAC#03b

Table 8: Safety Objectives (integrity/reliability)

2.10 Impacts of GBAS CAT III operations on adjacent airspace or on neighbouring ATM Systems

CAT III approach operation is limited to the final approach and landing part.

CAT III Optimised operation could affect the arrival management because in LVC the aircraft spacing could be lower compared to current ILS CAT III operations. Furthermore arrival management should consider carefully the mixed GBAS/ILS equipage operations where GBAS-ILS pairs shall be spaced differently than GBAS-GBAS or ILS-GBAS pairs (see SO#0070 and SO#0335).

Furthermore the TMA structure could be impacted if parallel approaches are strategically separated in order to be intercepted following RNP procedures (SO#0510) and not only through radar vectoring as currently required for parallel ILS approaches.

When considering an airport with multiple runways served by a single GBAS ground station or served by GBAS, the TMA structure and associated ATC procedures shall be sufficiently resilient to accommodate multiple and possibly simultaneous missed approach following e.g. a GBAS ground Station failure or global GNSS Signal In Space problem (new SO#0600). ATC shall be able to maintain aircraft separation in such case (SAC#02).

ID	Description
SO#0600	TMA structure and associated ATC procedures shall be sufficiently resilient to accommodate multiple and possibly simultaneous missed approach initiated during GBAS CAT III operations following an event affecting all runway ends (e.g. GBAS ground Station failure or global GNSS Signal In Space problem)

Table 9: Additional Safety Objectives (functionality and performance) for Compatibility

For guided take-off operations based on GBAS no impact on the climb phase has been identified.

2.11 Achievability of the SAfety Criteria

At the operational level, the main objective is to show that operations based on GBAS are at least as safe as ILS CAT III approach operation and guided take-off based on ILS.

Two essential aspects have been addressed; the first one is related to the technological change (moving from ILS to GAST-D) and the second is related to the introduction of a new concept of operation (optimised operation with or without mixed GBAS/ILS equipage). At this stage of the operational safety assessment (at OSED level), Safety Objectives which are either functional, performance or integrity/reliability have been specified to satisfy the Safety Criteria (SAC) identified for this OFA. Safety Objectives have been derived in a structured way in order to ensure completeness and have been validated by the project team to ensure correctness.

Following sections are addressing SAC achievability for CAT III approach and Landing (section 2.11.1) and for Guided take-off in LVC (section 2.11.2).

2.11.1 CAT III approach and Landing

In normal Conditions, Safety Objectives (functional and performance) have been identified following a description of an approach from the delivery of the approach clearance to the landed aircraft vacating the runway.

Two sets of Safety Objectives (functional and performance) have been derived:

- SOs to be as safe as ILS CAT III approach in equivalent operational conditions by respecting SAC#01(CFIT), SAC#02 (Mid Air Collision), SAC#03a (Runway Collision) and SAC#04(Runway excursion). These SOs have been derived to specify that the GAST-D technology change shall deliver at least the same performance than ILS for CAT III operation in fault free conditions.

  The following SOs are listed in table below with their traceability towards SAC. Safety Objectives details could be found in section 2.7.2.3 and in Appendix B

SAC reference	Safety Objectives (functional and performance)
SAC#02 (Mid Air Collision)	SO#0005; SO#0010; SO#0020; SO#0025; SO#0030; SO#0040; SO#0050; SO#0065; SO#0075; SO#0166;
SAC#01(CFIT)	SO#0015; SO#0020; SO#0030; SO#0035; SO#0040; SO#0045; SO#0050; SO#0060; SO#0065; SO#0150; SO#0155; SO#0160; SO#0165;
SAC#03a (Runway Collision)	SO#0090; SO#0100; SO#0105; SO#0110; SO#0115;
SAC#04(Runway excursion)	SO#0060; SO#0065; SO#0080; SO#0085;

- SOs to ensure that the operational concept change possible thanks to GBAS (optimised operations and mixed GBAS/ILS equipage operations) is acceptably safe by respecting also SAC#01(CFIT), SAC#02 (Mid Air Collision, SAC#03a (Runway Collision) and SAC#04(Runway excursion). These SOs have been derived to specifically address and specify optimised and mixed GBAS/ILS equipage operations which are new compared to current ILS CAT III operations.

  The following SOs are listed in table below with their traceability towards SAC. Safety Objectives details could be found in section 2.7.2.3 and in Appendix B

SAC reference	Safety Objectives (functional and performance)
SAC#02 (Mid Air Collision)	SO#0011; SO#0070; SO#0072; SO#0170;
SAC#01(CFIT)	SO#0055;
SAC#03a (Runway Collision)	SO#0095; SO#0120; SO#0125; SO#0130; SO#0135; SO#0140; SO#0145;
SAC#04(Runway excursion)	SO#0055;

In abnormal Conditions, Safety Objectives (functional and performance) have been identified considering abnormal conditions/events/errors external to GBAS or ILS functional systems which could affect the performance of CAT III approach and landing. Several abnormal conditions have been identified and three of them had led to specify specific Safety objectives.

The following SOs are listed in the table below with their traceability towards SAC and the relevant abnormal condition. Safety Objectives details could be found in section 2.8.2 and in Appendix B

SAC reference	Relevant Safety Objectives	Abnormal condition
SAC#02 (Mid Air Collision)	None	
SAC#01(CFIT)	SO#0300	Ionospheric disturbances
	SO#0315	Interference
	SO#0340; SO#0345	GPS constellation failure/degradation leading to GPS SIS loss
SAC#03a (Runway Collision)	None	
SAC#04(Runway excursion)	SO#0305; SO#0310	Ionospheric disturbances
	SO#0320; SO#0325	Interference
	SO#0335	Arrival Manager

In Failure Conditions, Safety Objectives (integrity/reliability) have been derived to limit the frequency with which the identified operational hazard could be allowed to occur. Operational Hazards are either relative to CAT III approaches conducted with GBAS (Hz 002; 003; 005; 006 and 007) or relative to optimised/mixed GBAS/ILS equipage operation (Hz 004 and 008). In addition during the assessment several preventive Safety Objectives have been also identified.

The following SOs are listed in table below with their traceability towards SAC and Operational Hazard. Safety Objectives and Operational Hazards details could be found in section 2.9 and in Appendix B

SAC reference	SO (integrity/reliability)	SO (preventive)	Operational Hazard
SAC#02 (Mid Air Collision)	SO#1010	SO#0510	Hz 002
	SO#1020	None	Hz 005
SAC#01(CFIT)	SO#1001	SO#0500; SO#0501; SO#0505; SO#0520;	Hz 004
	SO#1005	None	Hz 002
	SO#1015	SO#0520; SO#0530	Hz 003
SAC#03a (Runway Collision)	SO#1035	None (but REC#0006 is identified)	Hz 008
SAC#04(Runway excursion)	SO#1002	SO#0500; SO#0505; SO#0520	Hz 004
	SO#1025	None	Hz 006
	SO#1030	None	Hz 007

It should be noted that SO#0330 (corrective SO) derived during the analysis in abnormal conditions is relevant for the failure analysis.

When considering the impact on adjacent airspace and neighbouring ATM systems:

- For the impact on neighbouring ATM system, two SOs were derived during the analysis in normal and abnormal conditions (SO#0070 and SO#0335)[8] for the arrival manager. These SOs are considered to be sufficient to address this aspect.

[8] see in above tables for normal and failure conditions

- For the impact on adjacent airspace, one SO (SO#0510)[9] was derived during the analysis in failure conditions and a new SO (SO#0600) was considered necessary for the TMA airspace structure. SO#0600 specifies that TMA airspace structure and associated ATC procedures shall be resilient to multiple missed approaches due to GBAS specificities. This SO is traceable towards SAC#02 (Mid Air Collision).

2.11.2 Guided Take-Off in LVC

In normal Conditions, Safety Objectives (functional and performance) have been identified following a description of a take-off from the take-off roll to the initial climb.

Two sets of Safety Objectives (functional and performance) have been derived:

- SOs to be as safe as guided take-off supported by ILS (Localizer) in equivalent operational conditions by respecting SAC#03b (Runway Collision) and SAC#04(Runway excursion). These SOs have been derived to specify that the GAST-D technology change shall deliver at least the same performance than ILS (Localizer) in fault free conditions.

  The following SOs are listed in table below with their traceability towards SAC. Safety Objectives details could be found in section 2.7.2.3 and in Appendix B

SAC reference	Safety Objectives (functional and performance)
SAC#02 (Mid Air Collision)	No risk of Mid air collision during the take-off roll but risk of Runway collision (see below)
SAC#01(CFIT)	No risk of CFIT during the take-off roll but risk of Runway Excursion (see below)
SAC#03b (Runway Collision)	SO#0200; SO#0060; SO#0055; SO#0205; SO#0210;
SAC#04(Runway excursion)	SO#0200; SO#0060;

- SOs to ensure that the mixed GBAS/ILS equipage operations are acceptably safe. One S.O (SO#0055) has been derived to address this new aspect compared to current guided take-off operations based on ILS only. SO#0055 (see 2.7.2.3) is traceable towards SAC#04 (Runway Excursion).

In abnormal Conditions, Safety Objectives (functional and performance) have been identified considering abnormal conditions/events/errors external to GBAS or ILS functional systems which could affect the performance of Guided take-off in LVC. Several abnormal conditions have been identified and two of them had led to specify specific Safety objectives.

The following SOs are listed in the table below with their traceability towards SAC and the relevant abnormal condition. Safety Objectives details could be found in section 2.8.2 and in Appendix B

SAC reference	Relevant Safety Objectives	Abnormal condition
SAC#02 (Mid Air Collision)	No risk of Mid air collision during the take-off roll but risk of Runway collision	
SAC#01(CFIT)	No risk of CFIT during the take-off roll but risk of Runway Excursion	
SAC#03b (Runway Collision)	None	
SAC#04(Runway excursion)	SO#0400	Ionospheric disturbances
	SO#0450	Interference

In Failure Conditions, Safety Objectives (integrity/reliability) have been derived to limit the frequency with which the identified operational hazard could be allowed to occur. Operational Hazards are either

[9] see in above table for failure conditions

relative to Guided take-off based on GBAS (Hz 020) or relative to optimised/mixed GBAS/ILS equipage operations (Hz 021 and 022). In addition during the assessment one preventive Safety Objective has been also identified.

The following SOs are listed in table below with their traceability towards SAC and Operational Hazard. Safety Objectives and Operational Hazards details could be found in section 2.9 and in Appendix B

SAC reference	SO (integrity/reliability)	SO (preventive)	Operational Hazard
SAC#02 (Mid Air Collision)	No risk of Mid air collision during the take-off roll but risk of Runway collision		
SAC#01(CFIT)	No risk of CFIT during the take-off roll but risk of Runway Excursion		
SAC#03b (Runway Collision)	SO#2010	None	Hz 022
SAC#04(Runway excursion)	SO#2000	SO#0550	Hz 020
	SO#2005	SO#0550	Hz 021

It should be noted that SO#0410 (corrective SO) which was derived during the analysis in abnormal conditions is relevant for the failure analysis.

When considering the impact on adjacent airspace and neighbouring ATM systems: No impact has been identified with the climb phase or with neighbouring ATM system.

2.12 Validation & Verification of the Safety Specification

The consolidated list of Safety Objectives is listed in Appendix A. Several Webex for the safety assessment at OSED level have been organised and minutes of these discussions can be found in the SESAR extranet (See P15.3.6 → folder Execution -> D22).

A FHA workshop was organised in June 2013 with the support of operational people including controllers and pilots. FHA supporting material and workshop conclusions can be found in the SESAR extranet (P15.3.6 → folder Execution -> D22).

During the safety assessment at OSED level, several validation Items have been identified. These Items are listed in Table 10 below and should be considered during the OFA validation exercises.

These Items should be reviewed with the validation team in order to be considered in the Validation Plan.

Val ref/ Associated SO	Validation Items	Status
	CAT III approach and Landing	
VAL#001 (SO#0020)	It should be validated that the capture of the final approach supported by RNP is safe and efficient (with respect to the RNP corridor)	06.08.05 validation exercise
VAL#0002 (SO#0070; SO#0335)	In CAT III approach mixed GBAS/ILS equipage operation, appropriate spacing between aircraft pairs (GBAS-ILS; GBAS-GBAS and ILS-GBAS) should be validated to prevent ILS CAT III sensitive area infringement by a preceding aircraft during an ILS landing	06.08.05 validation exercise
VAL#0004 (SO#0095)	For optimised operations, the late landing Clearance shall be provided at a distance to the runway threshold which does not impair the aircraft ability to prepare the landing. This aspect	06.08.05 validation exercise

Val ref/ Associated SO	Validation Items	Status
	should be validated during validation exercise	
VAL#0005 (SO#0120)	It should be validated if Runway safety nets are suitable for optimised operations and mixed GBAS/ILS equipage operation or if they should be modified.	06.08.05 validation exercise
VAL#0006 (SO#0125 to SO#0145)	The landing clearance line concept should be validated for: *segregated runway operation (arrival) with GBAS optimised operations *segregated runway operation (arrival) with mixed GBAS/ILS equipage operations *mixed mode runway operation (arrival/departure) with GBAS optimised operations *mixed mode runway operation (arrival/departure) with mixed GBAS/ILS equipage optimised operations	06.08.05 validation exercise
VAL#0007 (SO#0170)	During optimised operations, the go-around rate (without considering failure) shall not be greater than in ILS CAT III only operations (without considering failure) in similar operational environment and weather conditions.	06.08.05 validation exercise
VAL#0008 (SO#0035)	For non CDO operations, it should be checked if a 2Nm (or 30 sec) straight and level flight segment prior to final approach track intercept is necessary.	06.08.05 validation exercise
VAL#0009	To prevent any detrimental impact on GAST-D operations, it should be determined if ATC measures are necessary in LVP to control the access of GBAS areas on the ground based on LOCA (Local Object Consideration Areas)	15.03.06 validation exercise
Guided-Take-Off		
VAL#0009	See above	See above

Table 10: Validation Items to be considered in Validation exercise

3 Safe Design at SPR Level

3.1 Scope

This section addresses the following activities:

- description of the SPR-level Model for CAT III approach and Guided Take-Off supported by GAST-D – section 3.2
- derivation of Safety Requirements for the SPR-level design and analysis of the operation under normal operational conditions – section 3.3
- analysis of the operation of the SPR-level design under abnormal conditions – section 3.4
- assessment of the adequacy of the SPR-level design under internal-failure conditions and mitigation of the system-generated hazards – section 3.5
- satisfaction of Safety Criteria by the SPR-level design – section 3.6
- realism of the SPR-level design – section 3.7
- validation & verification of the SPR-level design – section 3.8

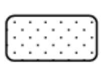
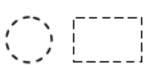
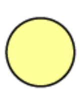
3.2 The GBAS CAT III-L1 SPR-level Model

The SPR-level Model in this context is a high-level architectural representation of the operations supported by GAST-D that is entirely independent of the eventual physical implementation of the design. The SPR-level Model describes the main human tasks (including procedures) and machine functions. In order to avoid unnecessary complexity, human-machine interfaces are not shown explicitly on the model - rather they are implicit between human actors and machine-based functions.

The GAST-D SPR-level Model is illustrated in section 3.2.1 below and description of the different data flows in Section 3.2.2.

3.2.1 SPR-level Model

The SPR-level model is described in **Figure 7** below and symbols used in this model are explained in the following table.

	Operational node: could be a machine-based element, a human element or a combination of the two.
	On demand needline: indicate on demand data flow between nodes
	Continuous needline: indicate a continuous data flow between nodes
xx : yyy	Needline information: indicate the type of required flow between nodes
	Set of operational nodes associated to a domain (ex ANSP-ATC, Aircraft,…)
	Optional node and/or data flow
	External node
	Human actor

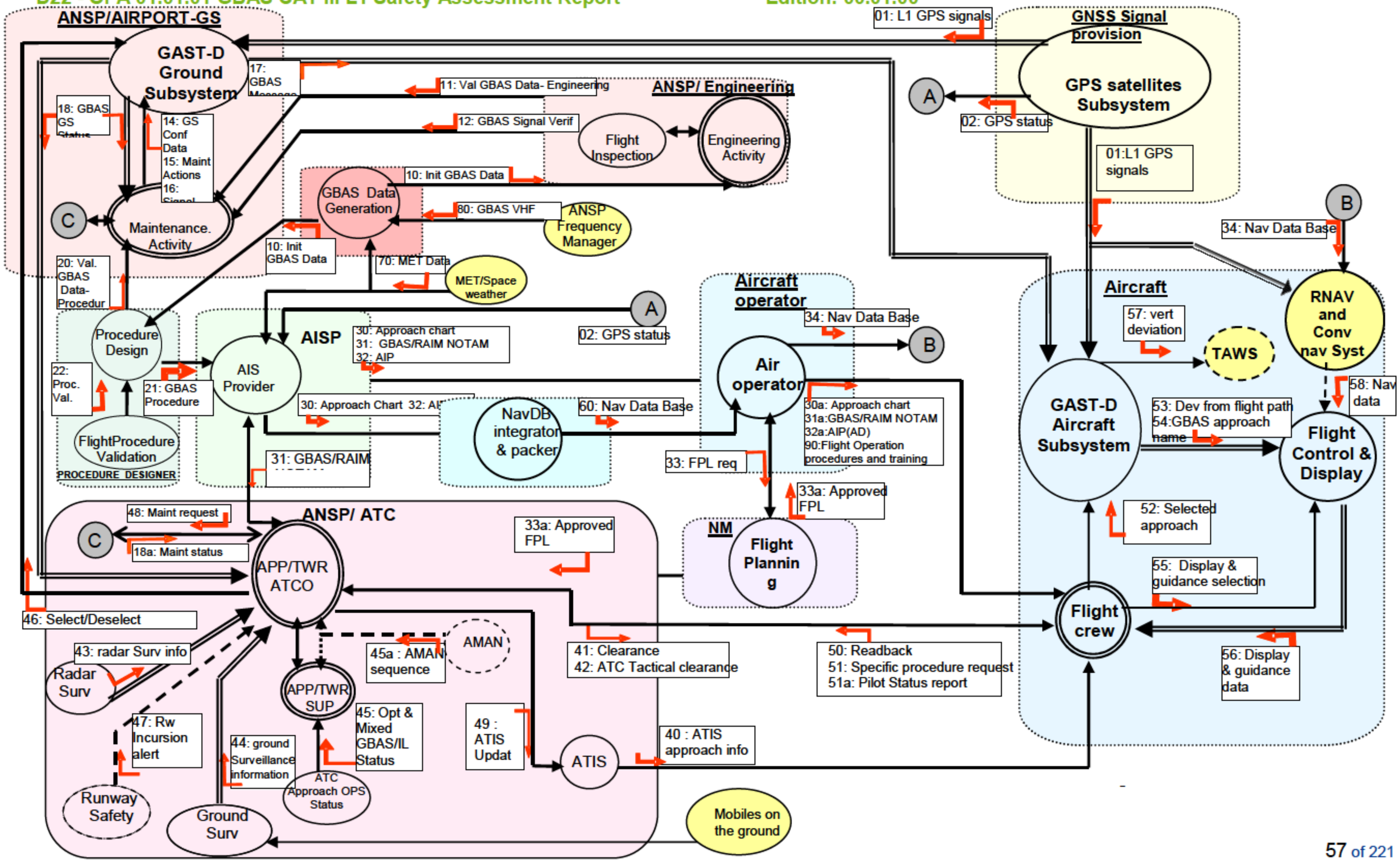

ANSP/AIRPORT-GS
GAST-D Ground Subsystem
17: GBAS Message
18: GBAS GS Status
14: GS Conf Data
15: Maint Actions
16: Signal
Maintenance. Activity
C
20: Val. GBAS Data-Procedur
11: Val GBAS Data- Engineering
12: GBAS Signal Verif
ANSP/ Engineering
Flight Inspection
Engineering Activity
GBAS Data Generation
10: Init GBAS Data
80: GBAS VHF
ANSP Frequency Manager
70: MET Data
MET/Space weather
GNSS Signal provision
01: L1 GPS signals
GPS satellites Subsystem
02: GPS status
01:L1 GPS signals
A
B
34: Nav Data Base
Procedure Design
22: Proc. Val.
21: GBAS Procedure
FlightProcedure Validation
PROCEDURE DESIGNER
AIS Provider
AISP
30: Approach chart
31: GBAS/RAIM NOTAM
32: AIP
30: Approach Chart 32: AIP
31: GBAS/RAIM
02: GPS status
60: Nav Data Base
NavDB integrator & packer
Aircraft operator
Air operator
30a: Approach chart
31a:GBAS/RAIM NOTAM
32a:AIP(AD)
90:Flight Operation procedures and training
33: FPL req
33a: Approved FPL
NM
Flight Planning
Aircraft
57: vert deviation
TAWS
RNAV and Conv nav Syst
58: Nav data
GAST-D Aircraft Subsystem
53: Dev from flight path
54:GBAS approach name
Flight Control & Display
52: Selected approach
55: Display & guidance selection
Flight crew
56: Display & guidance data
50: Readback
51: Specific procedure request
51a: Pilot Status report
ANSP/ ATC
48: Maint request
18a: Maint status
APP/TWR ATCO
33a: Approved FPL
46: Select/Deselect
43: radar Surv info
Radar Surv
47: Rw Incursion alert
Runway Safety
44: ground Surveillance information
Ground Surv
APP/TWR SUP
45a : AMAN sequence
AMAN
45: Opt & Mixed GBAS/IL Status
ATC Approach OPS Status
49 : ATIS Updat
ATIS
41: Clearance
42: ATC Tactical clearance
40 : ATIS approach info
Mobiles on the ground

Figure 7: GBAS CAT III-L1 SPR-level Model

3.2.2 Description of SPR-level Model

Description of the GBAS CAT III SPR-Level Model is provided in Table 11 below by identifying and describing all information exchanges that make up all information needlines between operational nodes.

item #	Information	Sending node	Receiving node	Usage(receiving node)
GNSS Signal Provision				
01	L1 GPS Signal	GPS satellite Subsystem	GAST-D aircraft Subsystem	To receive and decode GPS satellite signal for GBAS
			GAST-D Ground Subsystem	-To Receive and decode GPS satellite signals for GBAS -To monitor GPS satellite signals for GBAS -To compute corrections and performance parameters for "healthy" satellites for GBAS
			RNAV and Conv Nav System	To receive and decode GPS satellite signal for RNAV computation
02	GPS Status	GPS satellite Subsystem	AIS Provider	-To be informed on the status of the GPS navigation infrastructure (GPS satellite) - To elaborate GBAS or RAIM NOTAM when necessary
GBAS Data provider				
10	Initial GBAS Data	GBAS Data Generation	Engineering Activity	GBAS data are provided for validation and verification. GBAS data includes data for GS configuration, commissioning and maintenance but also for procedure design e.g. siting criteria; local iono model, VDB frequency; FAS data block ; GBAS antenna coordinates (GBAS reference antennas; GBAS Reference Point); local magnetic variation; aerodrome data (obstacles, terrain, coordinates,…); etc….
			Procedure Design	
ANSP/Engineering				
11	Validated GBAS Data	Engineering Activity	Maintenance activity	To obtain GBAS data validated from an engineering point of view for the GS configuration
12	GBAS Signal verification	Flight Inspection	Maintenance activity	To initiate maintenance activities for the GBAS signal inspection in accordance with the flight inspection programme (commissioning and periodic)
ANSP/AIRPORT-GS (Ground Station)				
14	GS Configuration Data	Maintenance Activity	GAST-D Ground Subsystem	To install and configure the GBAS GS in accordance with Validated GBAS Data
15	Maintenance actions	Maintenance Activity	GAST-D Ground Subsystem	To apply maintenance actions (preventive and/or corrective)
16	Signal Inspection	Maintenance Activity	GAST-D Ground Subsystem	To inspect and calibrate the GBAS GS signal by ground and flight verification in accordance with the flight inspection programme (commissioning and periodic)
17	GBAS Messages	GAST-D Ground Subsystem	GAST-D aircraft Subsystem	To receive and decode GBAS messages (correction, integrity data, FAS data)
18	GBAS GS Status	GAST-D Ground Subsystem	APP/TWR ATCO	To be informed on the operational status of the GBAS GS to schedule approaches (may include activation/de-activation of approaches) and inform maintenance in case of GS unavailability
			Maintenance Activity	To be informed on the operational status of the GBAS GS to schedule corrective maintenance actions

item #	Information	Sending node	Receiving node	Usage(receiving node)
18a	Maintenance Status Report	Maintenance activity	APP/TWR ATCO	To be informed on maintenance activity scheduled or not. To be informed of any other problem detected by maintenance staff and affecting GBAS performance
		Procedure Designer		
20	Validated GBAS data from Procedure	Procedure Design	Maintenance activity	To obtain GBAS data validated by the procedure designer for the GS configuration/installation
21	GBAS Procedure	Procedure Design	AIS Provider	To obtain all data relevant for the aeronautical data origination including the procedure design (approach chart)
22	Procedure validation	Flight Procedure Validation	Procedure Design	To validate that procedure has been designed in accordance with design criteria
		AISP		
30	Approach Chart	AIS provider	Aircraft Operator NavDB Integrator & packer	To be informed on the depiction/characteristics of the GBAS approach to be flown
31	GBAS/ RAIM NOTAM	AIS provider	Aircraft Operator APP/TWR ATCO	To be informed on GBAS procedure unavailability
32	AIP(AD)	AIS provider	Aircraft Operator NavDB Integrator & packer	To be informed of specific GBAS information (GBAS classification, identification, channel number, etc…)
		Aircraft Operator		
30a	Approach Chart	Aircraft Operator	Flight Crew	To obtain the approach chart for the flight in accordance with the operator's rule/format
31a	GBAS/RAIM NOTAM	Aircraft Operator	Flight Crew	To be informed of GBAS procedure unavailability in accordance with the operator's rule/format
32a	AIP	Aircraft Operator	Flight Crew	To be informed of specific GBAS information (GBAS classification, identification, channel number, etc…) in accordance with the operator's rule/format
33	FPL request	Aircraft Operator	Flight Planning	To be informed on the GBAS aircraft capability (using the latest ICAO flight plan format)
34	Nav Data Base	Aircraft Operator	RNAV and Conv nav data	To load the Navigation Data Base in the RNAV/FMS system in order to intercept and fly the GBAS approach appropriately
90	Flight operation procedures and training	Aircraft Operator	Flight Crew	To be informed of appropriate procedures relevant for GBAS CAT III operations including missed approach and to be trained on these procedures
		Network Manager (NM)		
33a	Approved FPL	Flight Planning	Aircraft Operator	To be informed on the status of the submitted flight plan
			APP/TWR ATCO	To be informed on the flight plan and of the GBAS aircraft capability (in accordance with the latest ICAO flight plan format)
		ANSP/ATC		
40	ATIS approach info	ATIS	Flight Crew	To obtain information relative to the available approaches at the destination aerodrome
41	Clearance	APP/TWR ATCO	Flight Crew	To respect ATC clearances (e.g. approach CLR, landing CLR,…)
42	Tactical Clearances	APP/TWR ATCO	Flight Crew	To respect ATC instructions for the final approach vectoring interception, in case of Go Around initiated by ATC, in case of trajectory deviation from the nominal path detected by ATC, etc ….
43	Radar Surveillance information	Radar Surv	APP/TWR ATCO	-To obtain surveillance information for aircraft intercepting and flying the GBAS approach. -To separate/monitor A/C during parallel approaches - To monitor spacing between A/C on the same final approach

item #	Information	Sending node	Receiving node	Usage(receiving node)
44	Ground surveillance information	Ground Surv	APP/TWR ATCO	-To obtain Surveillance information for mobiles (A/C or vehicles) on the movement area - To materialize/display the landing clearance line for optimised operations
45	Optimised & Mixed GBAS/ILS status	ATC Approach Operational Status	APP/TWR Supervisor APP/TWR ATCO	To be informed when optimised operations and/or mixed GBAS/ILS equipage operations are effective
45a	Arrival Manager sequence	Arrival Manager	APP/TWR Supervisor APP/TWR ATCO	To be informed about the proposed arrival sequence for the approach
46	Select/ Deselect Approaches	APP/TWR ATCO	GAST-D Ground Subsystem	To Select or deselect approaches at the GBAS GS level
47	Runway Incursion alert	Runway Safety net	APP/TWR ATCO	To be alerted of runway incursion (incorrect presence of a mobile on the runway protected area) or CSA infringement
48	Maintenance Request	APP/TWR ATCO	Maintenance activity	To request a GBAS GS maintenance activity in case of reported deficiency/problem
49	ATIS Update	APP/TWR ATCO	ATIS	To transmit up to date information regarding inter alia the available approach type (GBAS; ILS) and the LVP conditions including RVR
		Aircraft		
50	Readback	Flight Crew	APP/TWR ATCO	To confirm pilot acknowledgment of ATC clearances/instructions
51	Specific procedure request	Flight Crew	APP/TWR ATCO	To be informed about pilot's request to fly a specific approach e.g. the GBAS approach
51a	Pilot Status Report	Flight Crew	APP/TWR ATCO	To provide any specific information on GBAS functioning
52	Selected approach	Flight Crew	GAST-D Aircraft Subsystem	To select/tune the GBAS approach
53	Deviation from flight path	GAST-D Aircraft Subsystem	Flight Control and Display	-To display deviation (lateral/vertical) from the desired path (FAS) and distance to threshold -To guide the aircraft respecting the lateral/vertical desired path
54	GBAS Approach Name	GAST-D Aircraft Subsystem	Flight Control and Display	-To display the GBAS Reference Path Indicator (RPI) and the GBAS Channel Number
55	Display and guidance selection	Flight Crew	Flight Control and Display	- To provide display and guidance mode in accordance with pilot's selection. Autoland capability is required For CAT III approach.
56	Display and guidance data	Flight Control and Display	Flight Crew	-To verify the GBAS Ground Station Identity -To monitor lat/vert deviation -To be informed about availability of service and any service degradation (e.g. from GAST-D to GAST C) -To be informed about integrity alert (flag) -To monitor DH
57	Vertical deviation	GAST-D Aircraft Subsystem	TAWS	-To alert pilot in case of excessive downward GBAS vertical deviation
58	Nav data	RNAV and Conv nav data	Flight Control and Display	- To display/guide aircraft for the final approach interception either in accordance with: * RNAV/RNP (e.g. RNP transition to GLS) or - Conventional navigation (ILS, VOR,..)
		Navigation Data Base Supplier		
60	Nav Data Base	NavDB integrator & packer	Aircraft Operator	To obtain the navigation base including all relevant data for the GBAS approach interception and for conducting the approach
		MET Provider (MET Services or approved third parties)		

item #	Information	Sending node	Receiving node	Usage(receiving node)
70	MET Data	MET / Space Weather	GBAS Data Generation	To obtain appropriate data for configuring the tropospheric and ionospheric integrity parameters for the GBAS GS broadcasting.
			AIS Provider	To be informed of severe ionospheric disturbances requiring NOTAM publication
ANSP Frequency Manager				
80	GBAS VHF frequency	ANSP Frequency Manager	GBAS Data Generation	To obtain the VHF frequency (VDB) for the GBAS GS configuration

Table 11: GBAS CAT III-L1 SPR-level Model operational information description

3.2.3 Derivation of Safety Requirements (Functionality and Performance – success approach)

Table 12 below shows how the Safety Objectives (Functionality and Performance) derived in section 2 map on to the related elements of the SPR-level Model.

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / *Data flow number***
CAT III APPROACH AND LANDING		
SO#0005 ATIS shall inform arriving aircraft of the landing procedures available for the runway in use (ILS and GBAS or GBAS only) and indicate that LVP are in place	SR 005: ATIS shall indicate to the flight crew that GBAS approach is available at the destination aerodrome for the runway currently in use and that LVP are in force	ATIS → Flight Crew / *40(ATIS approach info)*
	SR 010: ATIS shall indicate to the flight crew that GBAS and ILS approaches are both available at the destination aerodrome if mixed GBAS/ILS operation is implemented for the runway currently in use and that LVP are in force	ATIS → Flight Crew / *40(ATIS approach info)*
	A#0045: ATC updates ATIS to provide the relevant landing aid information for the runway currently in use (GBAS only or both GBAS and ILS) and the LVP conditions (RVR)	APP ATCO →ATIS / *49(ATIS update)*
SO#0010 Approach clearance shall be provided to arriving aircraft which indicate the expected approach to be flown	A#0050: Flight crew is responsible for the approach choice when both GBAS and ILS approach are available at the destination aerodrome	ATIS → Flight Crew / *40(ATIS approach info)*
	SR 013: The operational status of the GBAS landing aid shall be displayed to the Approach and Tower Controllers	GAST-D GS → APP/TWR ATCO / 18(GBAS Status)
	SR 014: The Approach Controller shall check the operational status of the landing aids (GBAS or GBAS and ILS) before providing the approach clearance	GAST-D GS → APP/TWR ATCO / 18(GBAS Status)
	SR 015: The Approach Controller shall provide to the flight crew the approach clearance indicating that aircraft is cleared to the GBAS approach when GBAS is the only available landing aid at the destination aerodrome I#002 The phraseology to be used for GBAS approaches (GBAS or GLS) shall be clarified at ICAO level and should be determined to prevent any confusion with other landing aids (ILS or MLS). REC#0007: Naming and phraseology used for GBAS should be consistent for flight crew and controllers when considering radiotelephony communications, charting information, ATC displayed	APP ATCO → Flight Crew / *41(Clearance)*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / *Data flow number***
	information and flight deck indication.	
	SR 020: The Approach Controller shall provide to the flight crew the approach clearance considering the flight crew expected approach (GBAS or ILS) when both GBAS and ILS approach are available at the destination aerodrome	APP ATCO → Flight Crew / *41(Clearance)*
	SR 025: For optimised operations in LVP, the Approach Controller shall organize the arriving aircraft sequence considering the aircraft capability as indicated by flight plan information (with or without GBAS capability)	Flight Planning → APP ATCO / *33a(Approved FPL)*
	SR 030: The approach supervisor shall inform the approach controller that optimised and mixed GBAS/ILS operation in LVP are authorised for the CAT III approach on the runway in use	APP SUP → APP ATCO / *45 (Opt & Mixed GBAS/ILS status)*
	A#0055: Optimised operations are always implemented at the destination aerodrome when GBAS is the only available landing aid	APP SUP → APP ATCO / *45 (Opt & Mixed GBAS/ILS status)*
	A#0060: The Flight Plan system is updated to process the GBAS capability as specified in FPLN field 10.	Flight Planning → APP ATCO / *33a(Approved FPL)*
SO#0011 For optimised operations conducted in mixed GBAS/ILS equipage, aircraft shall inform ATC about the approach that will be flown: GBAS or ILS.	SR 035: Flight Crew shall inform the Approach Controller about the type of approach that she/he intent to conduct when both GBAS and ILS approach are available at the destination aerodrome considering that the preferred approach should be GBAS if aircraft is GBAS equipped	Flight Crew → APP ATCO / *51 (Specific procedure request)*
	SR 045: The Flight Crew shall read back to the Approach Controller the approach clearance (GBAS or ILS)	Flight Crew → APP ATCO/ *50 (Readback)*
	SR 046: At each frequency transfer, Flight Crew shall indicate to the controller the type of approach that she/he intent to conduct when both GBAS and ILS approach are available at the destination aerodrome	Flight Crew → APP ATCO / *51 (Specific procedure request)*
SO#0015 Before Final Approach Point, the aircraft shall capture the GBAS Lateral path before the GBAS vertical path to conduct stabilized approach	SR 050: The Flight Crew shall select/tune the GBAS final approach in accordance with the published procedure as soon as she/he has received the approach clearance	Flight Crew → GAST-D aircraft subsystem / *52 (selected approach)*
	SR 055: The Flight Crew shall check that the GBAS station is correctly tuned by cross-checking the charted GBAS ID (Reference Path Indicator (RPI)) with the GBAS ID (RPI) displayed in the cockpit	Flight Control & Display → Flight Crew / *56(display&guidance)* Air Operator → Flight Crew */30a(approach chart)*
	A#0061: The aircraft GBAS audio identification function is not available	
	SR 060: The Flight Crew shall check the aircraft GBAS CAT III capability before starting the GBAS approach	Flight Control & Display → Flight Crew / *56(display&guidance)*
	SR 065: The Approach controller shall provide to the flight crew the clearance for the final interception by specifying the type of landing aid ("cleared for GBAS approach")	APP ATCO → Flight Crew / *41(Clearance)*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / *Data flow number***
	SR 070: The GAST-D aircraft subsystem shall intercept the GBAS final approach course in accordance with the published approach chart	RNAV → Flight Control & Display / *58(Nav Data)* GAST-D aircraft Subsystem → Flight Control & Display / *53 (Dev from flight path)*
	SR 075: The Flight Crew shall inform the Approach Controller when she/he is established on the GBAS final approach course (“established GBAS approach”).	GAST-D Aircraft Subsystem → Flight Control & Display / *53(Dev from flight path)* Flight Crew → APP ATCO
	SR 080: The GAST-D aircraft subsystem shall intercept the GBAS vertical path in accordance with the published approach chart	RNAV → Flight Control & Display / *58(Nav Data)* GAST-D aircraft Subsystem → Flight Control & Display / *53 (Dev from flight path)*
SO#0020 Aircraft shall respect the lateral performance of the published approach intermediate segment which might include an RF leg during a final approach capture supported by RNAV/RNP.	SR 085: The Approach Controller shall clear the aircraft to the GBAS approach by specifying the RNAV transition to be respected when required	APP ATCO → Flight Crew / *41(clearance)*
	A#0063: The aircraft capability to fly the RNAV transition of the GBAS approach is indicated on the approach chart (e.g. RNP 1, GNSS required, RF required,…)	AIS Provider / *30(Approach chart)*
	A#0064: RNAV transition (RNAV/RNP initial/intermediate approach segments) are designed in accordance with PANS-OPS criteria amended by ICAO letter SP65/4-13/24 (14 June 2013) if RF legs are used.	Procedure Design → AIS Provider
	SR 090: The RNAV system shall guide the aircraft in accordance with the published RNAV transition until the GAST-D aircraft subsystem intercepts the GBAS final approach course	RNAV → Flight Control & Display/ *58(Nav Data)* GAST-D aircraft Subsystem → Flight Control & Display/*56(display& guidance data)*
	SR 091: The processes of producing and updating the RNAV system navigation data base shall meet the standards specified in EUROCAE ED-76/RTCA DO-200A (e.g. Letter Of Acceptance or equivalent process). In particular, the navigation data base shall contain electronic navigation data with an adequate level of accuracy and integrity to ensure proper transition to the GBAS final approach segment.	Nav DB integrator & packer → Aircraft Operator/*60(Nav data base)*
	SR 092: The Aircraft Operator shall use a navigation data base for the RNAV system which satisfies the requirements of the IR OPS (or equivalent OPS regulation) in order to meet standards of integrity that are adequate for the intended use of the electronic navigation data.	Aircraft Operator →RNAV System */34(Nav data base)*
	A#0065: The Flight Crew respect the RNAV system guidance during the RNAV transition of the GBAS approach	Flight Control & Display→Flight Crew/ *56(Display & guidance data)*
SO#0025 Aircraft shall respect ATC vectoring instructions for the final approach capture	SR 095: The Approach Controller shall provide radar vectors to the Flight Crew to intercept the GBAS final approach course when such interception is used	APP ATCO → Flight Crew/ *42(ATC tactical clearance)*
	A#0070: The Flight Crew respect the radar vectors and prepare the transition for the interception of the GBAS final approach course	Flight Crew→ Flight Control & Display/ *55 (Display & guidance selection)*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / *Data flow number***
SO#0030 Aircraft shall respect vertical altitude constraint at FAP during a final approach capture by transitioning properly from Baro-altitude to GBAS vertical path (xLS).	SR 100: The Flight Crew shall verify that glideslope capture is made at the altitude depicted on the chart.	AIS Provider / *30(Approach chart)* Flight Control & Display → Flight Crew */56(display& guidance data)*
SO#0035 For non CDO operations, a 2Nm (or 30 sec) straight and level flight segment prior to final approach track intercept shall be the flown to conduct stabilized approach	SR 110: When radar vectoring is used for the approach interception, the Approach Controller shall provide instructions to Flight Crew allowing the aircraft to be aligned on the final approach course at least 2Nm before FAP	APP ATCO → Flight Crew/ *42(ATC tactical clearance)*
	SR 111: When radar vectoring is used for the approach interception, the Approach Controller shall provide instructions to Flight Crew allowing the aircraft to intercept the GBAS final approach course with an angle lower than 45º.	APP ATCO → Flight Crew/ *42(ATC tactical clearance)*
	SR 115: The intermediate approach segment of the GBAS procedure shall be aligned with the final approach course and its segment length shall be sufficient to permit the aircraft to stabilize and establish on the final approach course prior to intercepting the glide path	Procedure Design → AIS Provider / *21(GBAS Procedure)*
	SR 120: The aircraft shall be established on the GBAS final approach course at a distance from the FAP sufficient to prevent GBAS glideslope capture from above	RNAV → Flight Control & Display/ *58(Nav Data)* GAST-D aircraft Subsystem → Flight Control & Display/ *53 (Dev from flight path)*
SO#0040 ATC shall not provide vectoring for aircraft conducting CDO when aircraft cannot conduct a fully optimised CDO with vectoring	SR 125: The Flight crew shall conduct CDO in accordance with instructions and/or limitations specified on the relevant arrival chart for a smooth capture the GBAS glideslope at the altitude depicted on the chart	AIS Provider / *30(Approach chart)* Flight Control & Display → Flight Crew */56(display& guidance data)*
	SR 130: The Approach Controller shall not provide radar vectoring instructions to aircraft during optimised CDO if aircraft does not support this capability	APP ATCO → Flight Crew
SO#0045 The GBAS CAT III approach is designed and promulgated to prevent loss of separation with terrain/obstacle	SR 135: The terrain, obstacle and aerodrome data used in the design of the GBAS CAT III approach procedure shall comply with the appropriate data quality requirements of ICAO Annex 14 and 15 and respect the European Regulation N°73/2010 on the quality of aeronautical data/information.	GBAS Data Generation → Procedure Design / *10(Init GBAS Data)*
	SR 140: The GBAS CAT III procedure shall be designed in accordance with PANS OPS criteria relative to ILS CAT III See also A#0035 ("The obstacle clearance during a GBAS CAT III approach is the same compared to ILS CAT III") but this assumption is not yet validated	Procedure Design → AIS Provider / *21(GBAS Procedure)*
	SR 145: The design and validation of the GBAS CAT III procedure shall be made in accordance with the Instrument Flight Procedure process specified in ICAO Doc 9906	Procedure Design → AIS Provider / *21(GBAS Procedure)* Flight procedure validation → Procedure Design */22(Procedure Validation)*
	SR 160: The "Radio navigation and landing aids" AIP section shall include the following GBAS information for each airport: Type of aids: GBAS; magnetic variation; GBAS ID (Reference Path	AIS Provider / *32 (AIP)*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / *Data flow number***
	Indicator); channel number; hours of operations and the relevant geographical coordinates	
	SR 165: The GBAS CAT III approach procedure shall be published in the state AIP in accordance with ICAO Annex 4 and be identified with the title "GLS RWY xx"	AIS Provider / *30(Approach chart)*
	SR 170: The promulgation of the GBAS CAT III approach procedure shall comply with the appropriate data quality requirements of ICAO Annex 15 and respect the European Regulation N°73/2010 on the quality of aeronautical data/information.	AIS Provider / *30(Approach chart)*
SO#0050 Aircraft shall respect the lateral and vertical path of the published GBAS approach	SR 175: The GAST-D aircraft subsystem shall be compliant with RTCA DO 253C complemented by 9.12 D07 "Specification Definition for mainline aircraft" and 9.12 D16 "Specification Definition for business aircraft" and be reflected in the last effective version of the Ground Based Augmentation System Positioning and Navigation Equipment ETSOs	GAST-D Aircraft Subsystem
	SR 180: The aircraft automatic landing system supported by GAST-D shall be approved in accordance with the applicable airworthiness EASA regulation (CS 25 airworthiness requirements and CS AWO Subpart 1 and 3 amended to consider GAST-D noise model) or equivalent airworthiness regulation (e.g. FAA AC120-XLS).	GAST-D Aircraft Subsystem ; Flight Control & Display
	SR 185: The Aircraft Operator shall be approved for GBAS CAT III operations in accordance with IR OPS (EU965/2012) Part SPA (LVO) or equivalent OPS regulation (E.g. FAA)	GAST-D Aircraft Subsystem ; Flight Control & Display; Flight Crew
	SR 155: The GBAS CAT III final approach segment shall be defined by a FAS data block transmitted by the GAST-D Ground Subsystem to the GAST-D Aircraft Subsystem in accordance with ICAO annex 10 SARPS amended as per ICAO GBAS CAT II-III Development Baseline SARPS proposal dated 28 May 2010	GAST-D Ground Subsystem → GAST-D Aircraft Subsystem / *17(GBAS Messages)*
	SR 156: GBAS FAS data shall be produced by the procedure design tool in an electronic format in accordance with the FAS file format descr bed in EUROCAE ED-114A Appendix M	Procedure Design → Maintenance activity / *20(Validated GBAS Data from procedure)*
	SR 157: The GBAS Ground Subsystem shall implement capability to load the appropriate FAS data file delivered by the procedure design in accordance with EUROCAE ED-114A Appendix M	Maintenance activity → GAST-D Ground Subsystem */ 14 GS configuration data)*
	A#0071: Maintenance of ATS systems is conducted by Air Traffic Safety Electronics Personnel (ATSEP) qualified and trained in accordance with the European Commission Regulation No 1035/2011 laying down common requirements for the provision of air navigation services which, in its Annex II Section 3.3 sets out "Safety requirements for engineering and technical personnel undertaking operational safety related tasks". ATSEP in charge of GBAS equipment have obtained the appropriate qualification in Navigation discipline. See also Appendix G	Maintenance activity →GAST-D Ground Subsystem / *14(GS configuration Data)*
SO#0055 For mixed GBAS/ILS equipage operations, all vehicles	SR 190: The Tower Supervisor shall inform the Tower Controller that optimised and mixed GBAS/ILS operation in LVP are effective on the current runway in use.	ATC App OPS status → TWR SUP → TWR ATCO

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	***Maps on to / Data flow number***
and aircraft on the ground remain outside the ILS CAT III critical and sensitive areas during an ILS approach/take-off	SR 195: In mixed GBAS/ILS equipage operations, the Tower Controller shall instruct mobiles on the ground to prevent infringement of ILS CAT III critical and sensitive areas during CAT III ILS landing or ILS guided take-off	TWR ATCO --> Flight crew + vehicle drivers
SO#0060 The aircraft GBAS Total System error (TSE) shall be equivalent or better than ILS CAT III TSE	SR 200: The GAST-D Ground Subsystem shall be compliant with ICAO Annex 10 SARPS amended as per ICAO GBAS CAT II-III Development Baseline SARPS proposal dated 28 May 2010	GAST-D Ground Subsystem → GAST-D Aircraft Subsystem / *17(GBAS Messages)*
	SR 205: GBAS CAT III Flight Inspection shall be conducted in accordance with ICAO Doc 8071 VOL 2 to confirm ability of the GAST-D Ground Subsystem to support GBAS CAT III operations See also A#0071. See also Appendix G	Flight Inspection → Maintenance */12(GBAS Signal Verif)*
	SR 210: GAST-D Ground Subsystem siting shall be carried out in accordance with EUROCAE ED 114 as amended by 15.3.6 D4 requirements (Ground architecture and airport installation)	GAST-D Ground Subsystem
	See SR 175, SR 180 and SR 185 above	See elements applicable to SO#0050 above
SO#0065 Aircraft shall respect accurately speeds, which have been defined for the CAT III operation, during the approach and the landing	A#0075: Aircraft speeds during a GBAS approach and landing operation are identical to ILS approach and landing operations when considering identical conditions (wind, temperature, weight, CG…),	Flight Crew; Flight Control & display
SO#0070 ATC procedures shall support the mixed GBAS/ILS equipage operations by providing appropriate spacing between the different aircraft pairs (GBAS-ILS; GBAS-GBAS and ILS-GBAS)	SR 225: For mixed GBAS/ILS equipage operations, the aircraft spacing between GBAS –ILS pair shall be established for each operational runway considering that GBAS landed aircraft must have vacated the ILS CAT III sensitive area before the ILS landing aircraft reaches a point at 2Nm from the threshold	ATC Approach OPS Status → APP/TWR ATCO / *45(Opt & Mixed GBAS/ILS Status)*
	SR 230: The Approach and Tower Controller shall provide appropriate aircraft spacing for the considered aircraft pair which could be either GBAS-ILS or GBAS-GBAS or ILS-GBAS pair.	APP/TWR ATCO → Flight Crew
SO#0072 For CAT III optimised operations, the reduced spacing between aircraft shall consider the necessary Runway Occupancy Time (ROT) in Low Visibility Conditions and not only that ILS CAT III critical/sensitive area does not need to be protected	SR 235: For optimised operations in LVP, the reduced aircraft spacing in front of a GBAS landing shall be established for each runway considering the ILS CAT III sensitive area suppression and the required Runway Occupancy Time (ROT) in Low Vis bility Conditions	ATC Approach OPS Status → APP/TWR ATCO / *45(Opt & Mixed GBAS/ILS Status)*
	VAL#0010: Aircraft spacing reduction of 1Nm in front of GBAS shall be validated	
	See SR 230 derived above	
SO#0075 For parallel approaches, the infringement rate of the Non Transgression Zone (NTZ) shall not be greater with GBAS (GBAS only operation or mixed GBAS/ILS equipage operation) compared to ILS	See SR 175, SR 180, SR 185, SR 200, SR 205 and SR 210 above	See elements applicable to SO#0060 above

Safety Objectives *(Functionality and Performance from success approach)*	Safety Requirements	Maps on to / *Data flow number*
SO#0080 During a GBAS CAT III operation, aircraft shall land in the prescribed touch down zone	See SR 175, SR 180, SR 185, SR 200, SR 205 and SR 210 above	See elements applicable to SO#0060 above
SO#0085 During a GBAS CAT III operation, aircraft shall respect the runway centre-line during the landing rollout and decelerates to a safe taxi speed	See SR 175, SR 180, SR 185, SR 200, SR 205 and SR 210 above	See elements applicable to SO#0060 above
SO#0090 Landing Clearance (and associated read back) shall be provided to the aircraft to ensure proper separation with other aircraft or vehicles on the runway	SR 245: Tower Controller shall provide to the Flight Crew the landing clearance when there is reasonable assurance that separation between the landing aircraft and the other aircraft on the runway (preceding landing or departure) will exist when the landing aircraft crosses the runway threshold.	TWR ATCO → Flight Crew / *41(Clearance)*
SO#0095 For optimised operations, the late landing Clearance shall be provided at a distance to the runway threshold which does not impair the aircraft ability to prepare the landing	SR 250: In LVP optimised operations and for GBAS landing, the Tower Controller shall provide to the Flight Crew the landing clearance when the preceding landing (GBAS or ILS) is clear of the Landing Clearance Line.	TWR ATCO → Flight Crew / *41(Clearance)*
	SR 255: In LVP optimised operations and for GBAS landing, the Tower Controller shall provide to the Flight Crew the landing clearance by 1nm from the threshold at the latest.	TWR ATCO → Flight Crew / *41(Clearance)*
	SR 260: In LVP optimised operations and for ILS landing, the Tower Controller shall provide to the Flight Crew the landing clearance by 2nm from the threshold at the latest.	TWR ATCO → Flight Crew / *41(Clearance)*
	VAL#0011: Possibility to provide the latest landing clearance at different points for ILS (2Nm) and GBAS (1Nm) should be validated	
SO#0100 All aircraft on the ground shall remain outside the Obstacle Free Zone (OFZ) during a landing	Initial SR 265: In GBAS only operation for CAT III, Tower controller shall verify that departing aircraft hold at the CAT I holding position	TWR ATCO
	SR 270: In mixed GBAS/ILS equipage operation for CAT III, Tower controller shall verify that departing aircraft hold at the CAT III holding position whatever the actually flown approach (GBAS or ILS)	TWR ATCO
SO#0105 The landed aircraft shall vacate the runway at the cleared exit point	SR 275: The aircraft shall vacate the runway at a specific runway exit point when required by the Tower Controller and if accepted by the Flight Crew	Flight Crew
SO#0110 The landed aircraft shall report when he has vacated the runway indicating that aircraft tail has left the runway	SR 280: In LVP optimised operations with mixed GBAS/ILS equipage and during an ILS landing, the Tower controller shall request the flight crew of the preceding landing to report when she/he has passed the CAT III Line if doubt exists on the exact location of the aircraft on the ground	TWR ATCO → Flight Crew
	SR 285: During a GBAS CAT III landing in optimised operation, the Tower controller shall request the flight crew of the preceding landing to report when she/he has passed the CAT I Line if doubt exists on the exact location of the aircraft on the ground	TWR ATCO → Flight Crew

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / *Data flow number***
	SR 290: In LVP optimised operations and when required by the Tower controller, the flight crew shall report to the controller that the runway is vacated when the entire aircraft has passed a point which is the CAT I line during a GBAS landing or the CAT III line during an ILS landing.	Flight Crew → TWR ATCO
SO#0115 ATC shall provide when necessary additional information to facilitate aircraft runway vacation	No SR identified SR so far	
SO#0120 Runway Incursion safety net (e.g. RIMCAS) shall be suitable for optimised operations. An aircraft holding inside ILS CAT III Critical and Sensitive Area (CSA) during a CAT III ILS landing is considered a Runway Incursion whereas an aircraft holding at the same position during a CAT III GBAS landing is not.	SR 295: In LVP optimised operations with mixed GBAS/ILS equipage and during an ILS CAT III landing, the Runway safety Net, if fitted, shall alert the Tower Controller when a mobile is inside the ILS CAT III Critical and Sensitive Area (CSA)	Runway Safety net → TWR ATCO / *47(Rw Incursion alert)*
	SR 300: During a GBAS CAT III landing in optimised operation, the Runway safety Net, if fitted, shall not alert the Tower Controller when a mobile is outside the landing clearance line area but inside the ILS CAT III Critical and Sensitive Area (CSA)	Runway Safety net → TWR ATCO / *47(Rw Incursion alert)*
	SR 301: During a GBAS CAT III landing in optimised operation, the Runway safety Net, if fitted, shall alert the Tower Controller when a mobile has infringed the landing clearance line	Runway Safety net → TWR ATCO / *47(Rw Incursion alert)*
SO#0125 For segregated runway operation (arrival only) with GBAS optimised operations, ATC shall provide the landing clearance to the next arrival when the preceding arrival has passed the landing clearance line	See SR 255 above	
SO#0130 For segregated runway operation(arrival) with mixed GBAS/ILS equipage optimised operations, ATC shall provide the landing clearance to the: *next GBAS arrival when the preceding arrival has passed the landing clearance line * next ILS arrival when the preceding arrival has vacated the ILS CAT III sensitive area	See SR 255 above for GBAS optimised operations	
	SR 310: In LVP optimised operations with mixed GBAS/ILS equipage and for an ILS CAT III landing, the Tower Controller shall provide the landing clearance to the flight crew when the preceding landing aircraft has passed the ILS CAT III Critical and Sensitive Area (CSA)	TWR ATCO → Flight Crew / *41(Clearance)*
SO#0135 For mixed mode runway operation (arrival/departure) with GBAS optimised operations, departing aircraft shall hold at the landing clearance line	See SR 265 above	
SO#0140 For mixed mode runway operation	See SR 265 and SR 270 above	

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Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / Data flow number**
(arrival/departure) with mixed GBAS/ILS equipage optimised operations, departing aircraft shall hold: *at the landing clearance line during a GBAS landing *at the CAT III holding point during an ILS landing		
SO#0145 For optimised operations, the landing clearance line shall be positioned where: *the risk of collision between the landing aircraft and obstacles (aircraft/vehicle) on the runway is shown to be acceptable. *wing tip clearance of the landing aircraft is provided from touchdown to end of roll out along the runway	SR 315: The landing clearance line shall be established no closer than 77,5m from runway centreline on runways where Super Heavy aircraft operate.	Ground Surv; ATC Approach OPS Status
	SR 320: The landing clearance line shall be established no closer than 60m from runway centreline on runways where Super Heavy aircraft do not operate.	Ground Surv; ATC Approach OPS Status
	SR 325: When considering the landing clearance line, the current holding positions (positioned in accordance to Annex 14 not closer to 90m from runway centre line or 107.5 m when Super Heavy aircraft operate) up to a distance of 900m after the threshold shall be maintained.	Ground Surv; ATC Approach OPS Status
SO#0150 Aircraft shall monitor operational conditions and technical capabilities at the Decision Height (DH) or at the Alert Height (for operations conducted with no DH) to decide if CAT III approach can be continued	SR 330: Flight Crew shall monitor operational conditions and technical capabilities at the Decision Height (DH) or at the Alert Height (for operations conducted with no DH) to decide if GBAS CAT III approach can be continued	Flight Control & Display → Flight Crew / *56 (Display & guidance data)*
SO#0155 For CAT III approach conducted with DH, aircraft shall execute a missed approach at DH if visual references not acquired	SR 335: During GBAS CAT III approach conducted with DH, Flight Crew shall execute a missed approach at DH if visual references not acquired	Flight Control & Display → Flight Crew / *56 (Display & guidance data)*
SO#0160 For CAT III approach conducted with no DH, aircraft shall execute a missed approach at or below the Alert Height in case of aircraft capability and/or performance degradation impacting the CAT III landing and visual references not acquired	SR 340: During GBAS CAT III approach conducted with no DH, Flight Crew shall execute a missed approach at or below the Alert Height in case of aircraft capability and/or performance degradation impacting the CAT III landing and if visual references not acquired	Flight Control & Display → Flight Crew / *56 (Display & guidance data)*
SO#0165 The Missed approach segment of a GBAS CAT III approach shall be designed to prevent loss of separation with terrain/obstacle and shall not rely on GBAS	See SR 135 above	Procedure Design → AIS Provider / *21 (GBAS Procedure)*
	See SR 140 above	
	See SR 145 above	
SO#0166 For independent parallel runway operations,	SR 345: For parallel runway operations, nominal tracks of the two missed approach procedures shall diverge by at least 30° and the	Procedure Design → AIS Provider / *21 (GBAS*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / *Data flow number***
the Missed approach track for one approach diverges by at least 30 degrees from the missed approach track of the adjacent approach	associated missed approach turns shall be specified as "as soon as practicable".	*Procedure)*
SO#0170 During optimised operations, the go-around rate (without considering failure) shall not be greater than in ILS CAT III only operations (without considering failure) in similar operational environment and weather conditions.	SR 350: In LVP optimised operations, the aircraft spacing between different aircraft pairs (GBAS-GBAS, ILS-GBAS and GBAS-ILS) shall be established to ensure that the need for issuing go-around is minimised.	ATC Approach OPS Status → APP/TWR ATCO / *45(Opt & Mixed GBAS/ILS Status)*
SO#0520 Aircraft shall execute a missed approach if excessive lateral and/or vertical deviation are detected during a GBAS CAT III approach	SR 355: During GBAS CAT III approach, Flight Crew shall execute a missed approach if excessive lateral and/or vertical deviation are detected	Flight Control & Display → Flight Crew / *56 (Display & guidance data)*
SO#0530 In case of GBAS system performance degradation leading to an aircraft capability downgrade from CAT III to CAT I during a CAT III approach, aircraft might continue the approach to CAT I minima or shall execute a missed approach	SR 360: When the aircraft capability downgrade from CAT III to CAT I due to GBAS, Flight Crew shall either execute a missed approach immediately or continue the approach down to CAT I minima and execute a missed approach if CAT I vis bility conditions are not met.	Flight Control & Display → Flight Crew / *56 (Display & guidance data)*
SO#0600 TMA structure and associated ATC procedures shall be sufficiently resilient to accommodate multiple and poss bly simultaneous missed approach initiated during GBAS CAT III operations following an event affecting all runway ends (e.g. GBAS ground Station failure or global GNSS Signal In Space problem)	SR 365: Arrival and Departing routes in TMA shall be designed to reduce the risk of separation infringement when considering the possibility of having multiple and simultaneous missed approaches following a GBAS failure	Procedure designer
	SR 370: GBAS Missed approaches for a given aerodrome shall be designed to reduce the risk of separation infringement when considering the possibility of having multiple and simultaneous missed approaches following a GBAS failure	Procedure Designer
	SR 375: ATC contingency procedures in terminal area shall be defined to address the situation where multiple GBAS missed approaches are executed simultaneously following a GBAS failure	APP/TWR ATCO
	GUIDED TAKE OFF in LVC	
SO#0200 Aircraft shall respect the GBAS lateral path for the guided take-off from the start of the take-off roll to the main wheel lift-off	See SR 055, SR 060 SR155, SR156, SR157, SR 175 , SR 185, SR 200 and SR 210 derived above for CAT III approach	
	SR 400: The directional guidance for take-off in low visibility supported by GAST-D shall be approved in accordance with applicable airworthiness EASA regulation (CS 25 airworthiness requirements and CS AWO Subpart 4 amended to consider GAST-D noise model) or equivalent regulation (e.g. FAA).	GAST-D Aircraft Subsystem ; Flight Control & Display

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements**	**Maps on to / *Data flow number***
	SR 405: Flight Inspection shall be conducted in accordance with ICAO Doc 8071 VOL 2 to confirm the ability of the GAST-D Ground Subsystem to support Guided Take-Off operations considering that GBAS Signal shall be received by the Aircraft during taxi-in operation.	Flight Inspection → Maintenance */12(GBAS Signal Verif)*
SO#0205 Take-Off Clearance (and associated read back) shall be provided to the aircraft to ensure appropriate separation with other aircraft and vehicles on the runway	SR 410: The Tower Controller shall check the operational status of the landing aids (GBAS or GBAS and ILS) before providing the Take-Off clearance	GAST-D GS → TWR ATCO / 18(GBAS Status)
	SR 415: For optimised operations in LVP, the Tower Controller shall organize the departing aircraft sequence considering the aircraft capability as indicated by flight plan information (with or without GBAS capability)	Flight Planning → TWR ATCO */ 33a(Approved FPL)*
	SR 420: The Tower Controller shall provide the Take-Off clearance to the flight crew indicating that aircraft is cleared for a GBAS Take-Off or an ILS Take-Off.	TWR ATCO → Flight Crew / *41(Clearance)*
	SR 425: The Flight Crew shall read back to the Tower Controller the Take-Off clearance	Flight Crew → TWR ATCO/ *50 (Readback)*
	See SR 013; SR 030 ; A#0055 and A#0060 derived above for CAT III approach	
SO#0210 All aircraft on the ground shall remain outside the Obstacle Free Zone (OFZ) during a take-off	Initial SR 430: During a guided Take-Off at an aerodrome with GBAS only operations, Tower controller shall verify that other departing aircraft hold at the CAT I holding position	TWR ATCO
	SR 435: During a guided Take-Off in mixed GBAS/ILS operations, Tower controller shall verify that other departing aircraft hold at the CAT III holding position whatever the guided Take-Off (GBAS or ILS)	TWR ATCO
SO#0550 Aircraft aborts the guided take-off in LVC if excessive lateral deviation is detected and manual take over impossible due to loss of external visual cues (centerline lights)	SR 440: During a guided Take-Off in LVC based on GBAS or ILS, Flight Crew shall abort the take off if excessive lateral deviation are detected and lateral path correction impossible	Flight Control & Display → Flight Crew */ 56 (Display & guidance data)*
SO#0055 For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside the ILS CAT III critical and sensitive areas during an ILS approach/take-off	See SR 190 and SR 195 derived above for CAT III approach	
SO#0060 The aircraft GBAS Total System error (TSE) shall be equivalent or better than ILS CAT III TSE	See SR 175 , SR 185 , SR 200 and SR 210 derived above for CAT III approach See SR 405 derived above for Guided take-off in LVC	

Table 12: Mapping of Safety Objectives to SPR-level Model Elements

All safety requirements derived in Table 12 above are listed in Appendix B.1 Safety Requirements (Functionality and Performance).

All Assumptions identified in Table 12 above are listed in Appendix C.1 Assumptions log

All Issues identified in Table 12 above are listed in Appendix C.2 Safety Issues log.

All Recommendations identified in Table 12 above are listed in Appendix C.3 Recommendation log.

3.3 Analysis of the SPR-level Model – Normal Operational Conditions

This section is concerned with ensuring that the SPR-level design is complete, correct and internally coherent with respect to the Safety Requirements (success approach) derived for the normal operating conditions (See Section 3.2.3) that were used to develop the corresponding Safety Objectives (success approach).

The analysis necessarily depends on proving the Safety Requirements (Functionality and Performance) from three perspectives:

- a static view of the system behaviour using a Thread Analysis technique, as described in section 3.3.2 for the scenarios for normal operations described in section 3.3.1

- check that the system design operates in a way that does not have a negative effect on the operation of related ground-based and airborne safety nets, through static analysis and simulation - see section 3.3.3

- a dynamic view of the system behaviour using in particular Real-time simulations - see section 3.3.4

3.3.1 Scenarios for Normal Operations

Scenarios for normal operations include the different Use Cases identified in OSED [5] Section 5 relative to the approach:

- GBAS Arrival Flight:
  - This use case details landing of arrival aircraft when using GBAS and start when the aircraft is entering the terminal area
- GBAS Arrival/Departure Flight management
  - This use case details low visibility procedures when GBAS is used and especially the management of arrival and departure on the same runway (mixed mode runway operations)
- GBAS/ILS Optimised mixed arrival management
  - This use case details landing of arrival aircraft when using ILS or GBAS and start when the aircraft is entering the terminal area
- GBAS/ILS Arrival/Departure Flight management
  - This use case details low visibility procedures when GBAS and ILS are used and especially the management of arrival and departure on the same runway (mixed mode runway operations)

Furthermore, one scenario is added to address the GBAS and GBAS/ILS Guided Take-Off. There is no associated Use case in the OSED.

ID	Scenario	Rationale for the Choice
1	GBAS Arrival Flight	OSED Use Case for Approach
2	GBAS Arrival/Departure Flight management	OSED Use Case for Approach

3	GBAS/ILS Optimised mixed arrival management	OSED Use Case for Approach
4	GBAS/ILS Arrival/Departure Flight management	OSED Use Case for Approach
5	GBAS and GBAS/ILS Guided-Take-Off	To describe Guided T/O in GBAS or GBAS/ILS operation

Table 13: Operational Scenarios – Normal Conditions

3.3.2 Thread Analysis of the SPR-level Model – Normal Operations

Thread Analysis is similar to Use Case analysis except that it uses a particular graphical presentation in which the actions of the individual elements of the SPR-level Model, and the interactions between those elements, are represented as a continuous 'thread', from initiation to completion.

The main equipment functions and human tasks are described by reference to the related Safety Requirements although some relatively minor functions / tasks may be represented only in the Threads themselves.

For each scenario, a consistency check is made between the Safety requirements derived in section 3.2.3 and the description of the nominal flow from the OSED (For Scenario #1 to #4).

From this consistency check and when needed, additional safety requirements (functionality and performance) are identified.

3.3.2.1 Scenario # 1 GBAS Arrival Flight

The use case details landing of arrival aircraft when using GBAS. The use case further describes the GBAS approach where initial approach is under TMA control and final approach under APP control. The use case describes the use of landing clearance line when aircraft is considered to have vacated the runway and provision of landing clearance to a minimum distance of up to 1 NM.

The Airport operates in segregated runway mode (arrivals only).

The airport is assumed to be equipped with an A-SMGCS (level 1).

The GBAS Ground System is considered as the only instrument landing system available for the runway.

Figure 8 describes the thread analysis in accordance with the different Step identified in the OSED Use Case. Table 14 identifies existing requirements from section 3.2.3 supporting the thread analysis and identify, when necessary, if requirements are missing (completeness) or need to be reworded (correctness).

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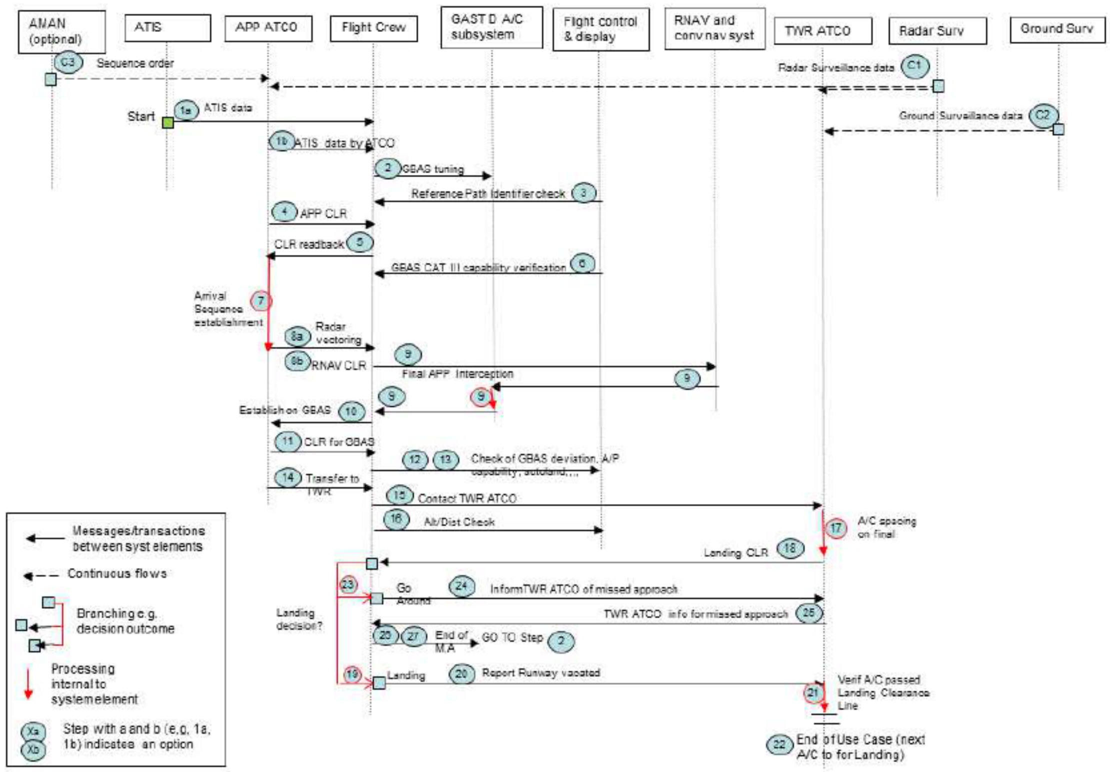


Figure 8 Thread Analysis for Scenario#1: GBAS arrival Flight

Step Ref[10]	Description and traceability towards Safety Requirements
	Nominal Flow
1a	Flight crew receive ATIS data (SR 005). ATIS information are up to date (A#0045)
1b	Approach Controller provides ATIS information to Flight Crew (No SR because ATIS is available and broadcast data (Environment requirement ENV#081))
2	Flight crew tune the GBAS approach (SR 050).
3	Flight crew verify that correct approach is selected (RPI) (SR 055).
4	Approach Controller gives the approach clearance (SR 015).
5	Flight crew read back the approach clearance (SR 045).
6	Flight crew verify GBAS CAT III aircraft capability (SR 060).
7	Approach controller organise the arrival sequence order (SR 025). Flight plan system is updated to process GBAS capability(A#0060)
8a	Approach Controller provides radar vectoring (SR 095) considering limitations of distance to FAP(SR 110) and angle of interception (SR 111).
8b	Approach Controller clears the aircraft for an RNAV transition (SR 085).
9	Flight crew intercepts the final approach: • For Radar vectoring: o Flight crew respects radar vectors and prepare transition for the interception (A#0070) ; A/C shall be established on the final approach course at a sufficient distance from FAP (SR 120); GBAS system intercepts final approach course (SR 070) • For RNAV transition: o RNAV transition is correctly designed (SR 115), (A#0063)& (A#0064); RNAV system guides the aircraft on the RNAV transition (SR 090, SR091 and SR092); Flight crew respects RNAV

[10] Step references from OSED Use Case

Step Ref[10]	Description and traceability towards Safety Requirements
	guidance during the transition (A#0065); A/C shall be established on the final approach course at a sufficient distance from FAP (SR 120); GBAS system intercepts final approach course (SR 070)
10	Flight crew confirm established on GBAS final approach course (SR 075)
11	Approach Controller provides cleared for GBAS approach message (SR 065)
12	GBAS system intercepts vertical path (SR 080); Flight crew verifies glideslope capture at the charted altitude (SR 100) and excessive lat/vert deviations (SR 355); Aircraft Operator is approved for CAT III operations (SR 185)
13	Flight crew monitors CAT III operational conditions and technical capabilities (SR 340) and (SR 360); Aircraft Operator is approved for CAT III operations (SR 185)
14	Approach Controller transfer to Tower controller (No SR)
15	Flight Crew contact Tower Controller (No SR)
16	Flight Crew perform a distance altitude/check between 5Nm to 3 Nm before threshold (No SR)
17	Tower Controller monitors the spacing between all arrivals (SR 230) & (SR 235)
18	Tower Controller provides the landing clearance (SR 245) at 1Nm at the latest (SR 255)
19	The flight crew decide to land at DH/DA (SR 330)
20	Flight crew report runway vacated (SR 285) (SR 290)
21	Tower Controller verifies on A-SMGCS that A/C has passed the landing clearance line (SR 250)
22- End of nominal flow: Next A/C for landing	
Alternate Flow	
23	Flight crew perform a go around (SR 335) (SR 340) (SR 360)
24	Flight Crew inform Tower Controller about Go around (No SR)
25	Tower Controller reads the missed approach to Flight Crew (No SR)
26	Flight crew continues the missed approach -See SR applicable to Step 23 above-
27- End of alternate flow: Flight crew start another approach or divert to an alternate	
Continuous Flow (No reference in OSED)	
C1	Radar surveillance data provided to Controllers (Environment requirement ENV#105)
C2	Ground surveillance data provided to Tower Controller (Environment requirement ENV#105)
C3	Arrival Sequence Manager sequence order provided to Approach controller (No SR because Optional)

Table 14: Thread Analysis description for Scenario#1: GBAS arrival Flight

Safety Requirements have not been identified in section 3.2.3 for the following Steps: 14, 15, 16, 24 and 25.
-For Steps 14, 15, 24 and 25 it is confirmed that no additional requirements are required because these requirements are already covered by current and basic procedures for the controller and furthermore not specific to GBAS.
-For Step 16 which is equally applicable for ILS approach, there is a temptation to suppress this altitude/distance check when considering GBAS therefore such requirement is formalized:

> SR 187: Flight crew shall make an altitude/distance check during GBAS approach between 5 Nm to 3 Nm before the threshold

3.3.2.2 Scenario # 2 GBAS Arrival/Departure flight Management

The use case details low visibility procedures when GBAS is used. The use case describes the use of different holding points for departing aircraft (CAT I or CAT III holding points).

The airport operates in mixed runway mode (arrival and departure on the same runway).

The airport is assumed to be equipped with an A-SMGCS (level 1).

The GBAS Ground System is considered as the only instrument landing system available for the runway.

Figure 9 describes the thread analysis in accordance with the different Steps identified in the OSED Use Case. Table 15 identifies existing requirements from section 3.2.3 supporting the thread analysis and identify , when necessary, if requirements are missing (completeness) or need to be reworded (correctness).

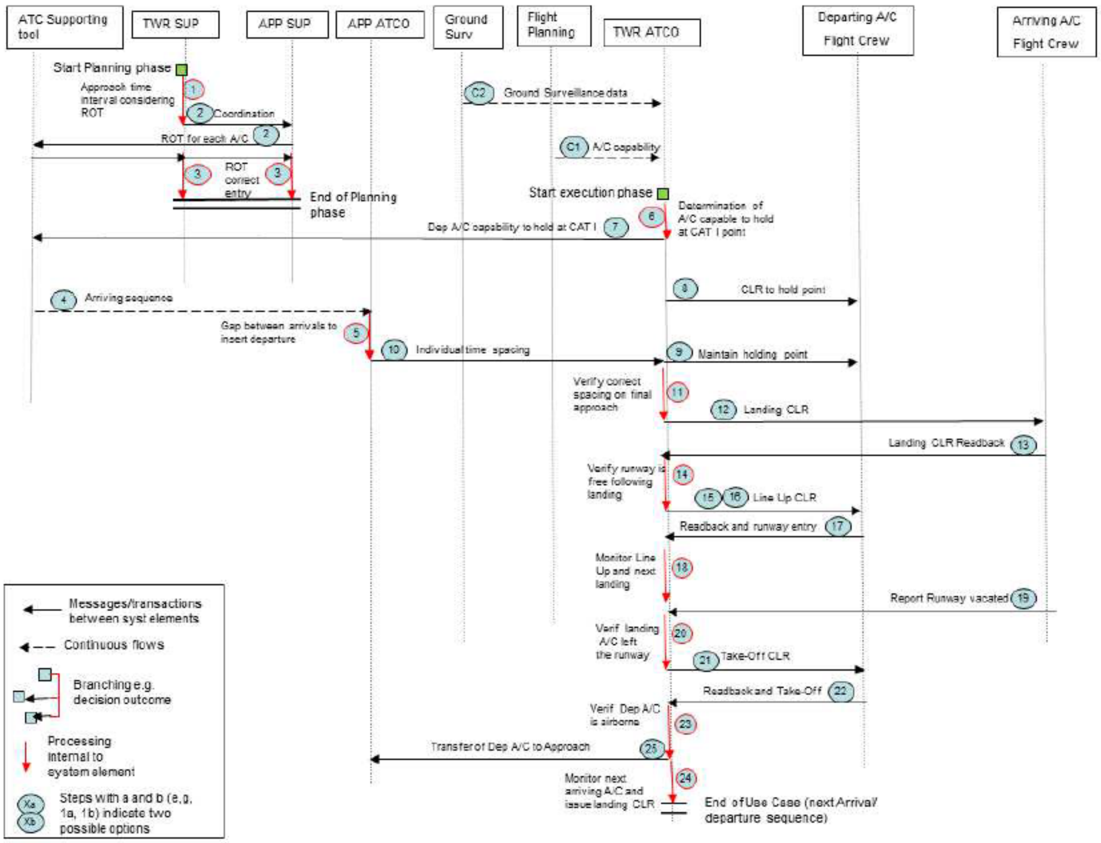


Figure 9 Thread Analysis for Scenario#2: GBAS arrival/departure flight management

Step Ref[11]	Description and traceability towards Safety Requirements
	Nominal Flow
Start of Planning phase	
1	Tower supervisor determines time interval between arrivals to accommodate ROT(SR 235)
2	Tower supervisor coordinate with approach supervisor ROT to be used in the ATC supporting tool (Concept has been updated and no ATC supporting Tool is proposed anymore)
3	Tower supervisor and approach supervisor check and confirm that correct ROT is entered in the ATC supporting tool - End of Planning phase- (Concept has been updated and no ATC supporting Tool is proposed anymore)
Start of execution phase	
6	Tower controller check A/C capability to depart and hold at CAT I holding points - (Concept has been updated and all departing A/C will hold at CAT III holding point) therefore no SR is needed.
7	Tower controller input this capability in the ATC supporting tool- (Concept has been updated and all departing A/C will hold at CAT III holding point) therefore no SR is needed
4	Approach controller uses ATC supporting tool to sequence arriving aircraft-(Concept has been updated and no ATC supporting Tool is proposed anymore) Approach controller organise the arrival sequence order (SR 025). Flight plan system is updated to process GBAS capability(A#0060)
5	Approach controller provides gaps between arrivals to accommodate anticipated runway departure (No SR)
8	Tower controller provides clearance to departing aircraft with a holding at CAT I or CAT III position depending on aircraft capability- (Concept has been updated and all departing A/C will hold at CAT III holding point). There is a correctness issue for SR 265 which needs to be modified by replacing

[11] Step references from OSED Use Case

Step Ref[11]	Description and traceability towards Safety Requirements
	CAT I holding position by CAT III holding position.
9	Tower controller holds each departing aircraft at the cleared holding position (No SR)
10	Approach controller provides individual spacing time considering tower controller input in the ATC supporting tool -(Concept has been updated and no ATC supporting Tool is proposed anymore)
11	Tower controller verifies that correct spacing is provided on final in order to line up departing aircraft from CAT I or CAT III holding point depending on the A/C capability-(Concept has been updated and all departing A/C will hold at CAT III holding point) Controllers provide appropriate A/C spacing for arrivals (SR 230) and A/C spacing between arrivals shall be established to ensure that need for issuing Go around is minimized(SR 350) however these SRs do not specify departure insertion
12	Tower controller provides landing clearance to first arriving aircraft (SR 245)
13	Flight crew read back the clearance and land (SR 330)
14	Tower controller verifies the runway is free from other traffic and landing aircraft has passed the holding point of the next departure (No SR)
15 & 16	Tower controller gives line up clearance to next departing A/C (No SR)
17	Flight Crew read back the clearance and move to take-off position (No SR)
18	Tower controller monitors the line up of the departing aircraft (No SR) and the progress of the next landing A/C (SR 230)
19	Flight crew of the preceding aircraft report runway vacated (SR 285) (SR 290)
20	Tower controller verifies preceding landing has left the runway and verifies runway is free The already identified SR 250 is applicable to this step even if it refers to the landing clearance line.
21	Tower controller provides the Take-Off clearance to departing aircraft (No SR)
22	Flight crew read back the clearance and start take-off (No SR)
23	Tower controller verifies departing aircraft is airborne (No SR)
25	Tower controller transfer the departing aircraft to the Approach controller (No SR)
24	Tower controller monitors next arriving aircraft and provide the landing clearance (SR 245) - End of execution phase
	Continuous Flow (No reference in OSED)
C1	Aircraft capability from Flight planning provided to Tower Controller for the selection of CAT I or CAT III holding points-(Concept has been updated and all departing A/C will hold at CAT III holding point)
C2	Ground surveillance data provided to Tower Controller (Environment requirement ENV#105)

Table 15: Thread Analysis description for Scenario#2: GBAS arrival/departure flight management

First, as detailed in the above Table, the operational concept has changed indeed no ATC supporting Tool is proposed anymore and all departing A/C will hold at CAT III holding point. Therefore for several Use Case Steps no SRs are required anymore.

However a correctness issue was identified for SR 265 (see Step 8 above) and the existing requirement needs to be modified as follows:

- Modified SR 265: In GBAS only operation for CAT III, Tower controller shall verify that departing aircraft hold at the ~~CAT I~~ CAT III holding position

Because the departing phase is not impacted by GBAS arrival considering the updated concept (no supporting tool and all aircraft hold at CAT III point) specific SRs were not derived for the following steps: 5, 9, 11, 14 to 18 and 21 to 25.

3.3.2.3 Scenario # 3 GBAS/ILS Optimised mixed arrival management

The use case details landing of arrival aircraft when using ILS or GBAS. The use case describes the use of landing clearance line and CAT II/III holding points and provision of landing clearance up to 1 NM for GBAS aircraft.

The airport is assumed to be equipped with an A-SMGCS (level 1).

The ILS and GBAS landing systems are considered available for the runway .

The airport operates in segregated runway mode.

Figure 10 describes the thread analysis in accordance with the different Step identified in the OSED Use Case. Table 16 identifies existing requirements from section 3.2.3 supporting the thread analysis and identify, when necessary, if requirements are missing (completeness) or need to be reworded (correctness).

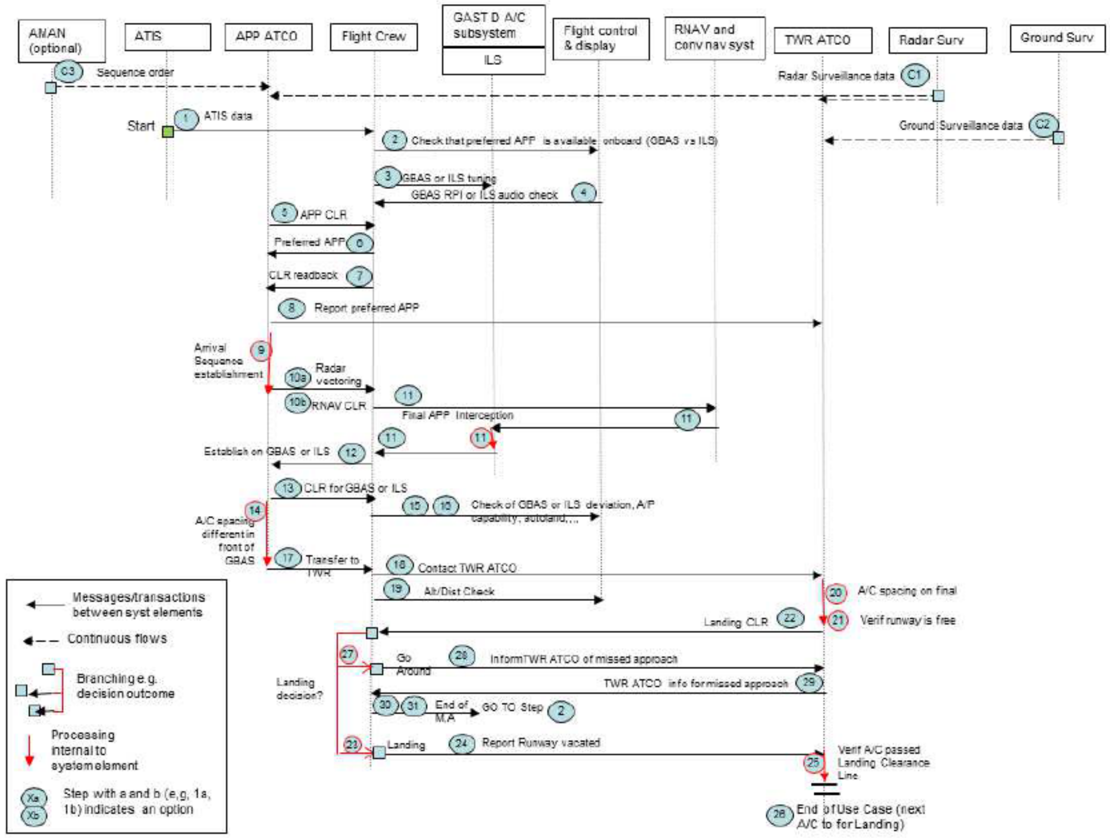


Figure 10 Thread Analysis for Scenario#3: GBAS/ILS optimised mixed arrival management

Step Ref[12]	Description and traceability towards Safety Requirements
	Nominal Flow
1	Flight crew receive ATIS data (SR 010). ATIS information are up to date (A#0045)
2	Flight Crew check that preferred approach is available onboard (GBAS vs ILS) (No SR)
3	Flight crew tune the GBAS approach (SR 050) or the ILS approach.
4	Flight crew verify that correct GBAS (SR 055) or ILS approach is selected
5	Approach Controller gives the approach clearance based on flight plan information (SR 020).
6	Flight crew informs approach controller about the preferred approach (SR 035). (A#0050)
7	Flight crew read back the approach clearance (SR 045).
8	Approach controller informs downstream sectors about the preferred approach (No SR) Instead of this coordination between controller it was decided that Flight crew at each frequency transfer will inform controller about the type of approach she/he intend to conduct (SR 046).
9	Approach controller organise the arrival sequence order (SR 025). Flight plan system is updated to process GBAS capability(A#0060)
10a	Approach Controller provides radar vectoring (SR 095) considering limitations of distance to FAP (SR 110) and angle of interception (SR 111).
10b	Approach Controller clears the aircraft for an RNAV transition (SR 085).
11	Flight crew intercepts the final approach:

[12] Step references from OSED Use Case

Step Ref[12]	Description and traceability towards Safety Requirements
	• For Radar vectoring: o Flight crew respects radar vectors and prepare transition for the interception (A#0070) ; A/C shall be established on the final approach course at a sufficient distance from FAP (SR 120); GBAS system (SR 070) or ILS system intercepts final approach course • For RNAV transition: o RNAV transition is correctly designed (SR 115), (A#0063)& (A#0064); RNAV system guides the aircraft on the RNAV transition (SR 090, SR091 and SR092); Flight crew respects RNAV guidance during the transition (A#0065); A/C shall be established on the final approach course at a sufficient distance from FAP (SR 120); GBAS system (SR 070) or ILS system intercepts final approach course
12	Flight crew confirm established on GBAS (SR 075) or ILS final approach course
13	Approach Controller provides cleared for GBAS message (SR 065) or for ILS approach
14	Approach controller provide reduced spacing in front of GBAS compared to ILS (SR 235) (SR 225)
15	GBAS system intercepts vertical path (SR 080); Flight crew verifies glideslope capture at the charted altitude (SR 100) and excessive lat/vert deviations (SR 355); Aircraft Operator is approved for CAT III operations (SR 185). Similar existing requirements are used for ILS.
16	Flight crew monitors CAT III operational conditions and technical capabilities (SR 340) and (SR 360); Aircraft Operator is approved for CAT III operations (SR 185). Similar existing requirements are used for ILS.
17	Approach Controller transfer to Tower controller (No SR)
18	Flight Crew contact Tower Controller (No SR)
19	Flight Crew perform a distance altitude/check between 5Nm to 3Nm before threshold. New SR 187 derived for scenario#1 above.
20	Tower Controller monitors the spacing between all arrivals (SR 225), (SR 230) & (SR 235)
21	Tower Controller verifies that runway is free (SR 245)
22	Tower Controller provides the landing clearance (SR 245) at 1Nm at the latest for GBAS (SR 255) and at 2Nm at the latest for ILS (SR 260)
23	The flight crew decide to land at DH/DA (SR 330)
24	Flight crew report runway vacated (SR 280) , (SR 285) & (SR 290)
25	Tower Controller verifies on A-SMGCS that A/C has passed the landing clearance line for GBAS landing (SR 250) or the ILS sensitive area for ILS landing (SR 310)
26- End of nominal flow: Next A/C for landing	
Alternate Flow	
27	Flight crew perform a go around (SR 335) (SR 340) (SR 360)
28	Flight Crew inform Tower Controller about Go around (No SR)
29	Tower Controller reads the missed approach to Flight Crew (No SR)
30	Flight crew continues the missed approach -See SRs applicable to Step 27 above-
31- End of alternate flow: Flight crew start another approach or divert to an alternate	
Continuous Flow (No reference in OSED)	
C1	Radar surveillance data provided to Controllers (Environment requirement ENV#105)
C2	Ground surveillance data provided to Tower Controller (Environment requirement ENV#105)
C3	Arrival Sequence Manager sequence order provided to Approach controller (No SR because Optional)

Table 16 Thread Analysis description for Scenario#3: GBAS/ILS optimised mixed arrival management

Safety Requirements have not been identified in section 3.2.3 for the following Steps: 2, 8, 17, 18, 19, 28 and 29.

- For Steps 2, 17, 18, 28 and 29 it is confirmed that no additional requirements are required because these requirements are already covered by current and basic procedures for controller/flight crew and furthermore not specific to GBAS.

For Step 8, instead of requiring the controller to transfer to downstream sectors the pilot's preferred approach information it is proposed to require at each frequency transfer that flight crew inform controller about the type of approach she/he intend to conduct as already specified in SR 046.

For Step 19, a requirement (SR 187) was derived in Scenario#1 Step 16 which is equally applicable to this step.

3.3.2.4 Scenario # 4 GBAS/ILS Arrival/Departure Flight Management

The use case details low visibility procedures when GBAS and ILS are used. The use case describes the use of different holding points for departing aircraft (CAT I or CAT III holding points).
The airport operates in mixed runway mode.
The airport is assumed to be equipped with an A-SMGCS (level 1).

Figure 11 describes the thread analysis in accordance with the different Step identified in the OSED Use Case. It should be noted that thread analysis is identical to Scenario#2 Thread analysis. Table 17 identifies existing requirements from section 3.2.3 supporting the thread analysis and identify, when necessary, if requirements are missing (completeness) or need to be reworded (correctness).

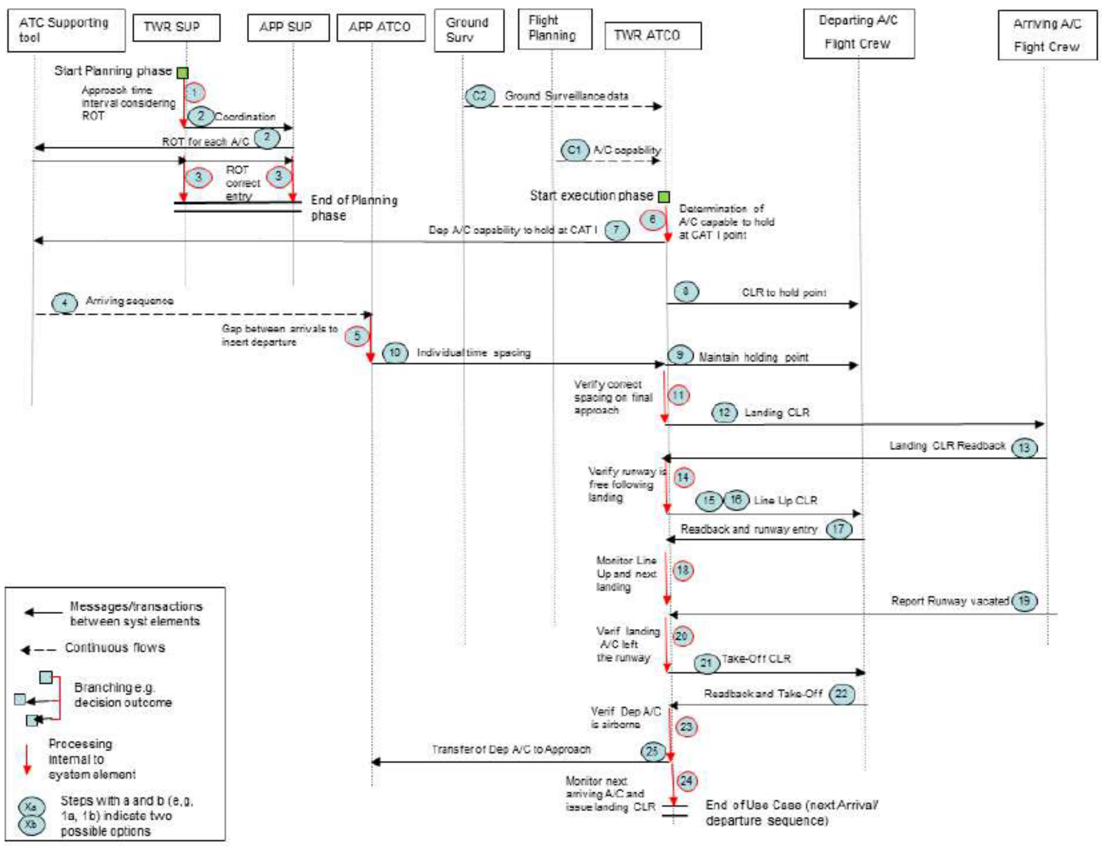


Figure 11 Thread Analysis for Scenario#4: GBAS/ILS Arrival/Departure Flight management

Step Ref[13]	Description and traceability towards Safety Requirements
	Nominal Flow
Start of Planning phase	
1	Tower supervisor determines time interval between arrivals to accommodate ROT(SR 225) & (SR 235)
2	Tower supervisor coordinate with approach supervisor ROT to be used in the ATC supporting tool (Concept has been updated and no ATC supporting Tool is proposed anymore)
3	Tower supervisor and approach supervisor check and confirm that correct ROT is entered in the ATC supporting tool - End of Planning phase- (Concept has been updated and no ATC supporting Tool is proposed anymore)

[13] Step references from OSED Use Case

Step Ref[13]	Description and traceability towards Safety Requirements
Start of execution phase	
6	Tower controller check A/C capability to depart and hold at CAT I holding points - (Concept has been updated and all departing A/C will hold at CAT III holding point) therefore no SR is needed.
7	Tower controller input this capability in the ATC supporting tool- (Concept has been updated and all departing A/C will hold at CAT III holding point) therefore no SR is needed
4	Approach controller uses ATC supporting tool to sequence arriving aircraft-(Concept has been updated and no ATC supporting Tool is proposed anymore) Approach controller organise the arrival sequence order (SR 025). Flight plan system is updated to process GBAS capability(A#0060)
5	Approach controller provides gaps between arrivals to accommodate anticipated runway departure (No SR)
8	Tower controller provides clearance to departing aircraft with a holding at CAT I or CAT III position depending on aircraft capability- (Concept has been updated and all departing A/C will hold at CAT III holding point). (SR 270).
9	Tower controller holds each departing aircraft at the cleared holding position (No SR)
10	Approach controller provides individual spacing time considering tower controller input in the ATC supporting tool -(Concept has been updated and no ATC supporting Tool is proposed anymore)
11	Tower controller verifies that correct spacing is provided on final in order to line up departing aircraft from CAT I or CAT III holding point depending on the A/C capability-(Concept has been updated and all departing A/C will hold at CAT III holding point) Controllers provide appropriate A/C spacing for arrivals (SR 230) and A/C spacing between arrivals shall be established to ensure that need for issuing Go around is minimized(SR 350) however these SRs do not specify departure insertion
12	Tower controller provides landing clearance to first arriving aircraft (SR 245)
13	Flight crew read back the clearance and land (SR 330)
14	Tower controller verifies the runway is free from other traffic and landing aircraft has passed the holding point of the next departure (No SR)
15 & 16	Tower controller gives line up clearance to next departing A/C (No SR)
17	Flight Crew read back the clearance and move to take-off position (No SR)
18	Tower controller monitors the line up of the departing aircraft (No SR) and the progress of the next landing A/C (SR 230)
19	Flight crew of the preceding aircraft report runway vacated (SR 280), (SR 285) & (SR 290)
20	Tower controller verifies preceding landing has left the runway and verifies runway is free. SR 250 for GBAS approach is applicable to this step even if it refers to the landing clearance line and SR 310 for ILS approach even if it refers to ILS sensitive areas
21	Tower controller provides the Take-Off clearance to departing aircraft (No SR)
22	Flight crew read back the clearance and start take-off (No SR)
23	Tower controller verifies departing aircraft is airborne (No SR)
25	Tower controller transfer the departing aircraft to the Approach controller (No SR)
24	Tower controller monitors next arriving aircraft and provide the landing clearance (SR 245) - End of execution phase
Continuous Flow (No reference in OSED)	
C1	Aircraft capability from Flight planning provided to Tower Controller for the selection of CAT I or CAT III holding points-(Concept has been updated and all departing A/C will hold at CAT III holding point)
C2	Ground surveillance data provided to Tower Controller (Environment requirement ENV#105)

Table 17 Thread Analysis description for Scenario#4: GBAS/ILS Arrival/Departure Flight management

First, as detailed in the above Table, the operational concept has changed indeed no ATC supporting Tool is proposed anymore and all departing A/C will hold at CAT III holding point. Therefore for several Use Case Steps no SRs are required anymore.
Because the departing phase is not impacted by GBAS/ILS arrival considering the updated concept (no supporting tool and all aircraft hold at CAT III point) specific SRs were not derived for the following steps: 5, 9, 11, 14 to 18 and 21 to 25.

3.3.2.5 Scenario # 5 GBAS or GBAS/ILS Guided Take-Off

The use case details guided Take off for departing aircraft when using ILS or GBAS.

The airport is assumed to be equipped with an A-SMGCS (level 1).
The ILS and GBAS landing systems are considered available for the runway .
The airport operates in segregated runway mode or mixed runway mode.

Figure 12 describes the thread analysis considering the limited set of information available for such operation. Table 18 identifies existing requirements from section 3.2.3 supporting the thread analysis and identify, when necessary, if requirements are missing (completeness) or need to be reworded (correctness).

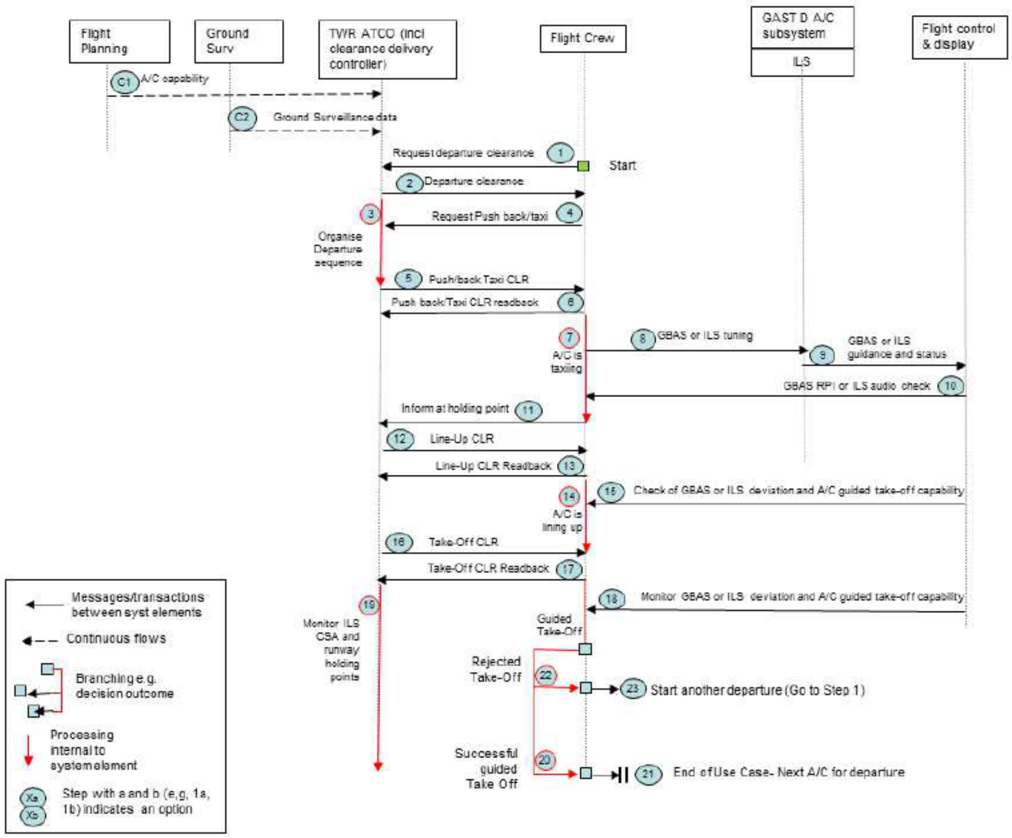


Figure 12 Thread Analysis for Scenario#5: GBAS or GBAS/ILS guided Take-off

Step Ref	Description and traceability towards Safety Requirements
	Nominal Flow
1	Flight Crew request departure clearance to clearance delivery controller (No SR)
2	Controller deliver the departure clearance (No SR)
3	Tower Controller organise the departure sequence (SR 415)
4	Flight Crew request push back/taxi (No SR)
5	Tower Controller provides push back/taxi clearance (No SR)
6	Flight Crew read back the clearance and start taxi off phase (No SR)
7	Departing aircraft is taxiing to the runway holding point (SR 430) (SR 435) (Concept has been updated and all departing A/C will hold at CAT III holding point). There is a correctness issue for SR 430 which needs to be modified by replacing CAT I holding position by CAT III holding position.
8	Flight crew tune the GBAS (SR 050) or the ILS landing aid. Regarding SR 50, it is assumed that the GBAS channel for the guided take off is published on the departure chart (No SR)
9	GBAS or ILS airborne system display guidance and status information (SR 175) (SR 400)
10	Flight crew verify that correct GBAS (SR 055) or ILS landing aid is selected
11	Flight crew inform tower controller that she/he reaches the runway holding point (No SR)

Step Ref	Description and traceability towards Safety Requirements
12	Tower controller gives line up clearance to departing A/C (No SR)
13	Flight Crew read back the clearance and move to take-off position (No SR)
14	Departing aircraft is lining up on the runway(No SR)
15	Flight crew check the GBAS or ILS guidance and the A/C capability for Take-Off in Low visibility (SR 60)
16	Tower controller provides the Take-Off clearance to departing aircraft (SR 420)
17	Flight crew read back the clearance and start take-off roll (SR 425)
18	Flight crew monitors GBAS or ILS guidance during the guided take-Off (SR 185)
19	Tower Controller verifies that mobiles does not infringed ILS sensitive area for ILS guided take-off (SR 195) and that other departing A/C hold at the CAT III holding points (SR 430) (SR 435)- See correctness issue for SR 430 described in Step 7 above.
20	Aircraft lift off and flight crew continue the climb phase (No SR)
21- End of nominal flow: Next A/C for departing	
Alternate Flow	
22	Flight crew abort the guided take-off (SR 440)
23- End of alternate flow: Flight crew start another departure following the aborted Take-Off	
Continuous Flow (No reference in OSED)	
C1	Aircraft capability from Flight planning provided to Tower Controller (A#0060)
C2	Ground surveillance data provided to Tower Controller (Environment requirement ENV#105)

Table 18 Thread Analysis description for Scenario#5: GBAS or GBAS/ILS guided Take-off

Safety Requirements have not been identified in section 3.2.3 for the following Steps: 1, 2, 4, 5 and 6 however it is recommended to include in all of the delivered clearances (Departure, Push back and Taxi) that guided take off is used without forgetting to include the supporting navaid (GBAS or ILS).

- REC#0008: For departure with guided take-off, Flight Crew and Tower Controller should indicate in each clearance (departure/Push back/Taxi) and during the readback the navigation aid (GBAS or ILS) supporting the guided take-off operations

Safety Requirement is not identified for Step 8 regarding the GBAS channel information to be used by the flight crew for the guided Take-Off. Therefore following requirement is added:

- SR 445: The GBAS channel number to be used by the flight crew for guided take-off shall be provided on aerodrome publication (e.g. departure chart)

For Steps 11 to 14 and 20, it is confirmed that no additional requirements are required because already covered by current and basic procedures for controller and flight crew and furthermore this not specific to GBAS.

A correctness issue was identified for SR 430 (see Step 7 above) and the existing requirement was modified as follows:

- Modified SR 430: During a guided Take-Off at an aerodrome with GBAS only operations, Tower controller shall verify that other departing aircraft hold at the ~~CAT I~~ CAT III holding position

3.3.3 Effects on Safety Nets – Normal Operational Conditions

Although no safety nets are credited in the safety assessment, any potential impact of optimised CAT III operations based on GAST-D on these safety nets has to be assessed for its safety implications, given that ACAS and TAWS are installed onboard a majority of aircraft and other ground safety nets might be implemented in local implementations.

This section assesses the potential impact of the new concept on each relevant ground and airborne safety net.

3.3.3.1 Ground Based Safety Nets

RIMS (Runway Incursion Monitoring System equivalent to A-SMGCS level 2)
Optimised CAT III operations based on GBAS could impact RIMS (or A-SMGCS level 2). Indeed anticipated landing clearance could be provided and therefore ILS sensitive area could be safely infringed during GBAS landing. However the nuisance alert rate during optimised operations needs to be considered and a specific validation item was identified (VAL#0005)

Safety requirements derived in section 3.2.3 will supplement existing RIMS requirements in order to have a suitable safety net for CAT III optimised operations (SR 295, SR 300,and SR 301).

MSAW (Minimum Safe Altitude Warning)
GBAS CAT III approach does not impact negatively MSAW operation because procedure design and GBAS performances are at least equivalent to ILS. Indeed safety requirements derived in section 3.2.3 will permit to safely design the procedure (SR 135, SR 140, SR 145, SR 160 and SR 165 and SR170) and will deliver same or better performance and functionality (in particular SR 155, SR 175, SR 180 and SR 185)

STCA (Short Term Conflict Alert)
STCA might be active or not for final approach. In case it is active, no negative effect on its operation is foreseen for GBAS. Indeed safety requirements derived in section 3.2.3 will permit to deliver same or better performance and functionality (in particular SR 155, SR 175, SR 180 and SR 185).

3.3.3.2 Airborne Safety Nets

TAWS (Terrain Avoidance Warning System)[14]

GBAS CAT III approach does not impact negatively TAWS. TAWS Glideslope mode will be used in a similar way than with ILS. The TAWS glideslope mode warns flight crew when the aircraft is below the nominal glidepath. Safety requirements derived in section 3.2.3 will permit to deliver same or better performance and functionality compared to ILS (in particular SR 155, SR 175, SR 180 and SR 185)

Note: TAWS was designed to overcome the shortcomings of the original Ground Proximity Warning Systems (GPWS) by providing "Forward Looking Terrain Avoidance".
Whilst GPWS was based only upon radio altimeter inputs, TAWS takes account of actual aircraft position in relation to a terrain map contained in the equipment. This actual position is determined horizontally by either built-in GPS or using an input from the aircraft FMS position, and vertically based on barometric altitude (and if available, on radio altimeter). TAWS using geometric altitude also exist.

ACAS (Airborne Collision Avoidance System)
Depending on the local environment, the potential for ACAS nuisance alerts might need to be considered. However, that potential is not higher than for ILS approaches.

3.3.4 Dynamic Analysis of the SPR-level Model – Normal Operational Conditions

3.3.4.1 06.08.05 Validation Exercise -VP563 “Concept Validation Plan for GBAS CAT II-III for V3”

The main objective of EXE-06.08.05-VP-563 is to validate the increased runway capacity in poor weather conditions provided by the use of GBAS CAT II-III based on GPS L1 for precision approaches. The validation activity is a real-time simulation based on Paris CDG operational

[14] TAWS (Class A) is required for all transport aircraft above 5.7t and more than 9 passengers

environment. The EUROCONTROL Approach simulator (Escape) and Airport simulator (eDEP platform) are used.

The main objectives described in the Validation Plan [7] of this real-time simulation are:

- To assess whether optimised operations using GBAS CATII-III produces an increase of runway throughput in LVP
- To assess whether mixed operations ILS / GBAS CAT II-III produces an increase of runway throughput in LVP
- To assess whether there is an impact of the GBAS CAT II-III operations on ATC workload
- To validate ATC procedures for appropriate spacing between aircraft pairs (GBAS-ILS, GBAS-GBAS, ILS-GBAS)
- To assess whether safety in optimised operations using GBAS CAT II-III in LVP is maintained and possibly increased

To be able to answer the objectives, six different scenarios are simulated. In the reference scenario only ILS landings are simulated. Two solution scenarios, one with a 60% GBAS and 40% ILS landings, and one with 100% GBAS landings, are simulated. Each of these 3 scenarios will be run for a segregated runway configuration as well as for a mixed mode runway configuration.

The following spacing between aircraft is used during the RTS:

- For the Reference scenario (ILS baseline scenario in LVP):
  - The nominal spacing between ILS aircraft in segregated arrival flows is 6 NM
  - The nominal spacing between ILS aircraft in mixed runway mode is 8 NM

  The above values represent the spacing used in LVP at busy airports such as: Charles de Gaulle, Heathrow and Zurich.

- For the GBAS (only) solution scenario in LVP:
  - The spacing between GBAS aircraft in segregated arrival flows is 5 NM
  - The spacing between GBAS aircraft in LVP in mixed runway mode is 7 NM

- For the Mixed GBAS/ILS equipage solution scenario in LVP:
  - The spacing in front of a GBAS aircraft in segregated arrival flows is 5 NM and for ILS 6 NM.
  - The spacing in front of a GBAS aircraft in mixed runway mode is 7 NM and for ILS 8 NM

The different Validation items identified in section 2.12 and in section 3.2.3 have been addressed by this validation exercise as detailed in the following table (see the draft Validation report [8] for more details).

VAL Item	Description	Validation Objective and Conclusion based on the draft report
VAL#0002	In CAT III approach mixed GBAS/ILS equipage operation, appropriate spacing between aircraft pairs (GBAS-ILS; GBAS-GBAS and ILS-GBAS) should be validated to prevent ILS CAT III sensitive area infringement by a preceding aircraft during an ILS landing	Addressed by OBJ-06.08.05-VALP-0563.0001, OBJ-06.08.05-VALP-0563.0002, OBJ-06.08.05-VALP-0563.0003 and OBJ-06.08.05-VALP-0563.0004. The RTS results show that the number of under-separation at 4 NM and at the landing threshold is lower in the solution scenario than in the reference scenario The RTS results show that for the solution scenarios with segregated runways less separation infringements for wake-pairs and non-wake pairs were recorded. This was not true for the solution scenario with mixed mode runway operations. Indeed more or the same amount of separation

		infringements were recorded than in the reference scenario. While in the scenario with segregated runway no or less separation infringements were recorded in the solution scenario than in the reference scenario, in the mixed mode runway scenarios the increase of separation infringements was due to the departure aircraft and the 1nm landing clearance combined with the closer spacing of GBAS aircraft which often lead to a radar separation conflict between arrival and departure aircraft. GBAS in LVP operations for mixed mode runway operations might however not bring any significant gain in runway throughput since the results indicate that the spacing cannot be reduced as much as expected. The results led to recommendations on the procedures that the magnitude of reduced spacing for GBAS operations should be assessed and determined locally as it is dependent on the local procedures and environment.
VAL#0004	For optimised operations, the late landing Clearance shall be provided at a distance to the runway threshold which does not impair the aircraft ability to prepare the landing. This aspect should be validated during validation exercise	Addressed by OBJ-06.08.05-VALP-0563.0001 and OBJ-06.08.05-VALP-0563.0002 Active airline pilots participating in the simulation agreed that that even if 1nm is quite short it is acceptable, as long as the flight crew is made aware that a late landing clearance is to be expected
VAL#0005	It should be validated if Runway safety nets are suitable for optimised operations and mixed GBAS/ILS equipage operation or if they should be modified.	Addressed by OBJ-06.08.05-VALP-0563.0001 and OBJ-06.08.05-VALP-0563.0005: Only one RIMCAS alert was recorded (runway incursion) and this alert occurred in the 100% GBAS landings mixed mode runway configurations. No conclusion can therefore be drawn on the controller feedback.
VAL#0006	The landing clearance line concept should be validated for: *segregated runway operation (arrival) with GBAS optimised operations *segregated runway operation (arrival) with mixed GBAS/ILS equipage operations *mixed mode runway operation (arrival/departure) with GBAS optimised operations *mixed mode runway operation (arrival/departure) with mixed GBAS/ILS equipage optimised operations	Addressed by OBJ-06.08.05-VALP-0563.0001 and OBJ-06.08.05-VALP-0563.0003 -Only one runway incursion was recorded. This occurrence was recorded in the 100% GBAS landings mixed mode runway configurations. -No increase of go-arounds was recorded in the solution scenarios compared to the reference scenarios.

VAL#0007	During optimised operations, the go-around rate (without considering failure) shall not be greater than in ILS CAT III only operations (without considering failure) in similar operational environment and weather conditions.	Addressed by OBJ-06.08.05-VALP-0563.0001. In the segregated runway scenarios no go-arounds were recorded. In the scenarios with mixed mode runway the same amount of go around was recorded in the GBAS 100 mix as in the ILS 100 mix. No go around were recorded in the GBAS 60 scenario. This success criterion is met as no increase of go-arounds was recorded in the solution scenarios compared to the reference scenarios.
VAL#0010	Aircraft spacing reduction of 1Nm in front of GBAS shall be validated	Addressed by OBJ-06.08.05-VALP-0563.0004. The validation results led to recommendations on the procedures that the magnitude of reduced spacing for GBAS operations should be assessed and determined locally as it is dependent on the local procedures and environment.
VAL#0011	Possibility to provide the latest landing clearance at different points for ILS (2Nm) and GBAS (1Nm) should be validated	Addressed by OBJ-06.08.05-VALP-0563.0011 All controllers applied the 1nm landing clearance procedure in front of a GBAS aircraft and did not find the different landing clearances for ILS and GBAS confusing. However concerns were raised that the 1nm distance for a landing clearance combined with the close spacing in front of a GBAS aircraft was too close for the mixed mode runway scenarios.

3.3.4.2 06.08.05 Validation Exercise -VP166 Concept Validation Report for Advanced Procedures (RNP to GLS concept) for V3

This exercise consists of real-time simulations on a A320 cockpit simulator from Airbus, aiming at validating the RNP/GLS approach procedures, reaching the V3 level and focusing on a realistic scenario at the location of the Palermo airport.

The main objectives described in the Validation Plan [29] of this real-time simulation are:

- To validate that the design of the RNP to GLS procedure can be correctly coded within FMS Navigation database
- To analyse the procedure flyability and operational acceptability
- To demonstrate the benefits achievable by the implementation of an RNP to GLS procedure with respect to current flight procedure in terms of safety, and human performance
- To demonstrate the benefits achievable by the provision of vertical guidance in terms of safety and human performance

The different Validation items identified in section 2.12 have been partially addressed by this validation exercise as detailed in the following table (see Validation report [30] for more details).

VAL Item	Description	Validation Objective and Conclusion
VAL#001	It should be validated that the capture of the final approach supported by RNP is safe and efficient (with respect to the	OBJ-06.08.05-VALP-0166.0002 and OBJ-06.08.05-VALP-0166.0003 06.08.05 validation exercise -VP 166 was not fully conclusive on this aspect. It is proposed that this

	RNP corridor)	validation item be addressed through SESAR Solution#09 by Project 06.08.08 (Enhanced terminal operation with automatic RNP transition to xLS and LPV).
VAL#0008	For non CDO operations, it should be checked if a 2Nm (or 30 sec) straight and level flight segment prior to final approach track intercept is necessary.	OBJ-06.08.05-VALP-0166.0001 06.08.05 validation exercise VP 166 was not fully conclusive on this aspect. It is proposed that this validation item be addressed through SESAR Solution#09 by Project 06.08.08 (Enhanced terminal operation with automatic RNP transition to xLS and LPV).

3.3.5 Additional Safety Requirements (functionality and performance) – Normal Operational Conditions

Table 19 below shows the additional success-case safety requirements, safety assumptions or recommendations that have been revealed by the analyses conducted above in sections 3.3.2, 3.3.3 and 3.3.4

ID **[SPR-level Model element]**	**Description**	**Scenario Reference** **Safety Objectives [ID]**
New SR 187 [Flight Crew]	Flight crew shall make an altitude/distance check during GBAS approach between 5 Nm to 3 Nm before the threshold	Scenario#1 and #3 [SO#0050]
Modified SR 265 [Tower Controller]	In GBAS only operation for CAT III, Tower controller shall verify that departing aircraft hold at the CAT III holding position	Scenario#2 [SO#0100]
Modified SR 430 [Tower Controller]	During a guided Take-Off at an aerodrome with GBAS only operations, Tower controller shall verify that other departing aircraft hold at the CAT III holding position	Scenario#5 [SO#0050]
New SR 445 [AIS provider]	The GBAS channel number to be used by the flight crew for guided take-off shall be provided on aerodrome publication (e.g. departure chart)	Scenario#5 [SO#0200]
New REC#0008 [Tower Controller] [Flight Crew]	For departure with guided take-off, Flight Crew and Tower Controller should include in the clearance (departure/Push back/Taxi clearances) and during the read back the navaid type (GBAS or ILS) used for the guided take-off	Scenario#5 [SO#0200]

Table 19: Additional SR, Assumption or Recommendation– Normal Operational Conditions

3.4 Analysis of the SPR-level Model – Abnormal Operational Conditions

This section ensures that the SPR-level Design is complete, correct and internally coherent with respect to the Safety Requirements (Functionality and Performance) derived for the abnormal operating conditions that were used to derive the corresponding Safety Objectives (success approach) in section 2.8.2.

The analysis is carried out from three perspectives:

- can the CAT III operations based on GAST-D continue to operate effectively when abnormal conditions are encountered

- if the CAT III operations based on GAST-D cannot continue to operate fully effectively– is the overall risk still within the tolerable limits and can the system recover sufficiently quickly when the abnormality is removed (or at least mitigated)

- to what degree could such abnormal conditions, while they persist, cause the CAT III operations based on GAST-D to behave in a way that could actually induce a risk that would otherwise not have arisen?

3.4.1 Scenarios for Abnormal Conditions

Table 20 below recalls the different scenarios relative to the abnormal conditions identified in section 2.8.1 and explain why such scenarios have been chosen.

ID	Scenario	Rationale for the Choice
1	Severe Ionospheric disturbances	GBAS positioning can be affected by this abnormal condition
2	Unintentional Interference (impacting GNSS and/or VDB)	GBAS continuity, integrity and availability – both on the ground and airborne- can be affected by this abnormal condition
3 + 7	Severe weather conditions (e.g. snow, heavy rain, ice, lightnings, etc) *Note- this scenario merges abnormal conditions #3* "Severe weather conditions (heavy snow, ice , heavy rain,…)" *and #7* "Local weather phenomena like thunderstorm"	GBAS ground station continuity, integrity and availability can be affected by this abnormal condition.
4	Over flight disruption of GBAS ground subsystem (Signal blockage)	GBAS ground station continuity and availability can be affected by this abnormal condition.
5	Excessive Multipath affecting GNSS at ground level	GBAS ground station continuity, integrity and availability can be affected by this abnormal condition.
6	Wrong Arrival Sequence Manager sequencing for optimised operation conducted in mixed GBAS/ILS equipage	Can lead to increased ATCo workload and eventually spacing reduction between aircraft performing optimised operations.
8	GPS constellation failure/degradation leading to GPS SIS loss	GBAS continuity, integrity and availability – both on the ground and airborne- can be

		affected by this abnormal condition

Table 20: Operational Scenarios – Abnormal Conditions

3.4.2 Derivation of Safety Requirements (Functionality and Performance) for Abnormal Conditions

3.4.2.1 Derivation of Safety requirements by considering the OSED potential mitigations

Table 21 below describes the required safety requirements to mitigate the consequence of the abnormal conditions considering scenarios identified in Table 20 above.

Preventive mitigations for abnormal conditions	Safety Requirements for abnormal conditions
#1 Severe Ionospheric disturbances	
Monitoring in the ground subsystem	See SR200 (includes provisions on iono gradient monitors).
	REC#0020: Depending on ionospheric conditions, the risk of exposure to scintillations should be taken into account in the monitor design
Monitoring in the airborne segment	See SR175 (includes provisions on airborne mitigation of iono anomalies).
Siting restriction on the ground subsystem	SR 500: The GAST-D Ground Station siting requirements shall include measures taking into account the effect of ionospheric disturbances. Technical traceability/comments: a. The maximum distance from GBAS reference point to any threshold served by the station shall be 5 km in order to mitigate ionospheric anomalies (from 15.03.06 D04 Req: [Iono1] and 15.3.6 GAST D Conops S4). *Note: It has been proposed that the 5 km limitation be replaced by a limit to be determined per site/per manufacturer. This change was not validated and/or implemented at the moment of writing this report.* b. Antenna separations shall be determined based on risk of correlated multipath, and the selected Ionospheric gradient monitoring scheme. (from 15.03.06 D04 Siting Consideration Req [Iono2] and 15.3.6 GAST D Conops S7). c. Depending on selected ionospheric gradient monitoring scheme, the effective baselines shall be perpendicular to the worst-case wave front and thus aligned with the runway for which GAST D operation shall be performed (from 15.03.06 D04 Req [Iono3]).
	REC#0021: The stability of the antenna foundation should be considered with respect to the selected ionospheric gradient monitoring scheme.
A standard threat space which defines the range of ionospheric anomalies to which the user will be exposed	REC#0022: MET and AIS providers should undertake specific studies in order to assess the feasibility of space weather forecast integration into the NOTAM system , to prevent usage of GBAS for Cat III operations in case of very large ionospheric storm.
#2 Unintentional Interference (impacting GNSS and/or VDB)	
Siting restriction on the ground subsystem	SR 505: Antenna height shall be determined on the basis of generic multipath considerations and risk of jamming and on-site activities Technical traceability/comments: 15.3.6 D04 - Integrity1
	REC#0023: GS architecture should take the risk of interference into account such that the GS is

Preventive mitigations for abnormal conditions	Safety Requirements for abnormal conditions
	robust against interference on a limited number of receivers.
	REC#0024: GS site selection should take the risk of jamming into account, i.e. antennas should be sited at as far as poss ble from public areas such as roads
	REC#0025: Local airport development plans should be considered in the development of local GAST D GS siting procedures.
State spectrum regulation, frequency management and enforcement of these regulation	A#0080: Frequency coordination activities are performed by the ANSPs to avoid radio frequency interference in the NAV frequency range (108 – 118 MHz), including ILS/GBAS interference.
	SR 510: Regulatory material in line with the applicable standards shall be defined and applied to ensure the operation of aeronautical equipment is free from radio frequency interference in the ARNS frequency range Technical traceability/comments: Includes GNSS repeater and pseudolite regulations / standards.
	SR 515: The GBAS service provider shall define interference monitoring and control procedures, such that: a. The interference environment at the reference receivers' sites is proven to be lower than the nominal interference environment, before the start of operations, and b. The GBAS GAST-D service is cancelled whenever the interference environment at the reference receivers sites is higher than the nominal interference environment. Technical traceability/comments: The nominal interference environment is given by the interference threshold masks in Appendix E of ED-114A
	SR 520: Interference assessment shall be conducted by means of: a. Ground tests shall be conducted during siting of the ground subsystem to verify the level of RFI complies with ED-114A App. E b. Flight tests during flight check of all GBAS approaches supported by a GBAS ground facility Technical traceability/comments: An appropriate ground test methodology is described in ED114A chapter 5.15.6.1. An appropriate flight test methodology is described in ED114A chapter 5.16.3.
	A#0085: GBAS GAST D equipment always contains RFI mitigations (e.g. an RFI monitor).
Making GNSS receivers (ground and airborne) robust against interference	See SR200 (includes provisions on robustness against interference).
	REC#0026: In order to support problem investigation and maintenance, the GBAS ground equipment should output the signal-to-noise ratio for each satellite.
Updated maintenance procedures	SR 525: If interference is confirmed, maintenance procedures shall ensure that the approach procedure be removed from operational status pending corrective action and appropriate authorities be notified.
	SR 530: Airport maintenance procedures shall include the maintenance and repairing of fencing/ barriers, if they exist, designed to block interfering signals
	REC#0027: If interference is suspected, maintenance procedures should define the conditions of investigation efforts and pre-commissioning surveys of the interference environment.
	REC#028: Airport maintenance procedures should include the development of additional mitigation methods, such as barrier construction or reference receiver relocation, in case interference sources cannot be removed.

Preventive mitigations for abnormal conditions	Safety Requirements for abnormal conditions
#3 + #7: Severe weather conditions[15]	
Design of ground antennas avoiding build-up of snow and ice	SR 535: The GBAS GNSS receiver antennas shall have as little horizontal surfaces as possible. If slanted surfaces are used, these should have a sufficient angle relative to horizontal plane to allow snow to slide off Technical traceability/comments: 15.3.6 D04 Section 5.5
	SR 540: The antenna height shall be adapted to local snow conditions. Technical traceability/comments: To reduce the need for snow removal activities. See 15.3.6 D04 section 5.3.2
Procedure for snow removal	SR 545:Snow removal and prevention procedures shall be put in place to prevent build-up of snow: a.Above ¾ of the mast height inside the inner LOCA b.Above 3 degrees as seen from the antenna base in the intermediate LOCA c.In areas where snow is likely, GBAS GNSS receiver antennas shall be polished each autumn. Technical traceability/comments: For point b): Starting at 35 cm above antenna base, 4 m from the mast. See 15.3.6 D04 section 5.5
Siting measures (ie. drainage in case of heavy rain)	SR 550: The GNSS Antennas shall not be sited in areas with poor drainage, or, alternatively, the GNSS ground subsystem design shall allow siting in water accumulation zones without performance impact.
	REC#0029: If the soil is considered to be insufficiently drained, and additional draining is not practicable, a layer of minimum 25 cm of gravel should be added in the inner LOCA
	REC#0030: Care should be taken during siting, to avoid areas where snow tends to build up, or areas which are used as snow deposits
Aircraft operations are affected (re-routing, capacity decrease,…) if GBAS SIS is impacted.	SR 555: The ANSP shall check that local meteo parameter (rainfall, wind, snow, etc) values do not surpass those indicated in specifications
	A#0090: The snowfall required for causing a GBAS SIS loss of continuity always triggers the airport's standard procedures for capacity decrease handling and alternate airports re-routing.
	A#0095: The volume of volcanic ash in the atmosphere required for causing GBAS SIS losses of continuity or availability always prevents GBAS flights to be conducted.
	A#0100: If earthquake damages displace THR position in a precision approach runway, CAT II/III operations are stopped.
#4: Over flight disruption of GBAS ground subsystem (Signal blockage)	
Siting restriction on the ground subsystem preventing masking of GBAS reference receivers	SR 560: Siting activities (data logging) shall be carried out during normal operation of the airport, and all operational modes shall be considered for impact on the GBAS Ground Subsystem. If missed approaches do not occur during siting, they shall be assessed on a theoretical basis.

[15] Earthquake was initially included as an additional "severe weather condition", to determine if current vibration levels (amplitude/frequency) were sufficient for GBAS CAT III systems. Eventually it has been decided not to define SR or recommendations from this event. If THR position changes, precision landing operations (in particular GBAS CAT II/III operations) shall be stopped. This is captured as an assumption. The case in which THR remains on its place, but some GBAS elements (e.g. Reference Receivers) are displaced from their original positions is mitigated by the relative nature of GBAS systems.

Preventive mitigations for abnormal conditions	Safety Requirements for abnormal conditions
antennas	Technical traceability/comments: 15.3.65 D04 Chapter 4.2.4
	SR 565: The GBAS service provider shall define co-ordination procedures with the airport authority regarding GBAS siting and building activities in the vicinity of the GBAS equipment. The airport authority shall validate such procedures.
Regular co-ordination with airport/ authorities to avoid new buildings blocking signals.	SR 570:The GBAS service provider shall define a building restricted area management process which should contain, at least: a. Awareness of GBAS Ground Subsystem installations when planning new infrastructure; b. A pre-installation evaluation to see if constructions may adversely affect the GBAS SiS; and c. Maintenance procedures which shall ask for re-assessments of GBAS parameters if construction in the vicinity of the airport is detected. Technical traceability/comments: For point a): It particularly applies to changes within the LOCA, and changes affecting the line-of-sight to operational areas from the VDB antenna(s). For point c): 15.3.6 D20 GAST D conops, section 12.4.1.2 applies to constructions that either changes the GPS signal multipath propagation or interferes with direct observation of low-elevation GPS satellites For points b) and c): ICAO EUR DOC 015 provides guidance about the activities to be conducted
#5: Excessive Multipath affecting GNSS at ground level	
GBAS reference receiver/antenna technology	SR 575:The GBAS GS manufacturer shall define a minimum number of installed antennas/receivers for achieving a GAST D performance level . Antenna separations shall be determined based on multipath and ionospheric gradient monitoring risks. Technical traceability/comments: Antenna separations shall be determined based on risk of correlated multipath, and the selected ionospheric gradient monitoring scheme. See15.3.6 D04-Iono 2 and 15.3.6 D04-Performance1.
	SR 580: The GBAS ground subsystem design shall include measures to avoid unsafe operation due to excessive multipath. A multipath assessment shall be performed for each GAST-D site. Technical traceability/comments: 15.3.6 D04-Performance3 and Performance 4. The impacted receiver technology concerns correlators and filters. The multipath assessment technique shall be based on Code-minus-carrier (CMC). *Note: see SR200 as well.*
Eliminate reflecting surfaces in the vicinity of the GBAS reference receivers antennas	See SR 570.
	REC#0031: Reflecting surfaces in the vicinity of the GNSS antennas, multipath should be avoided. LOCA should be respected.
#6: Wrong Arrival Sequence Manager sequencing for optimised operation conducted in mixed GBAS/ILS equipage	
When an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations, The Arrival Sequence Manager shall allocate a greater spacing between a GBAS-ILS pair, than that between ILS-GBAS or GBAS-GBAS pairs, to	REC#0032: When an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations, the ANSP should conduct a specific Arrival Sequence Manager failure case analysis to determine the assurance level to which it should be developed.
	A#0105: If an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations: a.The ANSP has updated the Arrival Sequence Manager sequencing criteria to allow for a greater separation between GBAS-ILS pairs than between ILS-GBAS or GBAS-GBAS pairs.

Preventive mitigations for abnormal conditions	Safety Requirements for abnormal conditions
guarantee that a preceding landed aircraft has vacated the ILS CAT III sensitive area during an ILS landing	b. ATCos using an Arrival Sequence Manager have been informed of the greater separation between GBAS-ILS pairs than between ILS-GBAS or GBAS-GBAS pairs. c.The ATC Arrival Sequence Manager procedures have been updated with the greater separation between GBAS-ILS pairs.
# 8 GPS constellation failure/degradation leading to GPS SIS loss	
GBAS missed approach procedure is based on conventional navigational aid or a safe aircraft extraction is poss ble when GPS is lost considering the airport environment (terrain, other arrivals and departure,…)	SR 585: The GBAS II/III approach missed procedure shall be either: a)based on conventional navaids, or b) based on GNSS. In this case, the GBAS CAT II/III operational approval shall require operators to define and implement (at least) one extraction contingency procedure per approach.
	SR 590: If a GBAS CAT II/III missed approach is based on GNSS, the airspace user's operating procedures shall be updated and flight crews shall be trained to conduct extraction contingency procedures in case of common GBAS and GNSS loss.
	SR 595: If a GBAS CAT II/III missed approach is based on GNSS, the GBAS service provider shall promulgate in the AIP the need for a contingency extraction procedure and the conditions to be complied with by local GBAS CAT II/III operators.
	REC#0033: ANSPs with GBAS CAT II/III procedures and/or Authorities should produce guidelines for operators to: a. Design extraction procedures in GBAS CAT II/III operations. b.Co-ordinate with the local ANSP and/or local authorities the implementation of extraction contingency procedures.
	A#0110: Conventional navaids supporting GBAS CAT II/III missed approaches comply with the applicable requirements in ICAO Annex 10 and are regularly flight-inspected and maintained according to EU regulation 1035/2011 (or equivalent).
	A#0115: If a GBAS CAT II/III missed approach is based on GNSS, operators have received operational approvals corresponding to the PBN navigation specification(s) used in the MA design.
	A#0120: All GBAS CAT II/III capable aircraft are equipped with inertial navigation systems providing accurate navigation on the M.A on a short term basis.
Approach based on conventional means is at least available at the alternate aerodrome	SR 600: Airspace users' GBAS CAT II/III flight planning procedures, and flight crew training, shall ensure in preflight phase that sufficient conventional means are available to navigate and land, at least, at an alternate aerodrome in the case of loss of GNSS-based navigation.

Table 21: Safety Requirements, Recommendations or Assumptions to mitigate abnormal conditions

3.4.2.2 Derivation of Safety requirements to satisfy the Safety Objectives

Table 22 below, take each of the Safety Objectives from section 2.8.2 and derive the corresponding Safety Requirements (Functionality and Performance) by considering the SPR level Model and requirements already identified in Table 22 above.

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements (functionality and Performance) for abnormal conditions**	**Maps on to / *Data flow number***

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements (functionality and Performance) for abnormal conditions**	**Maps on to / *Data flow number***
SO#0300 Aircraft shall respect the lateral and vertical path of the published GBAS approach when ionospheric disturbances are encountered or aircraft executes a safe go-around	See success approach requirements SR175 (airborne mitigation of iono anomalies) and SR200 (includes provisions on ground station iono gradient monitors).	See SR175 and SR200
	REC#0020: Depending on ionospheric conditions, the risk of exposure to scintillations should be taken into account in the monitor design	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)*
	SR 500: The GAST-D Ground Station siting requirements shall include measures taking into account the effect of ionospheric disturbances.	Engineering Activity → Maintenance Activity / *11 (Val GBAS data – engineering)* Maintenance Activity → GAST-D GS / *14 (GS Conf Data) and 15 (Maintenance Actions)*
	REC#0021: Depending on ionospheric conditions, the risk of exposure to scintillations should be taken into account in the monitor design	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)*
	REC#0022: MET and AIS providers should undertake specific studies in order to assess the feasibility of space weather forecast integration into the NOTAM system , to prevent usage of GBAS for Cat III operations in case of very large ionospheric storm.	MET/Space Weather → AIS Provider / *70 (MET data)*
	SR 640:The Flight Crew shall be alerted in case of GBAS approach unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances and shall execute a Go-around.	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)* GAST-D A/C → Display & Guidance / *53 (Deviation from flight path)* Display & Guidance → Flight Crew / *56 (Display and Guidance Data)*
	SR 645: The APP and TWR ATCOs shall be alerted of GBAS approach unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances	GAST-D GS→ APP/TWR ATCo / *18 (GBAS status)*
	A#0125 All iono events which can impact both the GBAS GAST-D and GNSS-based RNAV/RNP missed approach guidance can be considered as "very large".	GPS satellites → RNAV system / *01 (L1 GPS signals)*
SO#0305 Aircraft shall land in the prescribed touch down zone when ionospheric disturbances are encountered or aircraft executes a safe go-around	See SR175,SR200, SR 500, A#0125 and REC#0020-22 above,	
	SR 650: The Flight Crew shall be alerted in case of of GBAS landing unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances.and shall execute a Go-around.	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)* GAST-D A/C → Display & Guidance / *53 (Deviation from flight path)* Display & Guidance → Flight Crew / *56 (Display and Guidance Data)*
	SR 655: The APP and TWR ATCOs shall be alerted of GBAS landing unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances.	GAST-D GS→ APP/TWR ATCo / *18 (GBAS status)*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements (functionality and Performance) for abnormal conditions**	**Maps on to / *Data flow number***
	SR 660: The Flight Crew shall be trained in go-arounds from positions other than DA/MDA and the designated Stabilised Approach Gate.	Flight Crew → Display and Guidance / *55 (Display & Guidance selection)*
SO#0310 Aircraft shall conduct a successful GBAS landing rollout when ionospheric disturbances are encountered or aircraft executes a safe go-around	See SR175,SR200, SR 500, A#0125 and REC#0020-22 above,	
	SR 665:The Flight Crew shall be alerted in case of of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances.and shall execute a Go-around	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)* GAST-D A/C → Display & Guidance / *53 (Deviation from flight path)* Display & Guidance → Flight Crew / *56 (Display and Guidance Data)*
	SR 670:The APP and TWR ATCOs shall be alerted of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances.	GAST-D GS→ APP/TWR ATCo / *18 (GBAS status)*
	See success approach requirement SR200 (includes provisions on robustness against interferences).	
	SR 505: Antenna height shall be determined on the basis of generic multipath considerations and risk of jamming and on-site activities	Engineering Activity → Maintenance Activity / *11 (Val GBAS data – engineering)* Maintenance Activity → GAST-D GS / *14 (GS Conf Data) and 15 (Maintenance Actions)*
	REC#0023: GS architecture should take the risk of interference into account such that the GS is robust against interference on a limited number of receivers.	GAST-D GS
	REC#0024: GS site selection should take the risk of jamming into account, i.e. antennas should be sited at as far as possible from public areas such as roads	Engineering Activity → Maintenance Activity / *11 (Val GBAS data – engineering)* Maintenance Activity → GAST-D GS / *14 (GS Conf Data) and 15 (Maintenance Actions)*
	REC#0025: Local airport development plans should be considered in the development of local GAST D GS siting procedures.	Engineering Activity → Maintenance Activity / *11 (Val GBAS data – engineering)* Maintenance Activity → GAST-D GS / *14 (GS Conf Data) and 15 (Maintenance Actions)*
	A#0080: Frequency coordination activities are performed by the ANSPs to avoid radio frequency interference in the NAV frequency range (108 – 118 MHz), including ILS/GBAS interference.	ANSP Frequency Manager → GBAS Data Generation / *80 (GBAS VHF Freq)*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements (functionality and Performance) for abnormal conditions**	**Maps on to / Data flow number**
	SR 510: Regulatory material in line with the applicable standards shall be defined and applied to ensure the operation of aeronautical equipment is free from radio frequency interference in the ARNS frequency range	ANSP Frequency Manager
	SR 515: The GBAS service provider shall define interference monitoring and control procedures, such that: a. The interference environment at the reference receivers' sites is proven to be lower than the nominal interference environment, before the start of operations, and b. The GBAS GAST-D service is cancelled whenever the interference environment at the reference receivers sites is higher than the nominal interference environment.	Maintenance Activity → GAST-D GS / 15 *(Maintenance Actions)*
	SR 520: Interference assessment shall be conducted by means of: a. Ground tests shall be conducted during siting of the ground subsystem to verify the level of RFI complies with ED-114A App. E b. Flight tests during flight check of all GBAS approaches supported by a GBAS ground facility	Flight Inspec ion/ Engineering Activity → Maintenance Activity / 11 *(Val GBAS data – engineering) and 12 (GBAS signal Verif)* Maintenance Activity → GAST-D GS / 14 *(GS Conf Data) , 15 (Maintenance Actions) and 16 (Signal Insp)*
	A#0085: GBAS GAST D equipment always contains RFI mitigations (e.g. an RFI monitor).	GAST-D GS
	REC#0026: In order to support problem investigation and maintenance, the GBAS ground equipment should output the signal-to-noise ratio for each satellite.	GAST-D GS
	SR 525: If interference is confirmed, maintenance procedures shall ensure that the approach procedure be removed from operational status pending corrective action and appropriate authorities be notified.	Maintenance Activity → APP/TWR ATCo / 18a *(Maint Status Report).*
	SR 530: Airport maintenance procedures shall include the maintenance and repairing of fencing/ barriers, if they exist, designed to block interfering signals	Maintenance Activity → GAST-D GS / 15 *(Maintenance Actions)*
SO#0315 Aircraft shall respect the lateral and vertical path of the published GBAS approach when interference are encountered or aircraft executes a safe go-around	REC#0027: If interference is suspected, maintenance procedures should define the conditions of investigation efforts and pre-commissioning surveys of the interference environment.	Maintenance Activity → GAST-D GS / 15 *(Maintenance Actions)*
	REC#028: Airport maintenance procedures should include the development of additional mitigation methods, such as barrier construction or reference receiver relocation, in case interference sources cannot be removed.	Maintenance Activity → GAST-D GS / 15 *(Maintenance Actions)*
	SR 675:The Flight Crew shall be alerted in case of of GBAS approach unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference and shall execute a Go-around	GAST-D GS→ GAST-D A/C / 17 *(GBAS messages)* GAST-D A/C → Display & Guidance / 53 *(Deviation from flight path)* Display & Guidance → Flight Crew / 56 *(Display and Guidance Data)*
	SR 680:The APP and TWR ATCOs shall be alerted of GBAS approach unavailability (including detectable GBAS hazardously misleading	GAST-D GS→ APP/TWR ATCo / 18 *(GBAS status)* Flight Crew → APP/TWR

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements (functionality and Performance) for abnormal conditions**	***Maps on to / Data flow number***
	indication) due to GPS or VHF interference.	ATCo / *51a (Pilot status report)* Maintenance Activity → APP/TWR ATCo / *18a (Maintenance status report)*
	See SR 590 and SR 595 below for a common GBAS and GPS loss due to interferences.	See SR 590
SO#0320 Aircraft shall land in the prescribed touch down zone when interference are encountered or aircraft executes a safe go-around	See SR200, SR 505-530 , A#0080-85 and REC#0023-28 above, and SR 590 and SR 595 below.	
	SR 685 The Flight Crew shall be alerted in case of GBAS landing unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference and shall execute a Go-around.	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)* GAST-D A/C → Display & Guidance / *53 (Deviation from flight path)* Display & Guidance → Flight Crew / *56 (Display and Guidance Data)*
	SR 690 The APP and TWR ATCOs shall be alerted of GBAS landing unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference.:	GAST-D GS→ APP/TWR ATCo / *18 (GBAS status)* Flight Crew → APP/TWR ATCo / *51a (Pilot status report)* Maintenance Activity → APP/TWR ATCo / *18a (Maintenance status report)*
SO#0325 Aircraft shall conduct a successful GBAS landing rollout when interference are encountered or aircraft executes a safe go-around	See SR200, SR 505-530, A#0080-85 and REC#0023-28 above, and SR 590 and SR 595 below.	
	SR 695 The Flight Crew shall be alerted in case of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference and shall execute a Go-around.	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)* GAST-D A/C → Display & Guidance / *53 (Deviation from flight path)* Display & Guidance → Flight Crew / *56 (Display and Guidance Data)*
	SR 700 The APP and TWR ATCOs shall be alerted of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference.	GAST-D GS→ APP/TWR ATCo / *18 (GBAS status)* Flight Crew → APP/TWR ATCo / *51a (Pilot status report)* Maintenance Activity → APP/TWR ATCo / *18a (Maintenance status report)*
SO#0335 When Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised	REC#0032: When an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations, the ANSP should conduct an specific Arrival Sequence Manager failure case analysis to determine the assurance level to which it should be developed.	Arrival Sequence Manager → APP/TWR ATCo and SUP / *45a (Arrival Sequence Manager sequence)*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements (functionality and Performance) for abnormal conditions**	**Maps on to / *Data flow number***
operations, the Arrival Sequence Manager shall allocate a greater spacing between a GBAS-ILS pair, than that between ILS-GBAS or GBAS-GBAS pairs, to guarantee that a preceding landed aircraft has vacated the ILS CAT III sensitive area during an ILS landing		
	A#0105: If an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations: d.The ANSP has updated the Arrival Sequence Manager sequencing criteria to allow for a greater separation between GBAS-ILS pairs than between ILS-GBAS or GBAS-GBAS pairs. e.ATCos using an Arrival Sequence Manager have been informed of the greater separation between GBAS-ILS pairs than between ILS-GBAS or GBAS-GBAS pairs. f.The ATC Arrival Sequence Manager procedures have been updated with the greater separation between GBAS-ILS pairs.	Arrival Sequence Manager → APP/TWR ATCo and SUP / *45a (Arrival Sequence Manager sequence)*
SO#0340 To mitigate GPS loss events, the GBAS missed approach procedure shall be either: *based on conventional navigational aid or *allows the flight crew to conduct a safe aircraft extraction using raw data (e.g. heading, altitude) when GPS is lost considering the airport environment (terrain, other arrivals and departure,…)	SR 585: The GBAS II/III approach missed procedure shall be either: a)based on conventional navaids, or b) based on GNSS. In this case, the GBAS CAT II/III operational approval shall require operators to define and implement (at least) one extraction contingency procedure per approach.	Procedure Design Air Operator
	SR 590: If a GBAS CAT II/III missed approach is based on GNSS, the airspace user's operating procedures shall be updated and flight crews shall be trained to conduct extraction contingency procedures in case of common GBAS and GNSS loss.	Air Operator→ Flight Crew / *90 (Flight Operation procedures and training)*
	SR 595: If a GBAS CAT II/III missed approach is based on GNSS, the GBAS service provider shall promulgate in the AIP the need for a contingency extraction procedure and the conditions to be complied with by local GBAS CAT II/III operators.	Procedure Design → AIS provider / *21 (GBAS procedure)* AIS provider → Air Operator / *30 (Approach chart)* and *32 (AIP)* Air Operator → Flight Crew / *30a (Approach chart)* and *32a (AIP (AD))*
	REC#0033: ANSPs with GBAS CAT II/III procedures and/or Authorities should produce guidelines for operators to: a. Design extraction procedures in GBAS CAT II/III operations. b.Co-ordinate with the local ANSP and/or local authorities the implementation of extraction contingency procedures.	Procedure Design ANSP Engineering
	A#0110: Conventional navaids supporting GBAS CAT II/III missed approaches comply with the applicable requirements in ICAO Annex 10 and are regularly flight-inspected and maintained according to EU regulation 1035/2011 (or equivalent).	ANSP Engineering
	A#0115: If a GBAS CAT II/III missed approach is based on GNSS, operators have received operational approvals corresponding to the PBN navigation specification(s) used in the MA design.	Air Operator
	A#0120: All GBAS CAT II/III capable aircraft are equipped with inertial navigation systems providing accurate navigation on the M.A on a short term basis.	RNAV and Conv nav syst.
SO#0345 To mitigate GPS loss events, at least one approach	SR 600: Airspace users' GBAS CAT II/III flight planning procedures, and flight crew training, shall ensure in preflight phase that sufficient	Air Operator→ Flight Crew / *90 (Flight*

Safety Objectives *(Functionality and Performance from success approach)*	**Safety Requirements (functionality and Performance) for abnormal conditions**	**Maps on to / *Data flow number***
based on conventional means is available at the alternate aerodrome	conventional means are available to navigate and land, at least, at an alternate aerodrome in the case of loss of GNSS-based navigation.	*Operation procedures and training)*
SO#0400 Aircraft shall respect the lateral path of the guided take-off from the start of the take-off roll to the main wheel lift-off when ionospheric disturbances are encountered or aircraft aborts safely the take-off	See SR175,SR200, SR 500, A#0125 and REC#0020-22 above,	
	SR 705 The Flight Crew shall be alerted in case of GBAS guided take-off unavailability before main wheel lift-off (including GBAS hazardously misleading indication) due to ionospheric disturbances and shall abort the take-off.	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)* GAST-D A/C → Display & Guidance / *53 (Deviation from flight path)* Display & Guidance → Flight Crew / *56 (Display and Guidance Data)*
	SR 710 The TWR ATCOs shall be alerted of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference.	GAST-D GS→ APP/TWR ATCo / *18 (GBAS status)*
SO#0405 Aircraft shall respect the lateral path of the guided take-off from the start of the take-off roll to the main wheel lift-off when interference signals are encountered or aircraft aborts safely the take-off	See SR200, SR 505-535 , A#0080-85 and REC#0023-28 above.	
	SR 715 The Flight Crew shall be alerted in case of GBAS guided take-off unavailability before main wheel lift-off (including GBAS hazardously misleading indication) due to GPS or VHF interference and shall abort the take-off.	GAST-D GS→ GAST-D A/C / *17 (GBAS messages)* GAST-D A/C → Display & Guidance / *53 (Deviation from flight path)* Display & Guidance → Flight Crew / *56 (Display and Guidance Data)*
	SR 720 The TWR ATCO shall be alerted of GBAS approach unavailability before main wheel lift-off (including GBAS hazardously misleading indication) due to GPS or VHF interference.	GAST-D GS→ APP/TWR ATCo / *18 (GBAS status)*

Table 22: Mapping of Safety Objectives (Abnormal conditions) to SPR-level Model Elements

3.5 Design Analysis – Case of Internal System Failures

The objective of this analysis consists in determining how the system architecture (encompassing people, procedures, equipment) designed for the optimised CAT III operations based on GBAS can be made safe. For that purpose, the method consists in apportioning the Safety Objectives of each hazard into Safety Requirements to elements of the system.

Fault tree analysis is used to identify the causes of hazards and combinations thereof, accounting for safeguards already specified in the current standards and for any indication on their effectiveness.

Quantitative Safety Requirements are the means to express Safety Requirements for elements/parts of the system that will be subject to more in-depth safety assessment in further lifecycle steps.

The validity of the quantitative Safety Requirements is conditioned upon the validity of the Safety Objectives and on the accuracy of probabilistic data input to the fault trees.

Fault tree analysis is also used to identify mitigations to reduce the likelihood that specific failures would propagate up to the Hazard (i.e. operational level). These mitigations are then captured as additional Qualitative Safety Requirements (Functionality and Performance).

3.5.1 Causal Analysis

For each system-generated hazard (see chapter 2.9.1), a top-down identification of internal system failures that could cause the hazard was conducted. The hazards are:

- Hz 002: Failure to transition laterally and/or vertically from RNP or radar vectoring to GBAS CAT III approach
- Hz 003: Failure to follow the correct final approach path in GBAS CAT III
- Hz 004: Failure to maintain spacing between aircraft within the same final approach for optimised operations conducted in mixed GBAS/ILS equipage operations during CAT III approach
- Hz 005: Failure to maintain the separation between aircraft on adjacent CAT III approach operations
- Hz 006: Failure to land in the prescribed touch-down zone in GBAS CAT III approach
- Hz 007: Failure to maintain the A/C on the runway centreline during the CAT III GBAS landing rollout
- Hz 008: Failure to maintain aircraft longitudinal spacing on the runway during CAT III approaches in optimised operations
- Hz 020: Failure to maintain the A/C on the runway centreline during the Guided Take-Off in LVC based on GBAS
- Hz 021: Failure to maintain the A/C on the runway centreline during the Guided Take-Off in LVC based on ILS in mixed GBAS/ILS equipage operations
- Hz 022: Failure to maintain aircraft longitudinal spacing on the runway during Guided Take-Off in LVC

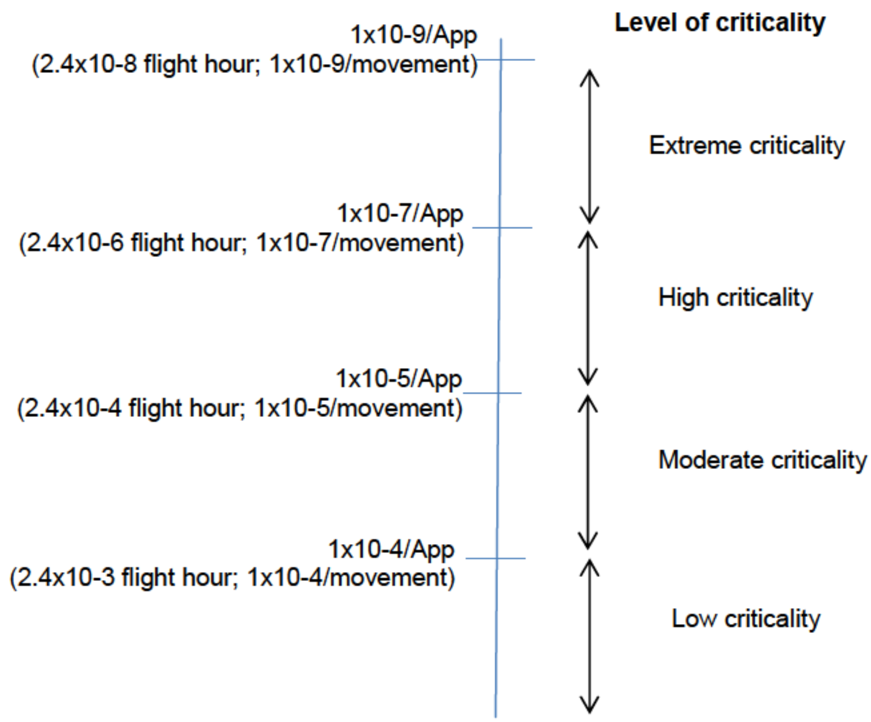
The purpose of the allocation of the causal analysis is to increase the detail of risk mitigation strategy through the identification of all possible causes. This way it will be possible to apportion the corresponding lower level Safety Objectives, and to identify the corresponding Safety Requirements allowing to meet the Safety Objective of the Operational Hazard under consideration. This top-down allocation is also made considering the bottom-up allocation due to compliance with standards (e.g. ICAO standard for continuity and integrity).

A fault tree is produced for each selected hazard that provides a detailed overview of the contribution of all domains for a given hazard. Fault trees are elaborated by decomposing the hazard in a combination of failures (i.e. Basic Causes) linked by different gates: "AND" gates and "OR" gates. Once the fault tree is decomposed, the safety objective assigned to the hazard is apportioned among the failures identified and safety requirements are allocated. Mitigation Means are proposed in order to reduce the likelihood of occurrence of the Operational Hazard.

Information relative to the Qualitative/Quantitative Requirements Allocation Process used in the different fault trees:

The first step of this process is to allocate a level of criticality to the top level event of the Fault Tree based on the associated safety objectives in accordance with the following allocation principle depicted in the diagram below:

IMPORTANT NOTE: The following diagram and the associated level of criticality are not endorsed yet by SESAR Project 16.06.01 therefore wording and definition may evolve in the future for other projects.



Then the next step is to "cascade" the level of criticality to the subsequent Fault Tree branches until a human error is isolated in a branch of a "AND" gate, e.g. Human Error is isolated as basic event.

The "cascade" process is applied using following rules:

- For an OR gate: the criticality of all "child" events is the same as this of parent event.
- For an AND gate: the level of criticality of parent event can be degraded of one level at child level provided the child events are independent and degradation is duly justified

The following principles are applied to human mitigations implied in the FT branch:

- Principle 2a: For human tasks/actions which are very specific to GBAS: no downgrading of the Level of Criticality is possible because no field experience or observation permits to justify the efficiency of this mitigation.
- Principle 2b: For human task/action which are similar to ILS: this permits a downgrading of the Level of Criticality justify by field experience/observation/expert judgement. These events are noted "P2b" in the Fault Trees.
- Principle 3: No mitigation possible by human action/task. These human tasks/actions are represented in the Fault Trees for information but they are not effective enough to be considered as mitigation considering the operational situation (e.g. LVP conditions). These events are noted "P3" in the Fault Trees.

When there is no more human cause in a branch, a quantitative objective is allocated on technical causes in order to derive quantitative safety requirement for the technical element. Considering this hybrid FT (quantitative/qualitative allocation), two cases are possible:

•The quantitative allocation is made through a “conventional” quantitative apportionment considering an accepted “quantitative” human-based risk reduction factor (RRF). Acceptance of this human-based quantitative figure should be based on e.g. ICAO figure, performance measured during operation, performance based on field experience, etc.
To illustrate this case, a CFIT accident due to a landing continuity failure could happen when there is a loss of GBAS guidance during the landing and the pilot does not execute the missed approach. Based on ICAO figures, probability that a pilot does not initiate a missed approach in such situation is considered to be 1/4000 therefore this risk reduction factor could be used to allocate quantitative objective for the loss of GBAS guidance during the approach (Requirements for the GBAS ground station and the GBAS airborne subsystems).

•The quantitative allocation is made directly considering the level of criticality allocated to the technical element with a quantitative allocation in accordance with the diagram depicted above. To illustrate this case, a technical cause having a “high criticality” allocation should lead to a requirement requiring a failure rate not greater than 1x10-7 per approach

For the human-based element, the level of criticality should be used to derive proper qualitative requirements. The following definition is proposed:

*Extremely critical task/procedure/process: A task/procedure/process which may lead to an accident if not properly conducted/accomplished. Considering this level of criticality, requirements must be identified to define specific skill, method or procedure. This criticality might require full automation or fully independent actions by different actors completed by actual verification before operation. E.g. procedure design validated by one team + FAS DB encapsulated with CRC+ flight check of this FAS DB + maintenance service level B required for any intervention on the FAS DB, etc.…

*Highly critical task/procedure/process: A task/procedure/process which is essential for the safety of the operation and requires specific and immediate action. Considering this level of criticality, requirements must be identified to define specific skill, method or procedure.

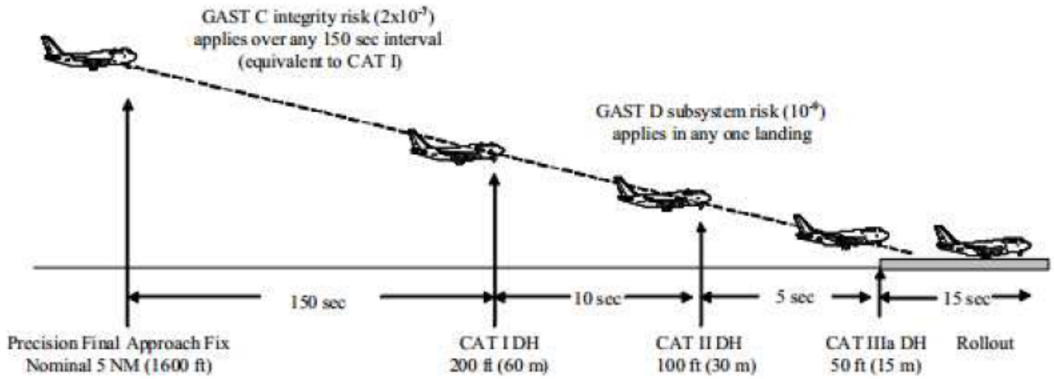
*Moderately critical task/procedure/process: A task/procedure/process which is important for the safety of the operation and requires specific attention but not necessarily immediate action. Considering this level of criticality, requirements must be identified to define specific skill, method or procedure.

*Low criticality task/procedure/process: A task/procedure/process which is conducted on a daily basis. Considering this level of criticality, requirements must be identified to define specific skill, method or procedure.

Information relative to the GAST-D Integrity and Continuity exposure time

Based on Appendix D of “concept paper for GAST D” [28], we consider the following exposure times as illustrated in Figure 13 below:

- For approach hazard: 150 sec for integrity and 15 sec for continuity.
- For landing hazards, including rollout: 30s both for integrity and continuity.



- GAST D integrity exposure applies in any one landing, which is a minimum of 15 sec, based on the time interval between 200 ft and 50 ft altitude. If the operation includes lateral guidance through rollout, the exposure time can be 30 sec for lateral.
- GAST D continuity exposure time is a minimum of 15 sec, based on the time interval between 200 ft and 50 ft altitude. If the operation includes lateral guidance through rollout, the exposure time can be 30 sec for lateral.

Figure 13: GAST-D integrity and continuity exposure time

Note 1: The exposure time to be considered for guided take-off is 60 seconds(see [32]): "The critical period of exposure to failures for lateral guidance during a guided take-off in Category III operations is taken to be the period between the thrust levers are set to FLX or TOGA until after lift-off at 50 feet above the ground. This is nominally 60 seconds."

Note 2: For hazards of which the SOs are expressed in « per approach or per landing», there is no conversion. Quantitative requirements on FTs are directly expressed in "per approach or per landing" In the Table 34, the safety requirements (integrity/reliability) are expressed "in any landing" for integrity failure and "during any 15 sec interval" for continuity failure.

3.5.1.1 Hz 002 - Failure to transition laterally and/or vertically from RNP or radar vectoring to GBAS CAT III approach

This hazard occurs during Intermediate Approach when an aircraft does not intercept correctly the GBAS CAT III approach.

This hazard could lead to 2 accident scenarios:

- A CFIT scenario, classified with a severity 3b, in which 2 situations can occur:

  1/ Aircraft overshoots the FAP --> interception of the GBAS vertical path late and from above --> no stabilized approach leading to risk of CFIT

  2/ A/C flies too low leading to risk of CFIT if terrain/obstacles
- A Mid Air Collision (MAC) scenario, classified with a severity 4a: when considering parallel approach operation, in case of lateral or vertical deviation of one of the two aircraft, this could lead to an imminent infringement with the other one.

Two fault trees have been developed (1 for CFIT and 1 for MAC). Causes are the same but some mitigation means are different.

Basic causes for such failures have been captured in the Hz 002 Fault Trees (See Figure 14 and Figure 15).

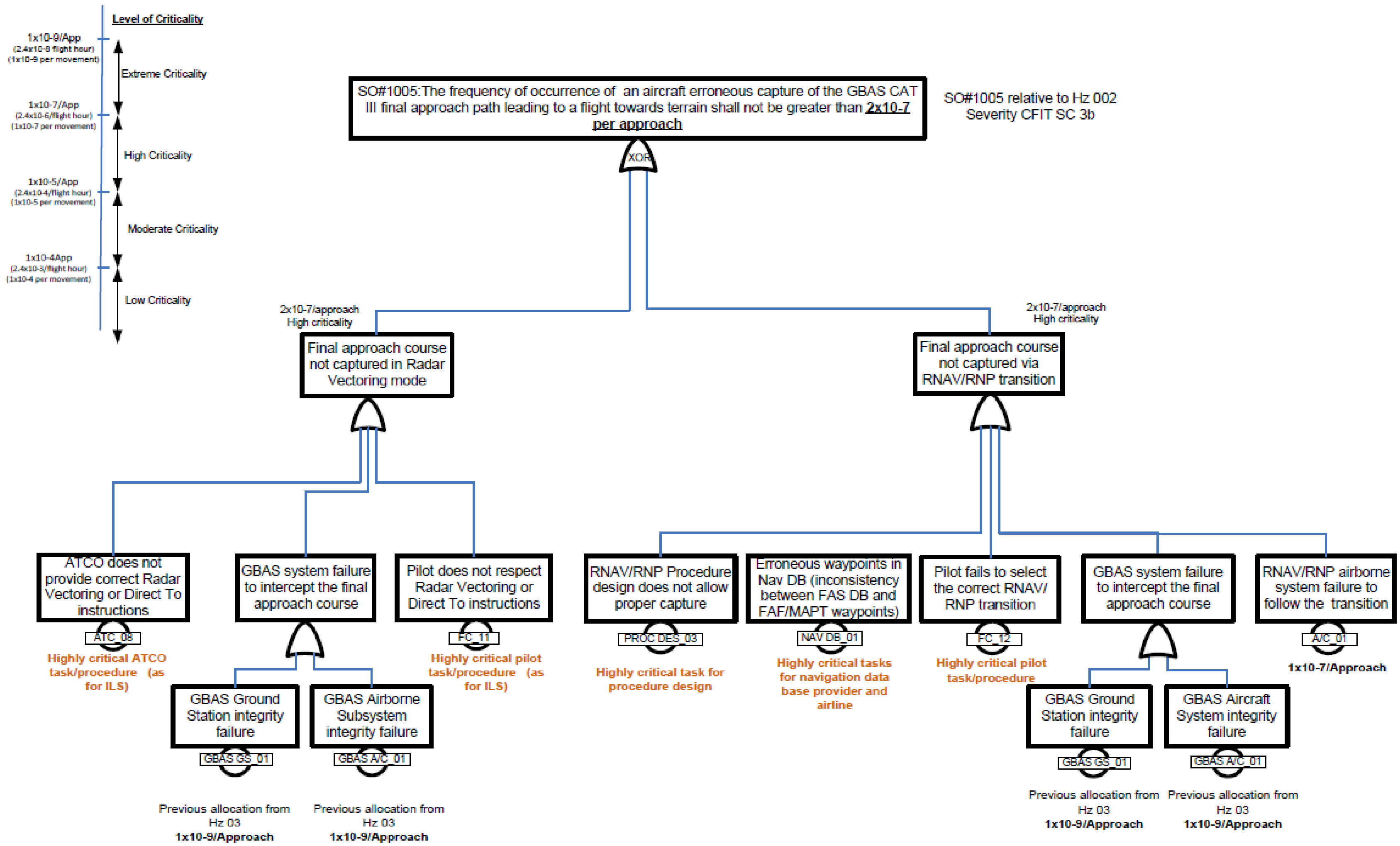


Figure 14 Hz 002 – Fault tree for CFIT scenario

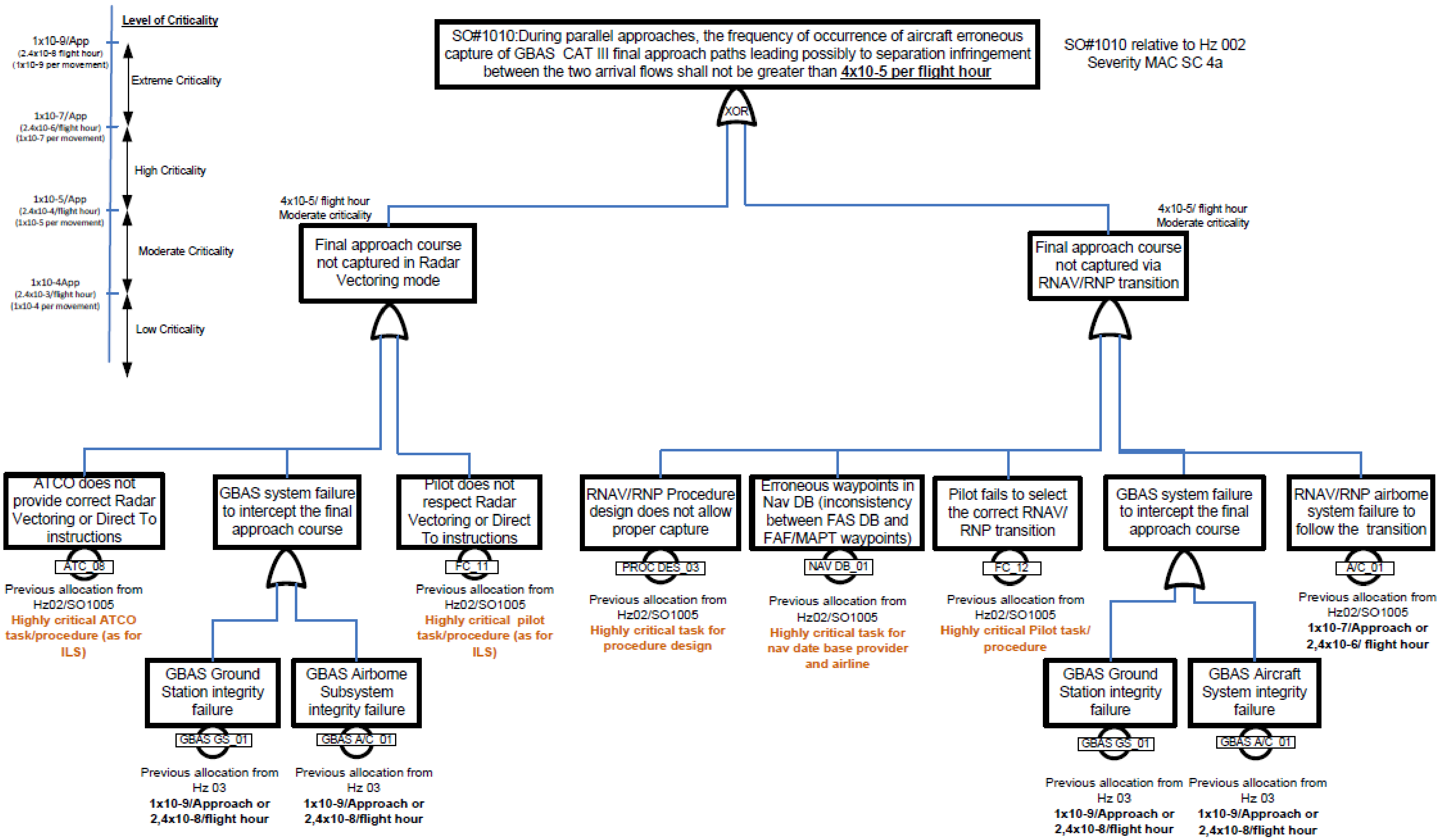


Figure 15 Hz 002 – Fault tree for MAC scenario

Table 23 below describes the basic causes of the Hz 002 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Final approach course interception in Radar Vectoring not satisfied			
ATCO instructions	ATC_08	ATCO doesn't provide correct Radar Vectoring or Direct To instructions	SR 095 "Normal Conditions" (Approach Controller shall provide radar vectors to FC to intercept the GBAS final approach course)
Flight Crew doesn't respect RV instructions	FC_11	Flight Crew doesn't respect Radar Vectoring or Direct To instructions	Assumption A#0070 (Respect of radar vectors and preparation of the transition for the interception of the GBAS final approach course)
GBAS system Failure	GBAS GS_01	GBAS Ground Station sends corrupted messages (correction, integrity data, FAS data, iono…) to the GBAS aircraft subsystem	SR 155 "Normal Conditions" (FAS Data Block transmission in accordance with ICAO Annex 10) SR 200 "Normal Conditions" (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 "Normal Conditions" (Flight inspection in accordance with ICAO Doc 8071)
	GBAS A/C _01	Integrity failure due to erroneous position computation by GBAS aircraft subsystem	SR 175 "Normal Conditions" (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
Final approach course interception via RNAV/RNP transition not satisfied			
RNAV/RNP Procedure	PROC DES_03	RNAV/RNP Procedure design doesn't allow proper capture	SR 145 "Normal Conditions" (design and validation of the GBAS CAT III procedure in accordance with ICAO doc 9906) Assumption A#0064 "Normal Conditions" (RNAV/RNP initial/intermediate approach segments are designed in accordance with PANS-OPS criteria)
Pilot selection	FC_12	Pilot fails to select the correct RNAV/RNP transition	New A#0200 "Flight Crew cross-check procedure insert in FMS with chart" New A#0205 "Flight Crew verify information on

			cockpit display (PFD/ND)”
RNAV/RNP airborne system failure	A/C_01	RNAV/RNP airborne system failure to follow the transition	SR 090 “Normal Conditions” (RNAV system shall guide the aircraft in accordance with the published RNAV/RNP procedure)
GBAS system Failure	GBAS GS_01	GBAS Ground Station sends corrupted messages (correction, integrity data, FAS data, iono…) to the GBAS aircraft subsystem	SR 155 “Normal Conditions” (FAS Data Block transmission in accordance with ICAO Annex 10) SR 200 “Normal Conditions” (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 “Normal Conditions” (Flight inspection in accordance with ICAO Doc 8071)
	GBAS A/C _01	Integrity failure due to erroneous position computation by GBAS aircraft subsystem	SR 175 “Normal Conditions” (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
	NAV DB_01	Integrity failure due to erroneous waypoints in Nav DB (inconsistency between FAS DB and FAF/MAPT waypoints)	SR 091 “Normal Conditions” “(Nav data base produced and updated in accordance with EUROCAE ED-76/RTCA DO-200A” SR 092 “Normal Conditions” “(Nav data base used for the RNAV system compliant with IR OPS (or equivalent OPS regulation))

Table 23 Derivation of Mitigation/Safety Requirements for Hazard 002

3.5.1.2 Hz 003Failure to follow the correct final approach path in GBAS CAT III

During final approach, an aircraft deviates laterally or vertically from approach path.

This hazard could lead to a CFIT accident, classified with a severity 1.

Basic causes for such failure have been captured in the Hz 003 Fault Tree (See Figure 16).

In this Fault tree for the Landing integrity risk ("Erroneous aircraft guidance during GBAS CAT III approach"), an "Independent OR" (IOR) is used. This gate is used because events leading to integrity risk are independents and then, individual elements leading to the integrity risk are not added all together but taken individually to fulfil the 1x10-9 per landing and not a more stringent objective. The independence of these individual elements is to be confirmed in the new 15.3.6 Task 33.

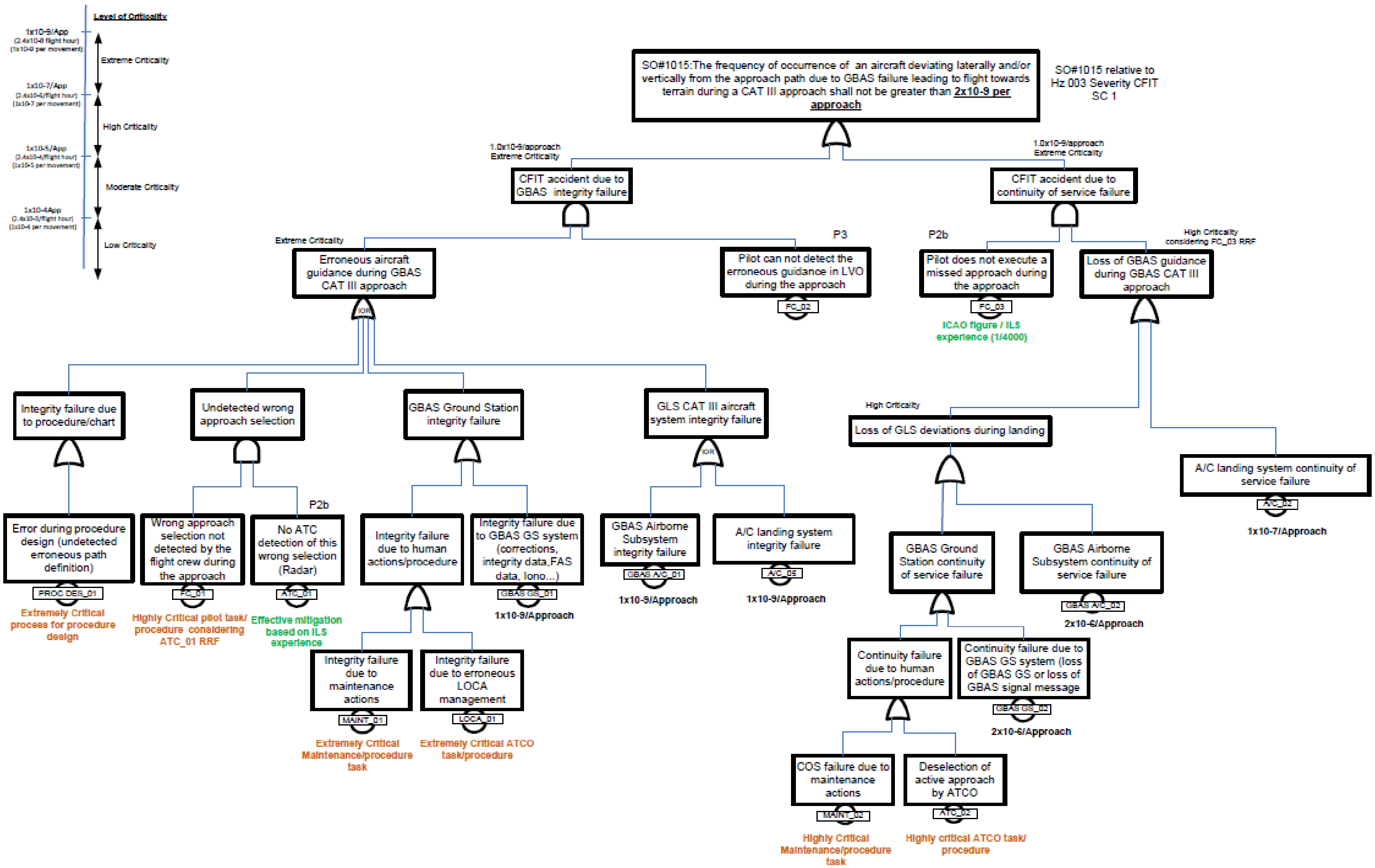


Figure 16 Hz 003 – Fault tree

Table 24 below describes the basic causes of the Hz 003 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
GBAS integrity failure			
Integrity failure due to procedure/chart	PROC DES_01	Error during procedure design (e.g. undetected erroneous path definition)	SR 145 “Normal Conditions” (Flight Procedure validation) in accordance with ICAO Doc 9906)
Undetected wrong approach selection	FC_01	Wrong approach selection by the flight crew	SR 55 “Normal Conditions” (pilot verification for the GBAS station selection)
	ATC_01	ATCO doesn't detect the lateral deviation of the aircraft (due to wrong approach selection by flight crew) on the radar screen	Assumption A#125: It is assumed in such situation that ATCO detection permits a downgrading of the Event Criticality
GBAS Ground Station Integrity failure	GBAS GS_01	GBAS Ground Station sends corrupted messages (correction, integrity data, FAS data, iono…) to the GBAS aircraft subsystem	SR 155 “Normal Conditions” (FAS Data Block transmission in accordance with ICAO Annex 10) SR 156 “Normal Conditions” (FAS generation by procedure designer) SR 157 “Normal Conditions” (Ground Station capability to load FAS) New SR 860: “FAS plausibility check by the Ground Station” SR 200 “Normal Conditions” (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 “Normal Conditions” (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_01	Integrity failure due to maintenance actions	New SR 800 “Maintenance Service Level B preventing integrity failure”.

			New SR 810 "Definition of procedures and training corresponding to Service Level B" See also A#0071 and Appendix G
	LOCA_01	Integrity failure due to erroneous LOCA management	New SR 815 "Training on GBAS area (LOCA) for maintenance personnel" New SR 820 "Training on GBAS area (LOCA) for Tower Controller if LOCA has an impact on operations" See also A#0071 and Appendix G
GBAS airborne sub system integrity failure	GBAS A/C _01	Integrity failure due to erroneous position computation by GBAS aircraft subsystem	SR 175 "Normal Conditions" (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
A/C landing system integrity failure	A/C_05	Integrity failure caused by the A/C automatic landing system	SR 180 "Normal conditions" (Automatic Landing System compliance with airworthiness requirements)
Pilot detection failure	FC_02	Pilot doesn't detect the erroneous guidance in LVO during the operation	Assumption A#150: No downgrading of the Event Criticality because pilot cannot detect such integrity failure
Loss of GBAS guidance during GBAS CAT III approach			
GBAS Ground Station continuity of service failure	GBAS GS_02	Loss of the GBAS Ground Station or loss of GBAS signal message	SR 155 "Normal Conditions" (FAS Data Block transmission in accordance with ICAO Annex 10) SR 200 "Normal Conditions" (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 "Normal Conditions" (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_02	Continuity of service failure due to maintenance actions	New SR 805 "Maintenance Service Level A preventing continuity of service failure" New SR 810 "Definition of procedures and training corresponding to Service Level A" See also A#0071 and Appendix G
	ATC_02	ATC deselects active approach	New SR 825 "ATCO Procedure and

			Training (limit operationally such selection/deselection))”
GBAS airborne subsystem continuity of service failure	GBAS A/C _02	Unexpected loss of the GBAS aircraft subsystem	SR 175 “Normal Conditions” (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
A/C landing system continuity of service failure	A/C_02	Unexpected loss of the A/C automatic landing system	SR 180 “Normal conditions” (Automatic Landing System compliance with airworthiness requirements)
Pilot fails to react in case of GBAS continuity of service failure	FC_03	Pilot does not execute a missed approach during the approach whereas guidance is lost	SR 185 “Normal Conditions” (Aircraft Operator approval in accordance with OPS regulation) Assumption A#155: Pilot executes a missed approach in such situation which permits a downgrading of the Event Criticality

Table 24 Derivation of Mitigation/Safety Requirements for Hazard 003

3.5.1.3 Hz 004 – Failure to maintain spacing between aircraft within the same final approach for optimised operations conducted in mixed GBAS/ILS equipage operations during CAT III approach

During Final Approach, if this hazard occurs, the risk is that preceding landing is still in ILS CSA leading to A/C deviation or signal fluctuation during ILS approach. This could lead to 2 accidents scenarios:

- A CFIT scenario, classified with a severity 2b, if aircraft deviates from the approach path
- A Runway Excursion (RE) scenario, classified with a severity 2b, if aircraft deviates from the runway centerline.

Two fault trees have been developed (1 for CFIT and 1 for RE). Causes are the same but some mitigation means are different.

Basic causes for such failure have been captured in the Hz 004 Fault Trees (See **Figure 17** and **Figure 18).**

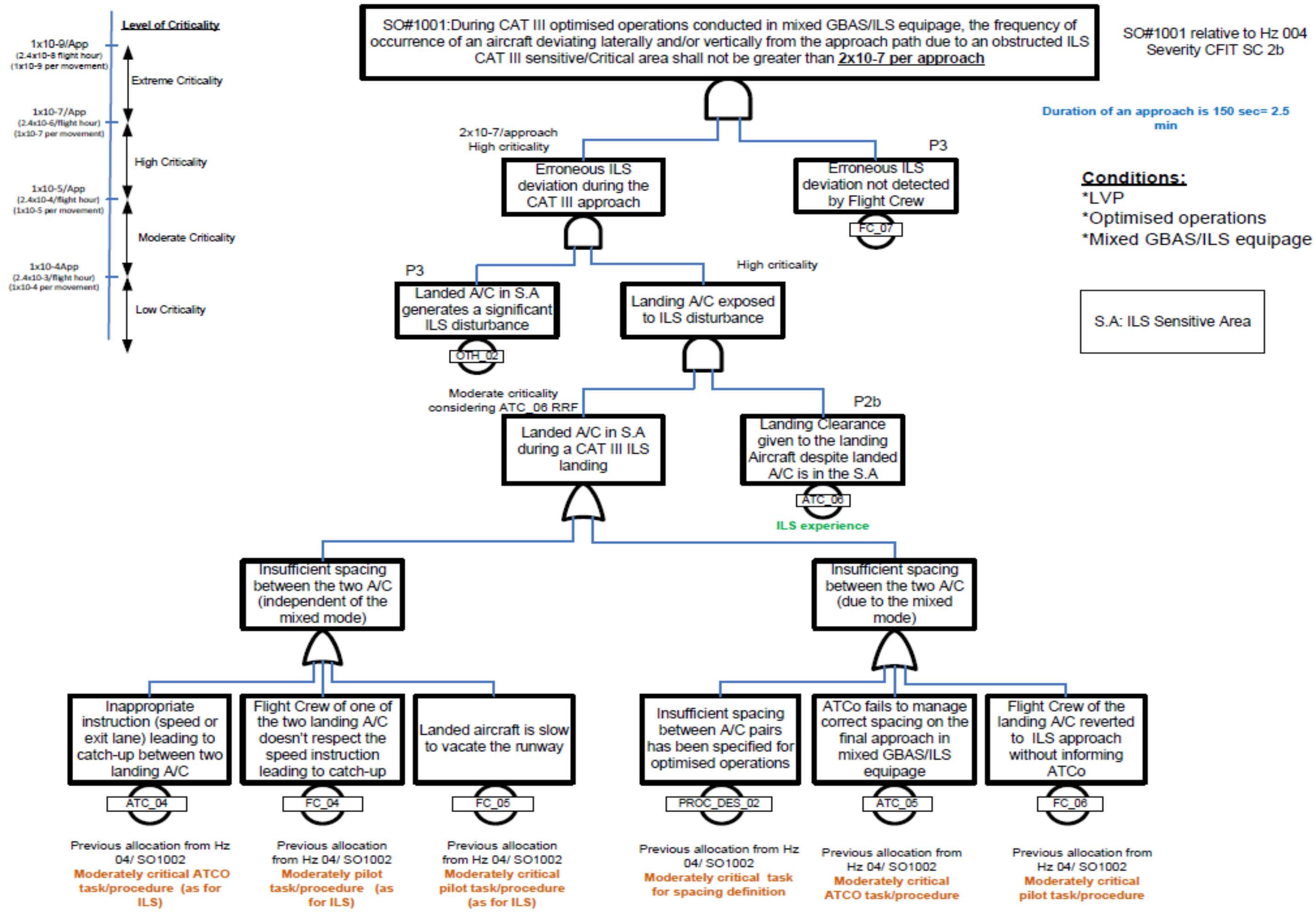


Figure 17 Hz 004 – Fault tree for CFIT scenario

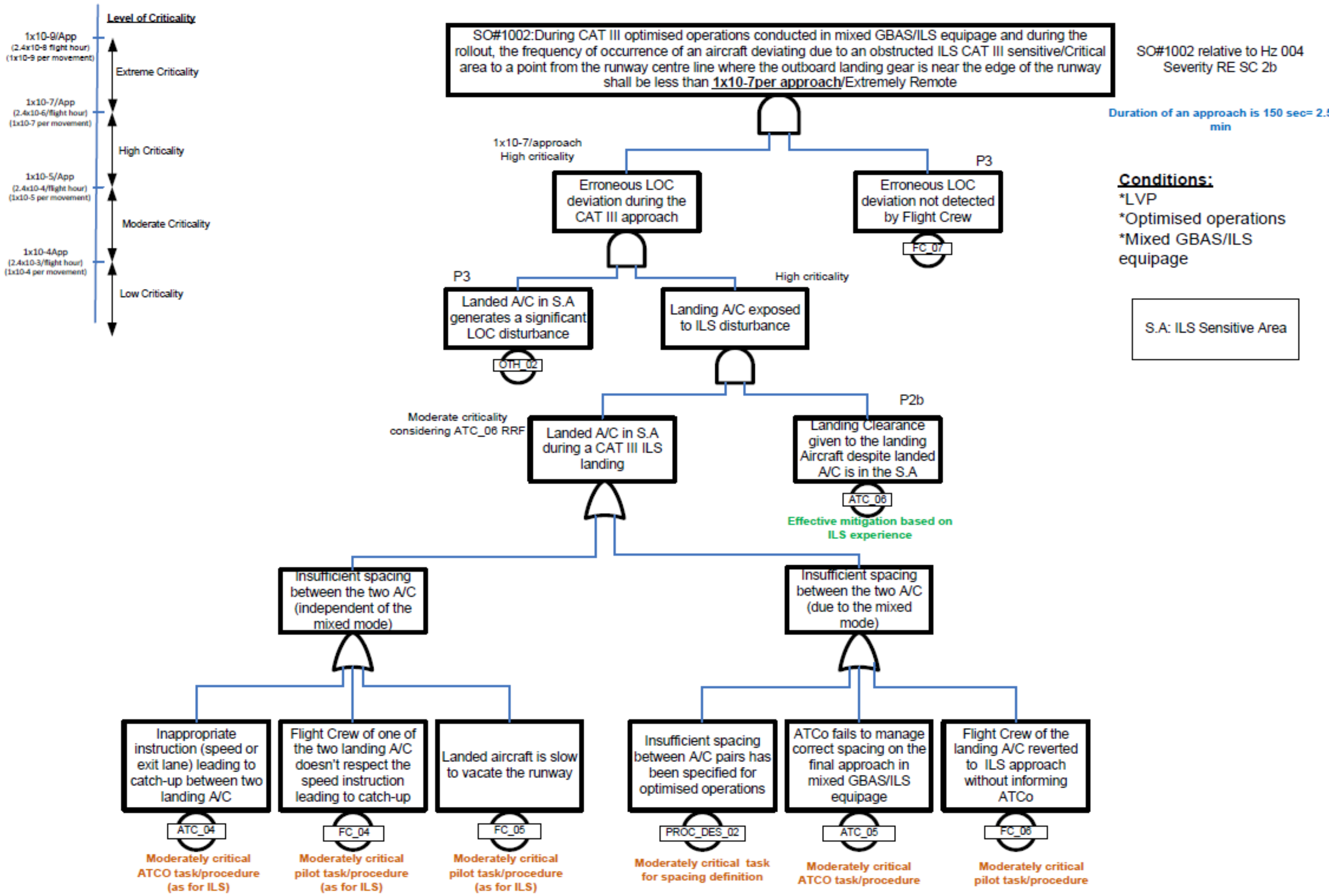


Figure 18 Hz 004 – Fault tree for RE scenario

Table 25 below describes the basic causes of the Hz 004 Fault Trees and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Insufficient spacing between the two A/C (independent of the mixed mode)			
Inappropriate instruction (speed or exit lane)	ATC_04	ATCO gives an erroneous speed or exit lane instruction leading to catch-up between two landing A/C	No SR Assumption A#161: ATCO procedure for A/C runway vacation is the same as in ILS CAT III
Flight Crew doesn't respect the speed instruction	FC_04	FC of one of the two landing A/C doesn't respect the speed instruction leading to catch-up	New A#0215 "Flight Crew respect speed instructions given by ATCO"
Landed aircraft is slow to vacate the runway	FC_05	The FC of the landed aircraft is slow to vacate the runway	Update of SR275 "Speed to vacate the runway) New A#0210 "If A/C is too slow to vacate, Tower Controller gives instruction to expedite runway vacation"
Insufficient spacing between the two A/C (due to the mixed mode)			
Insufficient spacing specification	PROC DES_02	Insufficient spacing between A/C pairs has been specified for optimised operations	SR 225 "Normal Conditions" (Establishment of spacing between GBAS-ILS pair) New SR835 (Local assessment and transition phase to determine acceptability of the reduction of spacing in front of GBAS)
ATCO spacing management	ATC_05	ATCO fails to manage correct spacing on the final approach in mixed GBAS/ILS equipage	SR 230 "Normal Conditions" (Appropriate aircraft spacing by Approach and Tower Controller)
Flight Crew reverts to ILS approach	FC_06	FC of the landing A/C reverted to ILS approach without informing ATCO	New SR 830 (Operational Procedure/Training for Flight Crew)
Pilot reaction			
Pilot doesn't detect the lateral deviation	FC_07	Pilot doesn't detect the lateral deviation	No SR Assumption A#160: Pilot cannot detect the deviation in such situation therefore no downgrading of the Event Criticality
ATCO			
Landing Clearance	ATC_06	ATCO gives a landing clearance to the landing A/C despite landed A/C is in the S.A.	SR310 "Normal Conditions" (Landing Clearance when the preceding arrival has passed the ILS CAT III CSA) Assumption A#135: ATCO detection permits a downgrading of the Event Criticality
Other			

Landed A/C in S.A generates a significant ILS disturbance	OTH_02	Landed A/C in S.A generates a significant ILS disturbance	No SR Assumption A#180: It is assumed that A/C in the sensitive area generates disturbances therefore no downgrading of the Event Criticality

Table 25 Derivation of Mitigation/Safety Requirements for Hazard 004

3.5.1.4 Hz 005 - Failure to maintain the separation between aircraft on adjacent CAT III approach operations

When considering parallel approach operation, one of the two aircraft deviates laterally of the approach path during final approach leading to possible loss of separation between aircraft.

This hazard could lead to a Mid Air Collision accident, classified with a severity 4a (Tactical conflict).

Basic causes for such failure have been captured in the Hz 005 Fault Trees (See Figure 19).

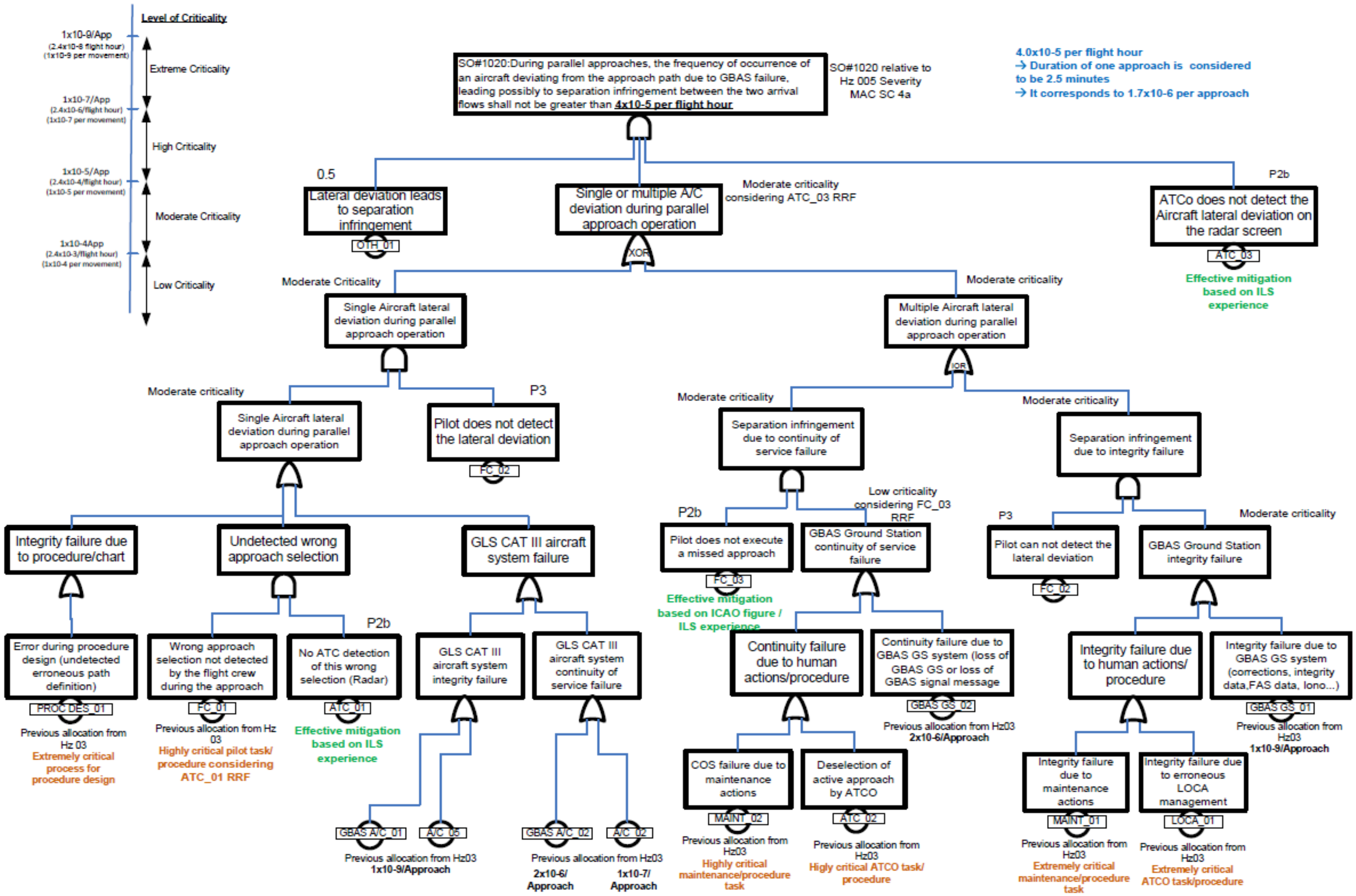


Figure 19 Hz 005 – Fault tree

Table 26 below describes the basic causes of the Hz 005 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Single aircraft lateral deviation			
Integrity failure due to procedure/chart	PROC DES_01	Error during procedure design (e.g. undetected erroneous path definition)	SR 145 "Normal Conditions" (Flight Procedure validation) in accordance with ICAO Doc 9906)
Undetected wrong approach selection	FC_01	Wrong approach selection by the flight crew	SR 55 "Normal Conditions" (pilot verification for the GBAS station selection)
	ATC_01	ATCO doesn't detect the lateral deviation of the aircraft (due to wrong approach selection by flight crew) on the radar screen	Assumption A#125: It is assumed that in such situation ATCO detects the problem which permits a downgrading of the Event Criticality
GBAS airborne sub system integrity failure	GBAS A/C _01	Integrity failure due to erroneous position computation by GBAS aircraft subsystem	SR 175 "Normal Conditions" (GBAS airborne equipment compliance with RTCA MOPS DO-253C)
A/C landing system integrity failure	A/C_05	Integrity failure caused by the A/C automatic landing system	SR 180 "Normal conditions" (Automatic Landing System compliance with airworthiness requirements)
GBAS airborne subsystem continuity of service failure	GBAS A/C _02	Unexpected loss of the GBAS aircraft subsystem	SR 175 "Normal Conditions" (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
A/C landing system continuity of service failure	A/C_02	Unexpected loss of the A/C automatic landing system	SR 180 "Normal conditions" (Automatic Landing System compliance with airworthiness requirements)
Pilot doesn't detect the lateral deviation	FC_02	Pilot doesn't detect the erroneous guidance in LVO during the operation	<u>Assumption A#126:</u> Probability of occurrence = 1 because this mitigation mean will probably be inefficient in LVP
Multiple aircraft lateral deviation			
GBAS Ground Station Integrity failure	GBAS GS_01	GBAS Ground Station sends corrupted messages (correction, integrity data, FAS data, iono…)to the GBAS aircraft subsystem	SR 155 "Normal Conditions" (FAS Data Block transmission in accordance with ICAO Annex 10) SR 156 "Normal Conditions" (FAS generation by procedure designer) SR 157 "Normal Conditions" (Ground Station capability to load FAS)

			New SR 860: "FAS plausibility check by the Ground Station" SR 200 "Normal Conditions" (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 "Normal Conditions" (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_01	Integrity failure due to maintenance actions	New SR 800 "Maintenance Service Level B preventing integrity failure" New SR 810 "Definition of procedures and training corresponding to Service Level B"
	LOCA_01	Integrity failure due to erroneous LOCA management	New SR 815 "Training on GBAS area (LOCA) for maintenance personnel" New SR 820 "Training on GBAS area (LOCA) for Tower Controller if LOCA has an impact on operations" See A#0071 and Appendix G
Pilot doesn't detect the lateral deviation	FC_02	Pilot doesn't detect the erroneous guidance in LVO during the operation	Assumption A#150: It is assumed that pilot cannot detect the deviation in such situation therefore no downgrading of the Event Criticality
GBAS Ground Station continuity of service failure	GBAS GS_02	Loss of the GBAS Ground Station or loss of GBAS signal message	SR 155 "Normal Conditions" (FAS Data Block transmission in accordance with ICAO Annex 10) SR 200 "Normal Conditions" (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 "Normal Conditions" (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_02	Continuity of service failure due to maintenance actions	New SR 805 "Maintenance Service Level A preventing continuity of service failure" New SR 810 "Definition of procedures and training corresponding to Service Level A" See A#0071 and Appendix G
	ATC_02	ATC deselects active approach	New SR 825 "ATCO Procedure and Training (limit operationally such

			selection/deselection))"
Pilot doesn't execute a missed approach	FC_03	Pilot does not execute a missed approach during parallel approach whereas guidance is lost	SR 185 "Normal Conditions" (Aircraft Operator approval in accordance with OPS regulation) SR 345 "Normal Conditions" (divergent track for missed approach in parallel approach operations) Assumption A#155: Pilot executes a missed approach in such situation which permits a downgrading of the Event Criticality
ATCO detection			
ATCo detection	ATC_03	ATCO doesn't detect the aircraft lateral deviation on the radar screen	Assumption A#0025 (ATCO procedure to monitor infringement of the NTZ area in accordance with PANS-ATM procedures) Assumption A#130: It is assumed in such situation that ATCO detection permits a downgrading of the Event Criticality
Other			
Lateral deviation leads to separation infringement	OTH_01	Lateral deviation leads to separation infringement	No SR Assumption A#131: when a lateral deviation occurs, it is assumed that it leads to separation infringement in 50% of cases (in other half of the cases, deviation takes the aircraft away from the other approach path and could lead to CFIT which is addressed by Hz 002 and Hz 003)

Table 26 Derivation of Mitigation/Safety Requirements for Hazard 005

3.5.1.5 Hz 006 - Failure to land in the prescribed touch-down zone in GBAS CAT III approach

In this hazard which occurs during landing, the failure could be:

- a lateral deviation. In this case, the A/C could land to the right or to the left of the prescribed zone leading to a runway veer-off.
- or, a longitudinal deviation. In this case, the A/C could land after the prescribed zone leading to a runway overrun

This hazard could lead to a Runway Excursion (RE) accident, classified with a severity 1.

Note: if the aircraft lands before the prescribed zone, this leads to a CFIT accident and this is addressed by hazard 3.

Basic causes for such failure have been captured in the Hz 006 Fault Trees (See Figure 20).

In this Fault tree for the Landing integrity risk ("Erroneous aircraft guidance during GBAS CAT III landing"), an "Independent OR" (IOR) is used. This gate can be used because events leading to integrity risk are independents and then, individual elements leading to the integrity risk are not added all together but taken individually to fulfil the 1x10-9 per landing and not a more stringent objective. The independence of these individual elements is to be confirmed in the new 15.3.6 Task 33.

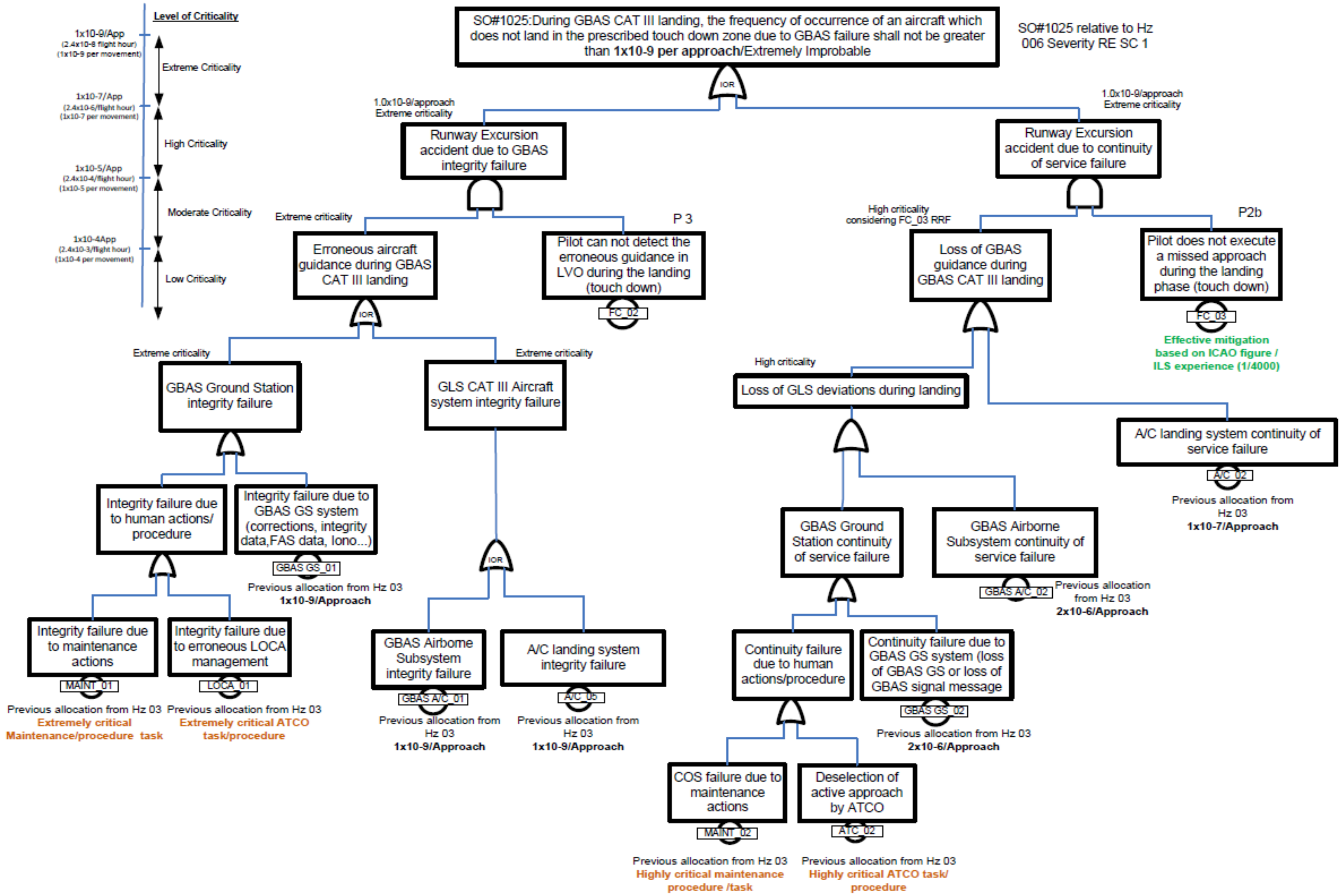


Figure 20 Hz 006 – Fault tree

Table 27 below describes the basic causes of the Hz 006 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
GBAS integrity failure			
GBAS Ground Station Integrity failure	GBAS GS_01	GBAS Ground Station sends corrupted messages (correction, integrity data, FAS data, iono…) to the GBAS aircraft subsystem	SR 155 "Normal Conditions" (FAS Data Block transmission in accordance with ICAO Annex 10) SR 156 "Normal Conditions" (FAS generation by procedure designer) SR 157 "Normal Conditions" (Ground Station capability to load FAS) New SR 860: "FAS plausibility check by the Ground Station" SR 200 "Normal Conditions" (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 "Normal Conditions" (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_01	Integrity failure due to maintenance actions	New SR 800 "Maintenance Service Level B preventing integrity failure" New SR 810 "Definition of procedures and training corresponding to Service Level B" See A#0071 and Appendix G
	LOCA_01	Integrity failure due to erroneous LOCA management	New SR 815 "Training on GBAS area (LOCA) for maintenance personnel" New SR 820 "Training on GBAS area (LOCA) for Tower Controller if LOCA has an impact on operations" See A#0071 and Appendix G
GBAS airborne sub system integrity failure	GBAS A/C _01	Integrity failure due to erroneous position computation by GBAS aircraft subsystem	SR 175 "Normal Conditions" (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
A/C landing system integrity failure	A/C_05	Integrity failure caused by the A/C automatic landing	SR 180 "Normal conditions" (Automatic

		system	Landing System compliance with airworthiness requirements)
Pilot detection failure	FC_02	Pilot doesn't detect the erroneous guidance in LVO during the operation	Assumption A#150: Pilot cannot detect the erroneous guidance in such situation therefore no downgrading of the Event Criticality
GBAS continuity of service failure			
GBAS Ground Station continuity of service failure	GBAS GS_02	Loss of the GBAS Ground Station or loss of GBAS signal message	SR 155 "Normal Conditions" (FAS Data Block transmission in accordance with ICAO Annex 10) SR 200 "Normal Conditions" (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 "Normal Conditions" (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_02	Continuity of service failure due to maintenance actions	New SR 805 "Maintenance Service Level A preventing continuity of service failure" New SR 810 "Definition of procedures and training corresponding to Service Level A" See A#0071 and Appendix G
	ATC_02	ATC deselects active approach	New SR 825 "ATCO Procedure and Training (limit operationally such selection/deselection))"
GBAS airborne subsystem continuity of service failure	GBAS A/C _02	Unexpected loss of the A/C automatic landing system	SR 175 "Normal Conditions" (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
A/C landing system continuity of service failure	A/C_02	Unexpected loss of the A/C automatic landing system	SR 180 "Normal conditions" (Automatic Landing System compliance with airworthiness requirements)
Pilot fails to react in case of GBAS continuity of service failure	FC_03	Pilot does not execute a missed approach during the approach or the landing phase	SR 185 "Normal Conditions" (Aircraft Operator approval in accordance with OPS regulation) Assumption A#155: Pilot executes a missed approach in such situation which permits a

			downgrading of the Event Criticality

Table 27 Derivation of Mitigation/Safety Requirements for Hazard 006

3.5.1.6 Hz 007 - Failure to maintain the A/C on the runway centreline during the CAT III GBAS landing rollout

In case of failure to maintain the A/C on the runway centreline, this could lead to a runway veer-off during the rollout.

This hazard could lead to a Runway Excursion (RE) accident, classified with a severity 2b.

Basic causes for such failure have been captured in the Hz 007 Fault Trees (See Figure 21).

In this Fault tree for the Landing integrity risk ("Erroneous aircraft guidance during GBAS CAT III rollout"), an "Independent OR" (IOR) is used. This gate is used because events leading to integrity risk are independents and then, individual elements leading to the integrity risk are not added all together but taken individually to fulfil the 1x10-9 per landing and not a more stringent objective. The independence of these individual elements is to be confirmed in the new 15.3.6 Task 33.

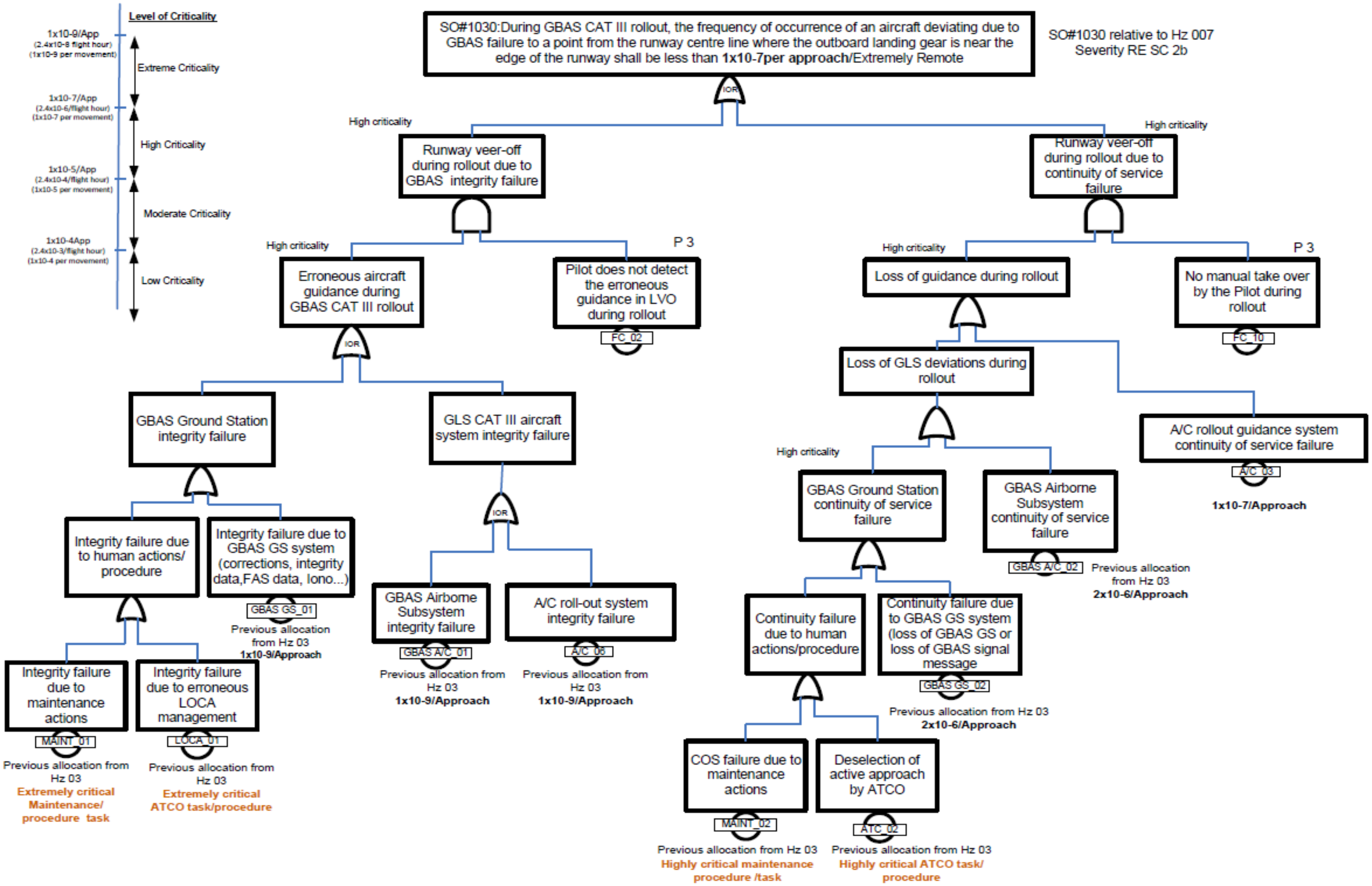


Figure 21 Hz 007 – Fault tree

Table 28 below describes the basic causes of the Hz 007 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
GBAS integrity failure			
GBAS Ground Station Integrity failure	GBAS GS_01	GBAS Ground Station sends corrupted messages (correction, integrity data, FAS data, iono…)to the GBAS aircraft subsystem	SR 155 "Normal Conditions" (FAS Data Block transmission in accordance with ICAO Annex 10) SR 156 "Normal Conditions" (FAS generation by procedure designer) SR 157 "Normal Conditions" (Ground Station capability to load FAS) New SR 860: "FAS plausibility check by the Ground Station" SR 200 "Normal Conditions" (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 "Normal Conditions" (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_01	Integrity failure due to maintenance actions	New SR 800 "Maintenance Service Level B preventing integrity failure" New SR 810 "Definition of procedures and training corresponding to Service Level B" See A#0071 and Appendix G
	LOCA_01	Integrity failure due to erroneous LOCA management	New SR 815 "Training on GBAS area (LOCA) for maintenance personnel" New SR 820 "Training on GBAS area (LOCA) for Tower Controller if LOCA has an impact on operations" See A#0071 and Appendix G
GBAS airborne sub system integrity failure	GBAS A/C _01	Integrity failure due to erroneous position computation by GBAS aircraft subsystem	SR 175 "Normal Conditions" (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
A/C roll-out guidance system integrity failure	A/C_06	Integrity failure caused by the A/C roll-out guidance system	SR 180 "Normal conditions" (Automatic Landing System compliance with airworthiness requirements)
Pilot detection failure	FC_02	Pilot doesn't detect the erroneous guidance in LVO	Assumption A#150: Pilot cannot detect the

		during the operation	erroneous guidance in such situation therefore no downgrading of the Event Criticality
GBAS continuity of service failure			
GBAS Ground Station continuity of service failure	GBAS GS_02	Loss of the GBAS Ground Station or loss of GBAS signal message	SR 155 “Normal Conditions” (FAS Data Block transmission in accordance with ICAO Annex 10) SR 200 “Normal Conditions” (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 205 “Normal Conditions” (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_02	Continuity of service failure due to maintenance actions	New SR 805 “Maintenance Service Level A preventing continuity of service failure” New SR 810 “Definition of procedures and training corresponding to Service Level A” See A#0071 and Appendix G
	ATC_02	ATC deselects active approach	New SR 825 “ATCO Procedure and Training (limit operationally such selection/deselection))”
A/C roll-out guidance system continuity of service failure	A/C _03	Unexpected loss of the A/C automatic landing system	SR 180 “Normal conditions” (Automatic Landing System compliance with airworthiness requirements)
GBAS airborne subsystem continuity of service failure	GBAS A/C _02	Unexpected loss of the GBAS aircraft subsystem	SR 175 “Normal Conditions” (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C)
Pilot fails to react in case of GBAS continuity of service failure	FC_10	Pilot does not execute a manual take over during rollout	Assumption A#165: Pilot cannot execute manual take over in such situation therefore no downgrading of the Event Criticality

Table 28 Derivation of Mitigation/Safety Requirements for Hazard 007

3.5.1.7 Hz 008 - Failure to maintain aircraft longitudinal spacing on the runway during CAT III approaches in optimised operations

In case of failure to maintain the A/C on the runway centreline, this could lead to situations:

- Infringement with another landing aircraft if A/C is landing too close to the preceding landing
- Infringement with a departing aircraft if the departing aircraft is still on the runway when the A/C is approaching the runway.

This hazard could lead to a Runway conflict classified with a severity 3.

Basic causes for such failure have been captured in the Hz 008 Fault Trees (See Figure 22).

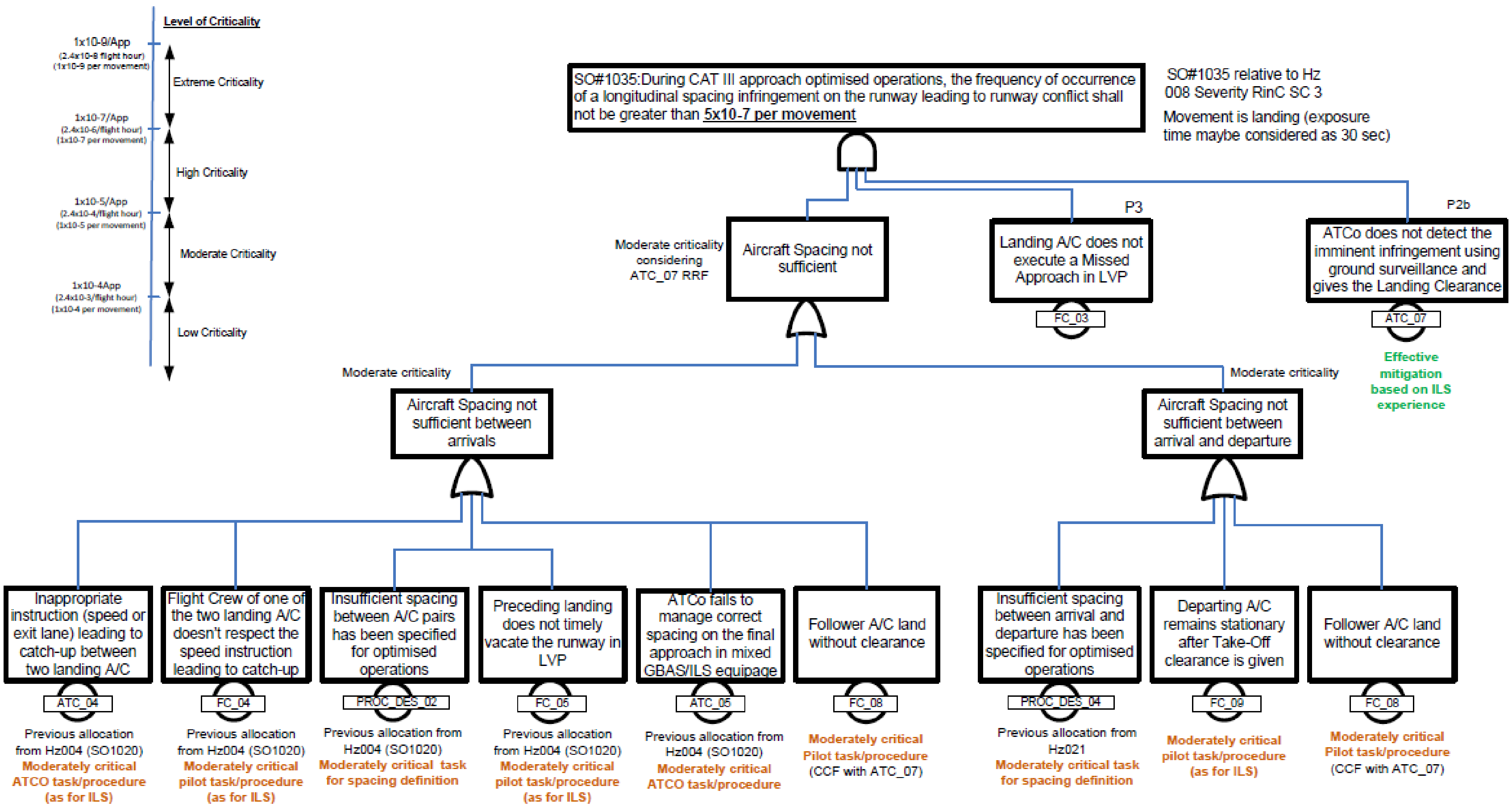


Figure 22 Hz 008 – Fault tree

Table 29 below describes the basic causes of the Hz 008 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Insufficient spacing not sufficient between arrivals			
Inappropriate instruction (speed or exit lane)	ATC_04	ATCO gives an erroneous speed or exit lane instruction leading to catch-up between two landing A/C	No SR Assumption A#161: ATCO procedure for A/C runway vacation is the same as in ILS CAT III (
Flight Crew doesn't respect the speed instruction	FC_04	FC of one of the two landing A/C doesn't respect the speed instruction leading to catch-up	New A#0215 "FC respect speed instructions given by ATCO"
Insufficient spacing specification	PROC DES_02	Insufficient spacing between A/C pairs has been specified for optimised operations	SR 225 "Normal Conditions" (Establishment of spacing between GBAS-ILS pair) New SR835 (Local assessment and transition phase to determine acceptability of the reduction of spacing in front of GBAS)
Landed aircraft is slow to vacate the runway	FC_05	The FC of the landed aircraft is slow to vacate the runway	Update of SR275 "Speed to vacate the runway) New A#0210 "If A/C is too slow to vacate, Tower Controller gives instruction to expedite runway vacation"
ATCO spacing management	ATC_05	ATCO fails to manage correct spacing on the final approach in mixed GBAS/ILS equipage	SR 230 "Normal Conditions" (Appropriate aircraft spacing by Approach and Tower Controller)
Follower A/C lands without clearance	FC_08	The FC of the following A/C lands without clearance	New A#0220 "FC respect the landing clearance given by ATCO"
Aircraft spacing not sufficient between arrival and departure			
Insufficient spacing specification	PROC DES_04	Insufficient spacing between arrival and departure has been specified for optimised operations	New SR 845(Establishment of spacing between arrival and departure in mixed GBAS-ILS equipage)
Departing A/C remains stationary after Take-Off clearance is given	FC_09	The FC of the departing A/C remains stationary on the runway after Take-Off clearance is given	New A#0225 "Flight Crew reads back the Take-Off clearance et start take-off roll immediately"

Follower A/C lands without clearance	FC_08	The FC of the following A/C lands without clearance	New A#0220 "Flight Crew respects landing clearance given by ATCO"
Pilot reaction			
Pilot doesn't execute a missed approach	FC_03	Pilot does not execute a missed approach during the approach or the landing phase	SR 185 "Normal Conditions" (Aircraft Operator approval in accordance with OPS regulation) Assumption A#155: Pilot cannot execute a missed approach in such situation therefore no downgrading of the Event Criticality
ATCO			
ATCO does not detect the imminent infringement using ground surveillance	ATC_07	ATCO does not detect the imminent infringement using ground surveillance and gives the Landing clearance	SR 295 "Normal Conditions" (Runway Safety Net shall alert the Tower Controller when a mobile is inside the ILS CAT III CSA) SR245 "Normal Conditions" (Landing Clearance when separation between the landing aircraft and the other aircraft on the runway (preceding landing or departure)) exist Assumption A#140: It is assumed in such situation that ATCO detects the problem which permits a downgrading of the Event Criticality

Table 29 Derivation of Mitigation/Safety Requirements for Hazard 008

3.5.1.8 Hz 020 - Failure to maintain the A/C on the runway centreline during the Guided Take-Off in LVC based on GBAS

In case of failure to maintain the A/C on the runway centreline, this could lead to a runway veer-off during the rollout.

This hazard could lead to a Runway Excursion (RE) accident, classified with a severity 2b.

Basic causes for such failure have been captured in the Hz 020 Fault Trees (See Figure 23).

In this Fault tree for the Landing integrity risk ("Erroneous aircraft guidance during GBAS CAT III rollout"), an "Independent OR" (IOR) is used. This gate is used because events leading to integrity risk are independents and then, individual elements leading to the integrity risk are not added all together but taken individually to fulfil the 1x10-9 per landing and not a more stringent objective. The independence of these individual elements is to be confirmed in the new 15.3.6 Task 33.

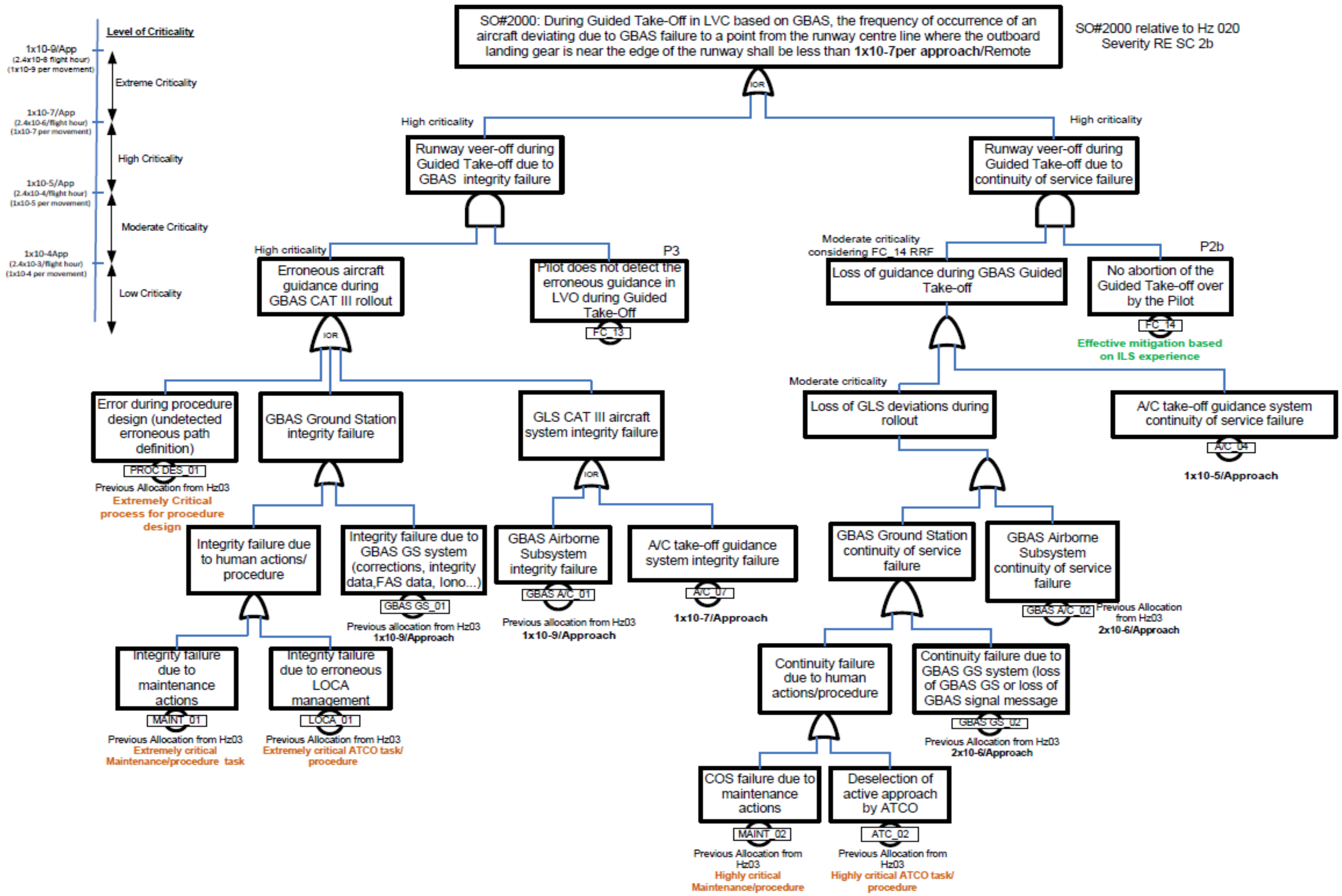


Figure 23 Hz 020 – Fault tree

Table 30 below describes the basic causes of the Hz 020 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Runway veer-off due to GBAS integrity failure			
Integrity failure due to procedure/chart	PROC DES_01	Error during procedure design (e.g. undetected erroneous path definition)	SR 145 “Normal Conditions” (Flight Procedure validation) in accordance with ICAO Doc 9906)
GBAS Ground Station Integrity failure	GBAS GS_01	GBAS Ground Station sends corrupted messages (correction, integrity data, FAS data, iono…) to the GBAS aircraft subsystem	SR 155 “Normal Conditions” (FAS Data Block transmission in accordance with ICAO Annex 10) SR 156 “Normal Conditions” (FAS generation by procedure designer) SR 157 “Normal Conditions” (Ground Station capability to load FAS) New SR 860: “FAS plausibility check by the Ground Station” SR 200 “Normal Conditions” (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 405 “Normal Conditions” (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_01	Integrity failure due to maintenance actions	New SR 800 “Maintenance Service Level B preventing integrity failure” New SR 810 “Definition of procedures and training corresponding to Service Level B” See A#0071 and Appendix G
	LOCA_01	Integrity failure due to erroneous LOCA management	New SR 815 “Training on GBAS area (LOCA) for maintenance personnel” New SR 820 “Training on GBAS area (LOCA) for Tower Controller if LOCA has an impact on operations” See A#0071 and Appendix G
GBAS airborne sub system integrity failure	GBAS A/C _01	Integrity failure due to erroneous position computation by GBAS aircraft subsystem	SR 175 “Normal Conditions” (GBAS airborne equipment compliance with last effective

			version of ETSO considering RTCA MOPS DO-253C) SR 400 "Normal Conditions "GAST-D in accordance with airworthiness EASA regulation or equivalent"
A/C take-off guidance system integrity failure	A/C_07	Integrity failure caused by the A/C take-off guidance system	See SIR#010
Pilot detection	FC_13	Pilot doesn't detect the erroneous guidance in LVO during Guided Take-Off	Assumption A#170: Pilot cannot detect the erroneous guidance in such situation therefore no downgrading of the Event Criticality
Runway veer-off due to continuity of service failure			
GBAS Ground Station continuity of service failure	GBAS GS_02	Loss of the GBAS Ground Station or loss of GBAS signal message	SR 155 "Normal Conditions" (FAS Data Block transmission in accordance with ICAO Annex 10) SR 200 "Normal Conditions" (GBAS Ground Station SIS integrity and continuity in accordance with ICAO Annex 10) SR 405 "Normal Conditions" (Flight inspection in accordance with ICAO Doc 8071)
	MAINT_02	Continuity of service failure due to maintenance actions	New SR 805 "Maintenance Service Level A preventing continuity of service failure" New SR 810 "Definition of procedures and training corresponding to Service Level A" See A#0071 and Appendix G
	ATC_02	ATC deselects active approach	New SR 825 "ATCO Procedure and Training (limit operationally such selection/deselection))"
GBAS airborne subsystem continuity of service failure	GBAS A/C _02	GBAS airborne subsystem continuity of service failure	SR 175 "Normal Conditions" (GBAS airborne equipment compliance with last effective version of ETSO considering RTCA MOPS DO-253C) SR 400 "Normal Conditions "GAST-D in accordance with airworthiness EASA regulation or equivalent"
A/C take-off guidance system	A/C _04	Unexpected loss of the A/C take-off guidance	See SIR#011

continuity of service failure		system	
Pilot reaction	FC_14	No abortion of the Guided Take-off over by the pilot	SR 440 “Normal Conditions” (Abortion of the take-off if excessive deviation is detected) Assumption A#175: Pilot abortion of the take-Off in such situation permits a downgrading of the Event Criticality

Table 30 Derivation of Mitigation/Safety Requirements for Hazard 020

3.5.1.9 Hz 021 – Failure to maintain the A/C on the runway centreline during the Guided Take-Off in LVC based on ILS in mixed GBAS/ILS equipage operations

During Guided Take-Off, if this hazard occurs, the risk is that preceding landing or another departing is still in ILS CSA leading to A/C deviation or signal fluctuation during ILS Guided Take-Off. This could lead to a Runway Excursion (RE) scenario, classified with a severity 2b.

Basic causes for such failure have been captured in the Hz 021 Fault Trees (See **Figure 24**)**.**

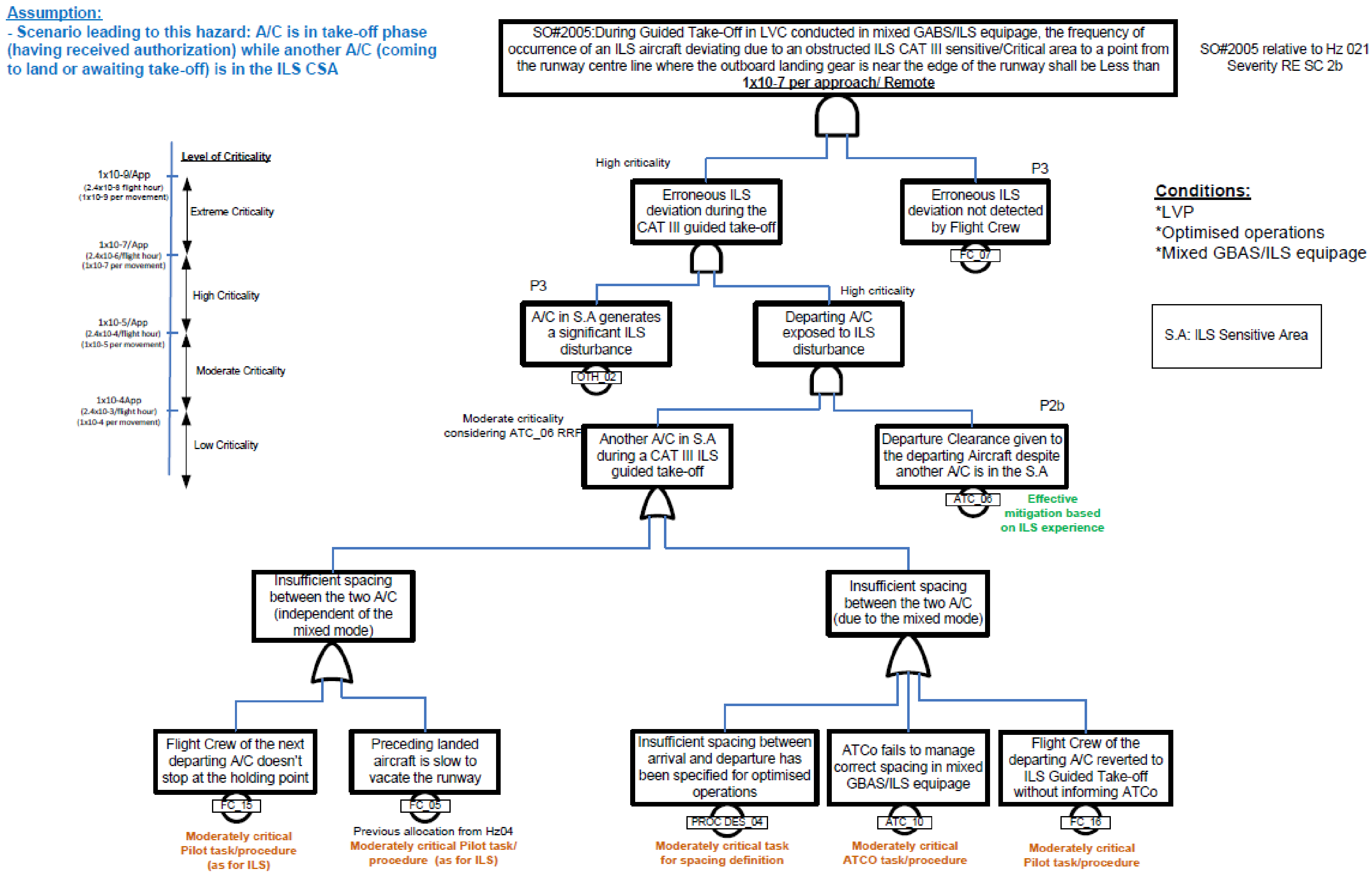


Figure 24 Hz 021 – Fault tree

Table 31 below describes the basic causes of the Hz 021 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Insufficient spacing between the two A/C (independent of the mixed mode)			
Flight crew of the next departing A/C doesn't stop at the holding point	FC_15	FC of the next departing A/C doesn't stop at the holding point	New A#0230 (FC holds at the CAT III holding point)
Landed aircraft is slow to vacate the runway	FC_05	The FC of preceding landed aircraft is slow to vacate the runway	Update of SR275 "Speed to vacate the runway) New A#0210 "If A/C is too slow to vacate, Tower Controller gives instruction to expedite runway vacation"
Insufficient spacing between the two A/C (due to the mixed mode)			
Insufficient spacing specification between arrival and departure	PROC DES_04	Insufficient spacing between arrival and departure has been specified for optimised operations	New SR 845(Establishment of spacing between arrival and departure in mixed GBAS-ILS equipage)
ATCO spacing management	ATC_10	ATCO fails to manage correct spacing between arrival and departure in mixed GBAS/ILS equipage	New SR 855(Appropriate aircraft spacing by Tower Controller)
Flight Crew reverts to ILS guided Take-Off	FC_16	FC of the departing A/C reverted to ILS Guided Take-Off without informing ATCO	New SR 840 (Operational Procedure/Training for Flight Crew)
Pilot detection			
Pilot detection	FC_07	Pilot doesn't detect the erroneous ILS deviation	No SR Assumption A#160: Pilot cannot detect the erroneous deviation in such situation therefore no downgrading of the Event Criticality
ATCO			
Departure Clearance	ATC_06	ATCO gives a departure clearance to the departing A/C despite another A/C is in the S.A.	SR310 "Normal Conditions" (Landing Clearance when the preceding arrival has passed the ILS CAT III CSA) SR 435 "Normal Conditions" (Tower controller shall verify that other departing aircraft hold at the CAT III holding position)

			Assumption A#135: It is assumed in such situation that ATCO detects the problem which permits a downgrading of the Event Criticality
Other			
A/C in S.A generates a significant ILS disturbance	OTH_02	A/C in S.A generates a significant ILS disturbance	No SR Assumption A#180: It is assumed that when A/C is in SA it generates disturbances therefore no downgrading of the Event Criticality

Table 31 Derivation of Mitigation/Safety Requirements for Hazard 021

3.5.1.10 Hz 022 – Failure to maintain aircraft longitudinal spacing on the runway during Guided Take-Off in LVC

In case of failure to maintain the A/C on the runway centreline, this could lead to infringement with another departure aircraft or with landing aircraft.

This hazard could lead to a Runway conflict classified with a severity 3.

Basic causes for such failure have been captured in the Hz 022 Fault Trees (See Figure 25).

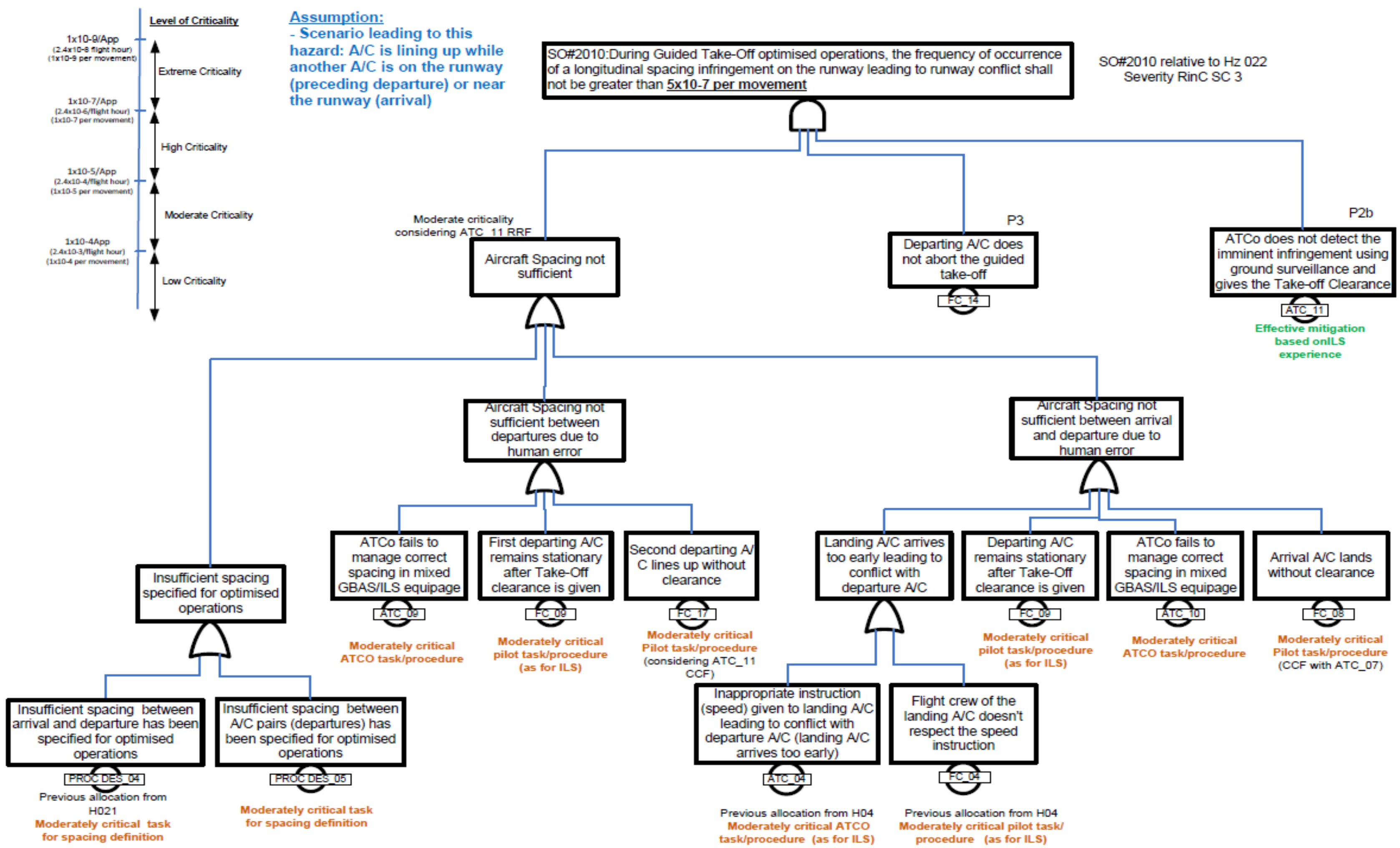


Figure 25 Hz 022 – Fault tree

Table 32 below describes the basic causes of the Hz 022 Fault Tree and identify the mitigations/safety requirements necessary to satisfy the associated Safety Objective.

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Insufficient spacing specified for optimised operations			
Insufficient spacing specification between departures	PROC DES_05	Insufficient spacing between A/C pairs (departures) has been specified for optimised operations	New SR 850 (Establishment of spacing between GBAS-ILS pair of departing aircraft)
Insufficient spacing specification between arrival and departure	PROC DES_04	Insufficient spacing between arrival and departure has been specified for optimised operations	New SR 845(Establishment of spacing between arrival and departure in mixed GBAS-ILS equipage)
Aircraft spacing not sufficient between departures due to human error			
ATCO spacing management	ATC_09	ATCO fails to manage correct spacing between departures in mixed GBAS/ILS equipage	SR 415 "Normal Conditions" (Appropriate aircraft spacing by Tower Controller)
First departing A/C remains stationary after Take-Off clearance is given	FC_09	The FC of the departing A/C remains stationary on the runway after Take-Off clearance is given	New A#0225 "Flight Crew reads back the Take-Off clearance et start take-off roll immediately"
Second departing A/C lines up without clearance	FC_17	The FC of the second departing A/C lines up without clearance	New A#0235 "Flight crew respects the line-up clearance given by ATCO"
Aircraft spacing not sufficient between arrival and departure due to human error			
Inappropriate instruction (speed)	ATC_04	ATCO gives an erroneous speed instruction to landing A/C leading to conflict with departure A/C	No SR (considered as Basic ATCO procedure)
Flight Crew doesn't respect the speed instruction	FC_04	FC of the landing A/C doesn't respect the speed instruction leading to catch-up	New A#0215 "Flight Crew respects speed instructions given by ATCO"
Departing A/C remains stationary after Take-Off clearance is given	FC_09	The FC of the departing A/C remains stationary on the runway after Take-Off clearance is given	New A#0225 "Flight Crew reads back the Take-Off clearance et start take-off roll immediately"
ATCO spacing management	ATC_10	ATCO fails to manage correct spacing between arrival and departure in mixed GBAS/ILS equipage	New SR 855(Appropriate aircraft spacing by Tower Controller)
Arrival A/C lands without clearance	FC_08	The FC of the arriving A/C lands without clearance	New A#0220 "Flight Crew respects the landing clearance given by ATCO"

Pilot reaction			
Pilot reaction	FC_14	No abortion of the Guided Take-off over by the pilot	SR 185 “Normal Conditions” (Aircraft Operator approval in accordance with OPS regulation) Assumption A#175: It is assumed in such situation that pilot cannot abort the take-off therefore no downgrading of the Event Criticality
ATCO detection			
ATCO does not detect the imminent infringement using ground surveillance	ATC_11	ATCO does not detect the imminent infringement using ground surveillance and gives the Take-off clearance	SR 295 “Normal Conditions” (Runway Safety Net shall alert the Tower Controller when a mobile is inside the ILS CAT III CSA) Assumption A#145: It is assumed in such situation that ATCO detects the problem which permits a downgrading of the Event Criticality

Table 32 Derivation of Mitigation/Safety Requirements for Hazard 022

3.5.2 Common Cause Analysis

Several causes (GBAS Ground Station integrity and Continuity of Service failure, GBAS Aircraft Subsystem integrity and continuity of service failure…) are common between Fault Trees.

1/ However, the way of which hazards have been determined guaranteed that when one of these failures occurs, it could eventually lead to several hazards but as these hazards are sequential, the severity is not increased.

Indeed, hazards have been identified by phase of flight. Thus, when a failure occurs during one of these phases:

- if the pilot detects it, he/she makes a missed approach. In this case, the approach is finished and the hazards of the following phases cannot occur
- otherwise, the approach continues and it is likely that the failure also leads to hazards of the following phase. However, in this case the severity of the second hazard remains the same.

Example:

A GBAS Ground Station integrity failure could lead to Hz 002 during Intermediate Approach. If the pilot doesn't detect this failure and continues the approach, it is probable that this GBAS Ground Station Integrity failure leads also to Hz 003 in Final Approach.

However, as Hz 002 is not relevant anymore when Hz 003 occurs, the severity of Hz 003 remains applicable.

2/ Inside each of the phase of flight, the hazards have been identified in different contexts (single GBAS CAT III approach, mixed GBAS/ILS equipage operations, parallel approaches). Then, when a failure occurs, only one of these hazards could happen.

3/ Compared to ILS approach a specific common cause has been envisaged: Indeed because the same GBAS Ground Station serves several runways, one could envisage that a failure of the ground station leads to flight path convergence during parallel approaches. An initial analysis based on expert judgment indicates that in this case of GBAS Ground Station failure, the two aircraft conducting the approach will encounter similar error and therefore should not be guided on a convergent path. However an open issue is identified in order to analyze in future work (e.g 15.3.6 T33 extended safety assessment) this possibility.

I#003: It should be determined if a GAST-D Ground Station failure mode could lead to a situation where two aircraft flying a parallel approach might diverge from their trajectories and be on convergent paths when the station is serving both approaches.

3.5.3 Formalization of Mitigations

Considering the outcome of the causal analysis (see section 3.5.1) and more particularly the Mitigations identified in each table accompanying the hazards fault trees, Table 33 below formalize the system generated hazard mitigation which have not been already captured during the design analysis in normal conditions.

Reference	Mitigation to System generated Hazards	Hazards
A#0200 [Flight Crew]	*(FC_12: Pilot fails to select the correct RNAV/RNP transition)* ***Highly critical pilot task/procedure*** When selecting a flight procedure, such as RNAV/RNP STAR or	Hz 002

Reference	Mitigation to System generated Hazards	Hazards
	transition, pilot cross-check the procedure inserted in the RNAV system with the published chart	
A#0205 [Flight Crew]	*(FC_12: Pilot fails to select the correct RNAV/RNP transition* ***Highly critical pilot task/procedure*** During RNAV/RNP transition, Flight crew verify that trajectory on the navigation display matches with the selected final approach and that indicated GBAS lateral deviation is converging.	Hz 002
SR 800 [Maintenance activity]	*(MAINT_01: Integrity failure due to maintenance actions)* ***Extremely critical maintenance procedure/ task*** When Maintenance tasks/actions can potentially affect the integrity performance of the Ground Subsystem, these actions/tasks shall be categorized as Level B maintenance tasks. See Appendix G for more guidance	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 805 [Maintenance activity]	*(MAINT_02: Continuity of service failure due to maintenance actions* ***Highly critical maintenance procedure/ task*** When Maintenance tasks/actions can potentially affect the continuity of service performance of the Ground Subsystem, these actions/tasks shall be categorized as Level A maintenance tasks. See Appendix G for more guidance	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 810 [Maintenance activity]	*(MAINT_01: Integrity failure due to maintenance actions)* ***Extremely critical maintenance procedure/ task leading to Critical event*** *(MAINT_02: Continuity of service failure due to maintenance actions* ***Highly critical maintenance procedure/ task leading to Hazardous event*** ANSP shall define procedure, training and competence scheme allowing to reach Level A and Level B maintenance task categories applicable to GBAS CAT III ground subsystem See Appendix G for more guidance	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 815 [Maintenance activity]	*(LOCA_01: Integrity failure due to erroneous LOCA management)* ***Extremely critical ATCO task/procedure task*** Maintenance personnel shall be trained on GBAS area (LOCA) management	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 820 [APP/TWR ATCO]	*(LOCA_01: Integrity failure due to erroneous LOCA management)* ***Extremely critical ATCO task/procedure task*** If LOCA has an impact on operations (e.g. part of taxiway including in LOCA), the Tower Controller shall be trained to manage this area	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020

Reference	Mitigation to System generated Hazards	Hazards
SR 825 [APP/TWR ATCO]	*(ATC_02: ATC deselects active approach)* ***Highly critical ATCO task/procedure task*** Procedure shall be defined to prevent the ATCO approach deselection when an aircraft is on the final approach or is landing	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
Update of SR 275 [Flight Crew]	*(FC_05: The FC of the landed aircraft is slow to vacate the runway)* ***Moderately critical pilot task/procedure*** The aircraft shall vacate the runway, as fast as possible, at a specific runway exit point when required by the Tower Controller and if accepted by the Flight Crew	Hz 004 Hz 008 Hz 021
A#0210 [Flight Crew]	*(FC_05: The FC of the landed aircraft is slow to vacate the runway)* ***Moderately critical pilot task/procedure*** If aircraft is too slow to vacate the runway, ATCO gives instructions to expedite runway vacation.	Hz 004 Hz 008 Hz 021
SR 830 [Flight Crew]	*(FC_06: FC of the landing A/C reverted to ILS approach without informing ATCO)* ***Moderately critical pilot task/procedure*** Operational Procedure shall be defined and Flight Crew shall be trained to inform ATCO in case of reversion from a GBAS approach to ILS approach	Hz 004
A#0215 [Flight Crew]	*(FC_04: FC of one of the two landing A/C doesn't respect the speed instruction leading to catch-up)* ***Moderately critical pilot task/procedure*** During CAT III approach, the Flight Crew respect speed instructions given by ATCO	Hz 004 Hz 008 Hz 022
A#0220 [Flight Crew]	*(FC_08: The FC of the following A/C lands without clearance)* ***Moderately critical pilot task/procedure*** During CAT III approach, the Flight Crew respect the landing clearance given by ATCO	Hz 008 Hz 022
SR 835 [ANSP]	*(PROC_DES_02: Insufficient spacing between A/C pairs has been specified for optimised operations)* ***Moderately critical task for spacing definition*** An ATC local assessment shall be conducted to determine the acceptability of the aircraft spacing reduction of 1Nm in front of GBAS landing (and eventually to determine a greater reduction) supported by an operational transition phase applied in non-LVP visibility condition	Hz 004 Hz 008
A#0225 [Flight Crew]	*(FC_09 The FC of the departing A/C remains stationary on the runway after Take-Off clearance is given)* ***Moderately criticality pilot task/procedure*** The Flight Crew reads back the Take-Off clearance and starts take-off	Hz 008 Hz 022

Reference	Mitigation to System generated Hazards	Hazards
	roll immediately	
A#0230 [Flight Crew]	*(FC_15 The Flight Crew of the next departing A/C doesn't stop at the holding point)* ***Moderately critical pilot task/procedure*** During a guided Take-Off in mixed GBAS/ILS operations, Flight Crew of the departing aircraft hold at the CAT III holding position whatever the navaid supporting the guided Take-Off (GBAS or ILS)	Hz 021
SR 840 [Flight Crew]	*(FC_16: FC of the departing A/C reverted to ILS Guided Take-off without informing ATCO)* ***Moderately critical pilot task/procedure*** Operational Procedure shall be defined and Flight Crew shall be trained to inform ATCO in case of reversion from GBAS to ILS Guided Take-Off	Hz 021
SR 845 [APP/TWR SUP]	*(PROC_DES_04: Insufficient spacing between arrival and departure has been specified for optimised operations)* ***Moderately critical task for spacing definition*** For mixed GBAS/ILS equipage operations, the aircraft spacing between arrival and departure shall be established for each operational runway	Hz 008 Hz 021 Hz 022
SR 850 [APP/TWR SUP]	*(PROC_DES_05: Insufficient spacing between A/C pairs (departures) has been specified for optimised operations)* ***Moderately critical task for spacing definition*** For mixed GBAS/ILS equipage operations, the aircraft spacing between GBAS-ILS departing aircraft shall be established for each operational runway	Hz 022
SR 855 [APP/TWR ATCO]	*(ATC_10: ATCO fails to manage correct spacing between arrival and departure in mixed GBAS/ILS equipage)* ***Moderately critical ATCO task/procedure task*** For optimised operations in LVP, the Tower Controller shall provide appropriate aircraft spacing between arrival and departure for the considered aircraft pair which could be either GBAS-ILS or GBAS-GBAS or ILS-GBAS pair	Hz 021 Hz 022
SR 860 [GAST-D GS]	(GBAS GS_01: GBAS Ground Station Integrity failure) The GBAS Ground Subsystem shall include a capability to perform plausability checks during new FAS data file loading as identified in EUROCAE ED-114A Appendix M	Hz 002;Hz 003; Hz 005; Hz 006; Hz 007; Hz 020
A#0235 [Flight Crew]	*(FC_17: The FC of the second departing A/C lines up without clearance)* ***Moderately critical pilot task/procedure*** During CAT III approach, the Flight Crew respect the line-up clearance given by ATCO	Hz 022

Table 33 Additional success-case safety requirements and assumptions to mitigate System generated Hazards

3.5.4 Safety Requirements (integrity/reliability)

Considering the outcome of the causal analysis (see chapter 3.5.1) the following Table 34 defines the safety requirements (integrity/reliability) to limit the frequency with which each identified system failure could be allowed to occur, taking into account of the mitigations, such that the residual risk is within the specified safety objectives.

Reference	Safety Requirement (Integrity/reliability)	Hazards
SIR#001 [GAST D GS]	A GAST D Ground Subsystem integrity failure shall not occur more frequently than $1x10^{-9}$ in any landing	**Hz 003** **Hz 006** Hz 002 Hz 005 Hz 007 Hz 020
SIR#002 [GAST D Aircraft Subsystem]	A GAST D Aircraft Subsystem integrity failure shall not occur more frequently than $1x10^{-9}$ in any landing	**Hz 003** **Hz 006** Hz 002 Hz 005 Hz 007 Hz 020
SIR#003 [GAST D GS]	A GAST D Ground Subsystem continuity of service failure shall not occur more frequently than $2x10^{-6}$ during any 15 sec interval	**Hz 003** **Hz 006** Hz 005 Hz 007 Hz 020
SIR#004 [GAST D Aircraft Subsystem]	A GAST D Aircraft Subsystem continuity of service failure shall not occur more frequently than $2x10^{-6}$ during any 15 sec interval	**Hz 003** **Hz 006** Hz 005 Hz 007 Hz 020
SIR#005 [RNAV and Conv nav Syst]	A RNAV/RNP airborne system failure to follow the transition shall not occur more frequently than $1x10^{-7}$ per approach	**Hz 002**

Reference	Safety Requirement (Integrity/reliability)	Hazards
SIR#006 [Aircraft automatic landing system]	An A/C automatic landing system integrity failure shall not occur more frequently than $1x10^{-9}$ in any landing	**Hz 003** **Hz 006** Hz 005
SIR#007 [Aircraft automatic landing system]	An A/C automatic landing system continuity of service failure shall not occur more frequently than $1x10^{-7}$ during any 15 sec interval	**Hz 003** **Hz 006** Hz 005
SIR#008 [Aircraft roll-out guidance system]	An A/C roll-out guidance system integrity failure shall not occur more frequently than $1x10^{-9}$ in any landing	Hz 007
SIR#009 [Aircraft roll-out guidance system]	An A/C roll-out guidance system continuity of service failure shall not occur more frequently than $1x10^{-7}$ during any 15 sec interval	Hz 007
SIR#010 [Aircraft roll-out guidance system]	An A/C take-off guidance system integrity failure shall not occur more frequently than $1x10^{-7}$ in any take-off	Hz 020
SIR#011 [Aircraft roll-out guidance system]	An A/C take-off guidance system continuity of service failure shall not occur more frequently than $1x10^{-5}$ during any 60 sec interval	Hz 020

Table 34: Safety Requirements (Integrity/Reliability)

Table 35 below lists assumptions which have been used during the failure analysis in the different Fault Trees to allocate requirements. It should be noted that these assumptions which have been used only for the FT allocation are not listed in Appendix C.1.

Reference	Safety Assumptions used in the Fault Trees	Hazards
A#125 [APP/TWR ATCO]	*(ATC_01: No ATC detection of this wrong selection (radar)* ***ILS field experience/observation*** When Flight Crew selects a wrong approach, detection by ATCO on radar screen is assumed to be an efficient mitigation.	Hz 003 Hz 005

Reference	Safety Assumptions used in the Fault Trees	Hazards
A#130 [APP/TWR ATCO]	*(ATC_03: ATCo does not detect the Aircraft lateral deviation on the radar screen* ***ILS field experience/observation*** In case of deviation of an aircraft from the approach path, detection by ATCO on radar screen is assumed to be an efficient mitigation	Hz 005
A#135 [APP/TWR ATCO]	*(ATC_06: Landing (or Take-off) Clearance given to the landing (or departing) Aircraft despite another A/C is in the ILS Sensitive Area)* ***ILS field experience/observation*** In case of an aircraft inside the ILS Sensitive Area, detection by ATCO is assumed to be an efficient mitigation and therefore she/he will not provide a landing or departure clearance	Hz 004 Hz 021
A#140 [APP/TWR ATCO]	*(ATC_07: ATCo does not detect the imminent infringement using ground surveillance and gives the Landing Clearance* ***ILS field experience/observation*** In case of longitudinal spacing infringement on the runway during CAT III approach, detection by ATCO is assumed to be an efficient mitigation and so she/he will not provide the landing clearance	Hz 008
A#145 [APP/TWR ATCO]	*(ATC_11: ATCo does not detect the imminent infringement using ground surveillance and gives the Take-off Clearance)* ***ILS field experience/observation*** In case of longitudinal spacing infringement on the runway during Guided Take-off, detection by ATCO is assumed to be an efficient mitigation and so she/he will not provide a Take-off clearance	Hz 022
A#150 [Flight Crew]	*(FC_02: Pilot cannot detect the erroneous guidance in LVO during the approach)* ***No mitigation possible*** During CAT III approach, the pilot is unable to detect the erroneous guidance in the event of integrity failure (annex 10 volume 1 Attachment A)	Hz 003 Hz 005 Hz 006 Hz 007
A#155 [Flight Crew]	*(FC_03: Pilot does not execute a missed approach during the approach)* ***ILS field experience/observation – Hz 003, Hz 005 and Hz 006*** During CAT III approach, the pilot executes a missed approach in the event of continuity of service failure. Based on study of accidents, the probability of occurrence of the non-execution of a missed approach by the pilot is $2,5x10^{-4}$ (annex 10 volume 1 Attachment A) ***No mitigation possible for Hz 008*** In case of longitudinal spacing infringement on the runway during CAT III approach, detection of this situation by the pilot and execution of a missed approach is considered not possible in Low Visibility Conditions.	Hz 003 Hz 005 Hz 006 Hz 008

Reference	Safety Assumptions used in the Fault Trees	Hazards
A#160 [Flight Crew]	*(FC_07: Erroneous ILS deviation not detected by Flight Crew)* ***No mitigation possible*** During CAT III approach or guided take-off in Low Visibility Conditions, the pilot is unable to detect erroneous ILS deviation	Hz 004 Hz 021
A#161 [TWR ATCO]	*(ATC_04: inappropriate instruction (speed or exit lane))* ATCO procedure for A/C runway vacation is the same as in ILS CAT III	Hz 004 Hz 008
A#165 [Flight Crew]	*(FC_10: No manual take over by the pilot during rollout)* ***No mitigation possible*** In case of loss of guidance during rollout, the manual take over by the pilot is considered to be an inefficient mitigation.	Hz 007
A#170 [Flight Crew]	*(FC_13: Pilot does not detect the erroneous guidance in LVO during Guided Take-Off)* ***No mitigation possible*** During CAT III guided take-off, the pilot is unable to intervene in the event of integrity failure	Hz 020
A#175 [Flight Crew]	*(FC_14: No abortion of the Guided Take-off over by pilot)* ***ILS field experience/observation for Hz 020*** In case of loss of guidance during GBAS guided take-off, abortion of the guided take-off by the pilot is assumed to be an efficient mitigation ***No mitigation possible for Hz 022*** In case of a longitudinal spacing infringement on the runway, detection of this situation by the pilot and abortion of the guided take-off is assumed to be an inefficient mitigation.	Hz 020 Hz 022
A#180	*(OTH_02: Landed A/C in ILS Sensitive Area generates a significant ILS disturbance)* ***No mitigation possible*** When an aircraft is in the ILS Sensitive area, it systematically generates a significant ILS disturbance because the landing A/C performing touchdown or roll-out will always see a disturbance when below 200ft.	Hz 004 Hz 021

Table 35: Assumptions (Integrity/Reliability)

3.6 Achievability of the Safety Criteria

In section 2.11 of the present document the assessment of the achievability of the Safety Criteria was performed through specifications of safety objectives. In the same section it was shown that Safety Objectives are satisfying Safety Criteria in order to support safe CAT III approach and landing or Guided Take-Off operations.

At SPR-design level, Safety Objectives have been mapped to safety requirements for normal conditions (see sections 3.2 and 3.3), for abnormal conditions (see section.3.4) and for failure conditions (see section 3.5). It was shown in these sections that these safety requirements satisfy the safety objectives which in turn have been shown to satisfy Safety Criteria as already explained in section 2.

3.7 Realism of the SPR-level Design

3.7.1 Achievability of Safety Requirements

3.7.1.1 Safety Requirement (Functionality & performance)

The vast majority of safety requirements are capable of being satisfied in a typical implementation because they are relying on either existing standards or on procedures similar to current operations in LVP. Indeed they are relying on compliance with ICAO SARPS (+ proposed amendment), RTCA/EUROCAE Standard, PANS-ATM, PANS-OPS for ANSP/GBAS ground station supplier or EASA documents (ETSO, CS AWO, IR OPS,…) for airframer/Aircraft operators. It is important to note that these requirements will be an input to the regulatory support task of Project 15.3.6. This should permit to determine that GAST-D specificities are fully addressed by the new regulation scheme.

Furthermore, the SESAR project15.3.6 provides elements for technical validation of GBAS CAT II/III L1 referred to as "system validation":

- This covers ground & airborne elements (through cooperation with P9.12 for the airborne part)
- System validation carried out by ANSPs with Pre-industrial prototypes (Thales, IndraNavia) implemented on Airports (Toulouse/Blagnac, Frankfurt)
- provide results with pre-industrial prototypes in realistic deployment scenarios (V3)

Several Validation Exercises are relevant for this activity:

- 15.03.06-VP-236 - Thales (Ground PT1) integrated on Toulouse Airport (site1)
- 15.03.06-VP-637 (Phase 1) and -VP-644 (Phase 2)-: NATMIG (Ground PT2)) integrated on Frankfurt Airport (site2)).

System Validation Reports for each above validation exercise are not yet available. These reports will summarize the signal in space and performance verification of the two independently developed GAST-D compliant ground station prototypes at the installation sites and they will provide verification results on a system level (ground and airborne part). These reports will contain synthetic results with strongly referring for the airborne part to the 9.12 Technical validation reports for the autoland demonstration with GAST-D.

It is however recalled that the GBAS CAT III operational safety assessment is based on the assumptions that ground and aircraft subsystems are compliant with ICAO SARPS [20] and the proposed SARPS amendment [21].

3.7.1.2 Safety Requirement (Integrity/Reliability)

The achievability of the failure-case safety requirements is less obvious but they are relying on continuity and integrity requirements similar to ILS which are well known by ANSP and GBAS ground Station supplier. For the airborne part, Project 9.12 conducted autoland simulation and failure mode simulation.

3.7.1.3 Assumptions and Issues

Most of assumptions have been validated and therefore are capable of being satisfied in a typical implementation. The main assumption not validated yet is relative to the GBAS CAT III obstacle clearance and should be addressed at the ICAO level (IFPP) to confirm that GBAS CAT III obstacle clearance is identical to ILS CAT III

No conclusion was reached for the phraseology to be used for GBAS approach (GBAS or GLS) during the safety assessment and during the 6.8.5 Validation Exercise VP 563. One safety Issue and one safety recommendation are related to this problem. The VP 563 Validation exercise results indicate that the phraseology was not applied homogeneously throughout the simulation by all controllers. These results were backed up by debriefing results: When using the phraseology "GLS" controllers did not agree on the acceptability in fact they were in favour of the "GBAS phraseology". The proposed phraseology was discussed deeply in the debriefings both by controllers and pilots. The result of this discussion reveals that a more distinct difference of the phraseology compared to ILS would be appreciated in order to avoid misunderstandings

3.7.2 "Testability" of Safety Requirements

Most of the safety requirements are verifiable by direct means which could be flight procedure validation procedure/process, validation report, training certificate, procedure designer software tool approval, etc..

For some safety requirements, verification should rely on an appropriate assurance process to be implemented. This is particularly true for the procedure design and procedure publication. In such case the principle of the quality assurance process described in the ICAO Doc 9906 and the quality of aeronautical data of the Regulation (EU) N° 73/2010 should help the relevant actors to demonstrate their compliance against these safety requirements.

3.8 Validation & Verification of the Safe Design at SPR Level

A safety team encompassing ANSP, Airframer, and GBAS Ground Station supplier have conducted this operational safety assessment.

The first step was the validation of the SPR level model then safety requirements have been derived in normal, abnormal and failure conditions to satisfy the Safety Objectives derived at OSED level (see Chapter 2).

Several Webex have been organised and minutes of these discussions can be found in the SESAR extranet (P15.3.6 → folder Execution -> D22).

A PSSA workshop was organised in May 2014 with the support of operational people including controllers and pilots. PSSA supporting material and conclusion can be found in the SESAR extranet(P15.3.6 → folder Execution -> D22).

Several Validation exercises have been conducted as already discussed in Section 3.3.4

Appendix B provides the consolidated list of Safety Requirements.

Appendix C provides the consolidated list of Safety Assumptions, Issues, Recommendations, limitations and validation items.

4 Conclusion

This document contains the Specimen Safety Assessment for a typical application of the OFA01.01.01 (LVPs using GBAS) relative to GBAS CAT II-III operations based on single GPS frequency (L1) known as GAST-D (GBAS Approach Service Type D). The applicable Operational Improvement is AO-0505-A.

This operational safety assessment addresses both CAT III approach & landing operations and Guided Take-Off in Low Visibility Conditions.

This assessment was conducted considering the operational change (optimised operations) described in the GBAS CAT II/III Functional Description Report/OSED (06.08.05 D11) and the technical change described in the GBAS CONOPS including CAT II/III specificities (15.03.06 D20).

This operational safety assessment does not address GBAS CAT II approach operations because there is no ICAO GAST-D requirements specific to CAT II. Furthermore GBAS CAT III approach and landing operations are considered to be more challenging and demanding than CAT II operations.

This operational safety assessment started by the identification of Safety Criteria describing what is acceptably safe for the operational concept supported by GAST-D. Then Safety Objectives were derived at operational level (OSED) to satisfy the Safety criteria in normal, abnormal and failure conditions. Finally when the high-level design architecture supporting the operational level was defined, Safety Requirements in normal/abnormal conditions and considering failure aspects were derived to satisfy the Safety Objectives. Safety Requirements were determined though the success and the failure approach as described by the SESAR Safety reference Material (SRM) developed by Project 16.06.01.

During this iterative process, safety validation objectives have been identified and have been addressed during Validation Exercises.

The report presents the assurance that the Safety Requirements for the V1-V3 phases are complete, correct and realistic.

Furthermore, assumptions, issues, recommendations and limitations have been identified during the safety assessment.

- The main assumption not validated yet is relative to the GBAS CAT III obstacle clearance and should be addressed at the ICAO level (IFPP) to confirm that GBAS CAT III obstacle clearance is identical to ILS CAT III.

- The safety issue which remains open is relative to the phraseology to be used during GBAS operation (GBAS or GLS) and this issue shall be addressed at ICAO level.

- Several recommendations remains open in particular the one associated to naming and phraseology used for GBAS which recommends consistency between radiotelephony communications, charting information, ATC displayed information and flight deck indication.

It should be noted that this safety assessment will be revisited considering the new task T33 of SESAR Project 15.03.06.

Appendix A Consolidated List of Safety Objectives

A.1 Safety Objectives (Functionality and Performance) for CAT III approach and landing

SO ref	Safety Objective (Functionality and Performance)	Traceability
SO#0005	ATIS shall inform arriving aircraft of the landing procedures available for the runway in use (ILS and GBAS or GBAS only) and indicate that LVP are in place	Normal operation SAC#02 (MAC)
SO#0010	Approach clearance shall be provided to arriving aircraft which indicate the expected approach to be flown	Normal operation SAC#02 (MAC)
SO#0011	For optimised operations conducted in mixed GBAS/ILS equipage, aircraft shall inform ATC about the approach that will be flown: GBAS or ILS.	Normal operation SAC#02 (MAC)
SO#0015	Before Final Approach Point, the aircraft shall capture the GBAS Lateral path before the GBAS vertical path to conduct stabilized approach	Normal operation SAC#01 (CFIT)
SO#0020	Aircraft shall respect the lateral performance of the published approach intermediate segment which might include an RF leg during a final approach capture supported by RNAV/RNP.	Normal operation SAC#01 (CFIT) SAC#02 (MAC)
SO#0025	Aircraft shall respect ATC vectoring instructions for the final approach capture	Normal operation SAC#02 (MAC)
SO#0030	Aircraft shall respect vertical altitude constraint at FAP during a final approach capture by transitioning properly from Baro-altitude to GBAS vertical path (xLS).	Normal operation SAC#01 (CFIT) SAC#02 (MAC)
SO#0035	For non CDO operations, a 2Nm (or 30 sec) straight and level flight segment prior to final approach track intercept shall be the flown to conduct stabilized approach	Normal operation SAC#01 (CFIT)
SO#0040	ATC shall not provide vectoring for aircraft conducting CDO when aircraft cannot conduct a fully optimised CDO with vectoring	Normal operation SAC#01 (CFIT) SAC#02 (MAC)
SO#0045	The GBAS CAT III approach is designed and promulgated to prevent loss of separation with terrain/obstacle	Normal operation SAC#01 (CFIT)
SO#0050	Aircraft shall respect the lateral and vertical path of the published GBAS approach	Normal operation SAC#01 (CFIT) SAC#02 (MAC)
SO#0055	For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside the ILS CAT III critical and sensitive areas during an ILS approach/take-off	Normal operation SAC#01 (CFIT) SAC#04 (R.E)
SO#0060	The aircraft GBAS Total System error (TSE) shall be equivalent or better than ILS CAT III TSE	Normal operation SAC#01 (CFIT) SAC#04 (R.E)

SO ref	Safety Objective (Functionality and Performance)	Traceability
SO#0065	Aircraft shall respect accurately speeds, which have been defined for the CAT III operation, during the approach and the landing	Normal operation SAC#01 (CFIT) SAC#02 (MAC) SAC#04 (R.E)
SO#0070	ATC procedures shall support the mixed GBAS/ILS equipage operations by providing appropriate spacing between the different aircraft pairs (GBAS-ILS; GBAS-GBAS and ILS-GBAS)	Normal operation SAC#02 (MAC)
SO#0072	For CAT III optimised operations, the reduced spacing between aircraft shall consider the necessary Runway Occupancy Time (ROT) in Low Visibility Conditions and not only that ILS CAT III critical/sensitive area does not need to be protected	Normal operation SAC#02 (MAC)
SO#0075	For parallel approaches, the infringement rate of the Non Transgression Zone (NTZ) shall not be greater with GBAS (GBAS only operation or mixed GBAS/ILS equipage operation) compared to ILS	Normal operation SAC#02 (MAC)
SO#0080	During a GBAS CAT III operation, aircraft shall land in the prescribed touch down zone	Normal operation SAC#04 (R.E)
SO#0085	During a GBAS CAT III operation, aircraft shall respect the runway centre-line during the landing rollout and decelerates to a safe taxi speed	Normal operation SAC#04 (R.E)
SO#0090	Landing Clearance (and associated read back) shall be provided to the aircraft to ensure proper separation with other aircraft or vehicles on the runway	Normal operation SAC#03a (R.C)
SO#0095	For optimised operations, the late landing Clearance shall be provided at a distance to the runway threshold which does not impair the aircraft ability to prepare the landing	Normal operation SAC#03a (R.C)
SO#0100	All aircraft on the ground shall remain outside the Obstacle Free Zone (OFZ) during a landing	Normal operation SAC#03a (R.C); SAC_Assumption #01 (OFZ protection)
SO#0105	The landed aircraft shall vacate the runway at the cleared exit point	Normal operation SAC#03a (R.C)
SO#0110	The landed aircraft shall report when he has vacated the runway indicating that aircraft tail has left the runway	Normal operation SAC#03a (R.C)
SO#0115	ATC shall provide when necessary additional information to facilitate aircraft runway vacation	Normal operation SAC#03a (R.C)
SO#0120	Runway Incursion safety net (e.g. RIMCAS) shall be suitable for optimised operations. An aircraft holding inside ILS CAT III Critical and Sensitive Area (CSA) during a CAT III ILS landing is considered a Runway Incursion whereas an aircraft holding at the same position during a CAT III GBAS landing is not.	Normal operation SAC#03a (R.C)

SO ref	Safety Objective (Functionality and Performance)	Traceability
SO#0125	For segregated runway operation (arrival only) with GBAS optimised operations, ATC shall provide the landing clearance to the next arrival when the preceding arrival has passed the landing clearance line	Normal operation SAC#03a (R.C)
SO#0130	For segregated runway operation(arrival) with mixed GBAS/ILS equipage optimised operations, ATC shall provide the landing clearance to the: *next GBAS arrival when the preceding arrival has passed the landing clearance line * next ILS arrival when the preceding arrival has vacated the ILS CAT III sensitive area	Normal operation SAC#03a (R.C)
SO#0135	For mixed mode runway operation (arrival/departure) with GBAS optimised operations, departing aircraft shall hold at the landing clearance line	Normal operation SAC#03a (R.C)
SO#0140	For mixed mode runway operation (arrival/departure) with mixed GBAS/ILS equipage optimised operations, departing aircraft shall hold: *at the landing clearance line during a GBAS landing *at the CAT III holding point during an ILS landing	Normal operation SAC#03a (R.C)
SO#0145	For optimised operations, the landing clearance line shall be positioned where: *the risk of collision between the landing aircraft and obstacles (aircraft/vehicle) on the runway is shown to be acceptable. *wing tip clearance of the landing aircraft is provided from touchdown to end of roll out along the runway	Normal operation SAC#03a (R.C)
SO#0150	Aircraft shall monitor operational conditions and technical capabilities at the Decision Height (DH) or at the Alert Height (for operations conducted with no DH) to decide if CAT III approach can be continued	Normal operation SAC#01 (CFIT)
SO#0155	For CAT III approach conducted with DH, aircraft shall execute a missed approach at DH if visual references not acquired	Normal operation SAC#01 (CFIT)
SO#0160	For CAT III approach conducted with no DH, aircraft shall execute a missed approach at or below the Alert Height in case of aircraft capability and/or performance degradation impacting the CAT III landing and visual references not acquired	Normal operation SAC#01 (CFIT)
SO#0165	The Missed approach segment of a GBAS CAT III approach shall be designed to prevent loss of separation with terrain/obstacle and shall not rely on GBAS	Normal operation SAC#01 (CFIT)
SO#0166	For independent parallel runway operations, the Missed approach track for one approach diverges by at least 30 degrees from the missed approach track of the adjacent approach	Normal operation SAC#02 (MAC)
SO#0170	During optimised operations, the go-around rate (without considering failure) shall not be greater than in ILS CAT III only operations (without considering failure) in similar operational environment and weather conditions.	Normal operation SAC#02 (MAC)
SO#0300	Aircraft shall respect the lateral and vertical path of the published GBAS approach when ionospheric disturbances are encountered or aircraft executes a safe go-around	Abnormal operation SAC#01(CFIT)
SO#0305	Aircraft shall land in the prescribed touch down zone when ionospheric disturbances are encountered or aircraft executes a safe go-around	Abnormal operation SAC#04(R.E)

SO ref	Safety Objective (Functionality and Performance)	Traceability
SO#0310	Aircraft shall conduct a successful GBAS landing rollout when ionospheric disturbances are encountered or aircraft executes a safe go-around	Abnormal operation SAC#04(R.E)
SO#0315	Aircraft shall respect the lateral and vertical path of the published GBAS approach when interference are encountered or aircraft executes a safe go-around	Abnormal operation SAC#01(CFIT)
SO#0320	Aircraft shall land in the prescribed touch down zone when interference are encountered or aircraft executes a safe go-around	Abnormal operation SAC#04(R.E)
SO#0325	Aircraft shall conduct a successful GBAS landing rollout when interference are encountered or aircraft executes a safe go-around	Abnormal operation SAC#04(R.E)
SO#0330	Aircraft shall execute a missed approach in case of loss of GBAS continuity during a GBAS CAT III approach	Hz 002; Hz 003; Hz 004; Hz 006 and Hz 007SAC#01(CFIT) and SAC#04(R.E)
SO#0335	When an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations, the Arrival Sequence Manager shall allocate a greater spacing between a GBAS-ILS pair, than that between ILS-GBAS or GBAS-GBAS pairs, to guarantee that a preceding landed aircraft has vacated the ILS CAT III sensitive area during an ILS landing	Abnormal operation SAC#04(R.E)
SO#0340	To mitigate GPS loss events, the GBAS missed approach procedure shall be either: *based on conventional navigational aid or *allows the flight crew to conduct a safe aircraft extraction using raw data (e.g. heading, altitude) when GPS is lost considering the airport environment (terrain, other arrivals and departure,…)	Abnormal operation SAC#01(CFIT)
SO#0345	To mitigate GPS loss events, at least one approach based on conventional means is available at the alternate aerodrome	Abnormal operation SAC#01(CFIT)
SO#0500	For CAT III optimised operations conducted in mixed GBAS/ILS equipage and before starting the final approach, an aircraft shall confirm that he is conducting an ILS approach (not required for GBAS approach)	Hz 004 SAC#01(CFIT); SAC#04(R.E)
SO#0501	During the initial approach, aircraft shall verify that GBAS CAT III approach can be conducted. If not the aircraft might revert to another GBAS approach or to an ILS approach (only for mixed GBAS/ILS equipage operations). GBAS capability indication might be different between aircraft and ATC.	Hz 004 SAC#01(CFIT)
SO#0505	In CAT III mixed GBAS/ILS equipage operations, if an aircraft informs ATC before starting the approach that he will conduct an ILS approach whereas ATC foresees a GBAS approach, either ATC verify that ILS CAT III sensitive area will be clear of obstacle or ask the aircraft to initiate a go-around	Hz 004 SAC#01(CFIT); SAC#04(R.E)

SO ref	Safety Objective (Functionality and Performance)	Traceability
SO#0510	For CAT III parallel approaches and when final approach track intercept are not supported by radar vectoring, the two approach flows shall be strategically separated by an adequate FAP positioning for the two approaches (different position/altitude)	Hz 002 SAC#02(MAC)
SO#0520	Aircraft shall execute a missed approach if excessive lateral and/or vertical deviation are detected during a GBAS CAT III approach	Hz 003; Hz 004 SAC#01(CFIT); SAC#04(R.E)
SO#0530	In case of GBAS system performance degradation leading to an aircraft capability downgrade from CAT III to CAT I during a CAT III approach, aircraft might continue the approach to CAT I minima or shall execute a missed approach	Hz 003 SAC#01(CFIT)
SO#0600	TMA structure and associated ATC procedures shall be sufficiently resilient to accommodate multiple and possibly simultaneous missed approach initiated during GBAS CAT III operations following an event affecting all runway ends (e.g. GBAS ground Station failure or global GNSS Signal In Space problem)	Impact on adjacent airspace SAC#02 (MAC)

A.2 Safety Objectives (Functionality and Performance) for Guided Take Off in LVC

SO ref	Safety Objective (Functionality and Performance)	Traceability
SO#0200	Aircraft shall respect the GBAS lateral path for the guided take-off from the start of the take-off roll to the main wheel lift-off	Normal operation SAC#04 (R.E) SAC_Assumption#01 (OFZ protection) SAC#03b (R.C)
SO#0060	The aircraft GBAS Total System error (TSE) shall be equivalent or better than ILS CAT III TSE	Normal operation SAC#04 (R.E) SAC_Assumption#01 (OFZ protection) SAC#03b (R.C)
SO#0055	For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside the ILS CAT III critical and sensitive areas during an ILS approach/take-off	Normal operation SAC#04 (R.E) SAC_Assumption#01 (OFZ protection)
SO#0205	Take-Off Clearance (and associated read back) shall be provided to the aircraft to ensure appropriate separation with other aircraft and vehicles on the runway	Normal operation SAC#03b (R.C)
SO#0210	All aircraft on the ground shall remain outside the Obstacle Free Zone (OFZ) during a take-off	Normal operation SAC#03b (R.C)
SO#0400	Aircraft shall respect the lateral path of the guided take-off from the start of the take-off roll to the main wheel lift-off when ionospheric disturbances are encountered or aircraft aborts safely the take-off	Abnormal operation SAC#04(R.E)
SO#0405	Aircraft shall respect the lateral path of the guided take-off from the start of the take-off roll to the main wheel lift-off when interference signals are encountered or	Abnormal operation SAC#04(R.E)

SO ref	Safety Objective (Functionality and Performance)	Traceability
	aircraft aborts safely the take-off	
SO#0410	Aircraft shall abort the guided take-off in LVC in case of loss of GBAS continuity and loss of external visual cues (centerline lights)	Hz 020; Hz 021 SAC#04(R.E)
SO#0550	Aircraft aborts the guided take-off in LVC if excessive lateral deviation is detected and manual take over impossible due to loss of external visual cues (centerline lights)	Hz 020; Hz 021 SAC#04(R.E)

A.3 Safety Objectives (Integrity/reliability) and Operational Hazards for CAT III approach and landing

ID	Safety Objectives	Traceability
SO#1001	During CAT III optimised operations conducted in mixed GBAS/ILS equipage, the frequency of occurrence of an aircraft deviating laterally and/or vertically from the approach path due to an obstructed ILS CAT III sensitive/Critical area shall not be greater than **2x10-7 per approach**	Hz004 SAC#01(CFIT
SO#1002	During CAT III optimised operations conducted in mixed GBAS/ILS equipage and during the rollout, the frequency of occurrence of an aircraft deviating due to an obstructed ILS CAT III sensitive/Critical area to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Extremely Remote	Hz004 SAC#04 (R.E)
SO#1005	The frequency of occurrence of an aircraft erroneous capture of the GBAS CAT III final approach path leading to a flight towards terrain shall not be greater than **2x10-7 per approach**	Hz 002 SAC#01(CFIT)
SO#1010	During parallel approaches, the frequency of occurrence of aircraft erroneous capture of GBAS CAT III final approach paths leading possibly to separation infringement between the two arrival flows shall not be greater than **4x10-5 per flight hour**	Hz 002 SAC#02(MAC)
SO#1015	The frequency of occurrence of an aircraft deviating laterally and/or vertically from the approach path due to GBAS failure leading to flight towards terrain during a CAT III approach shall not be greater than **2x10-9 per approach**	Hz 003 SAC#01(CFIT)
SO#1020	During parallel approaches, the frequency of occurrence of an aircraft deviating from the approach path due to GBAS failure, leading possibly to separation infringement between the two arrival flows shall not be greater than **4x10-5 per flight hour**	Hz 005 SAC#02(MAC)
SO#1025	During GBAS CAT III landing, the frequency of occurrence of an aircraft which does not land in the prescribed touch down zone due to GBAS failure shall not be greater than 1x10-9 per approach/Extremely Improbable	Hz 006 SAC#04(R.E)
SO#1030	During GBAS CAT III rollout, the frequency of occurrence of an aircraft deviating due to GBAS failure to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Extremely Remote	Hz 007 SAC#04(R.E)

ID	Safety Objectives	Traceability
SO#1035	During CAT III approach optimised operations, the frequency of occurrence of a longitudinal spacing infringement on the runway leading to runway conflict shall not be greater than **5x10-7 per movement**	Hz 008 SAC#03a (R.C)

Operational Hazard	Severity (most probable effect)
Hz 002: Failure to transition laterally and/or vertically from RNP or radar vectoring to GBAS CAT III approach	CFIT-SC3b / Flight Toward Terrain Commanded.
	MAC-SC4a/Tactical conflict (crew/aircraft induced).
Hz 003: Failure to follow the correct final approach path in GBAS CAT III	CFIT-SC1 / CFIT.
Hz 004: Failure to maintain spacing between aircraft within the same final approach for optimised operations conducted in mixed GBAS/ILS equipage operations during CAT III approach	*CFIT-SC2b / Imminent CFIT
	*RE-SC2b / Imminent Runway excursion
Hz 005: Failure to maintain the separation between aircraft on adjacent CAT III approach operations	MAC-SC4a/Tactical conflict (crew/aircraft induced)
Hz 006: Failure to land in the prescribed touch-down zone in GBAS CAT III approach	RE-SC1 /R.E accident
Hz 007: Failure to maintain the A/C on the runway centreline during the CAT III GBAS landing rollout	RE-SC 2b/ Imminent Runway Excursion
Hz 008: Failure to maintain aircraft longitudinal spacing on the runway during CAT III approaches in optimised operation	RInc-SC 3/ Runway conflict

A.4 Safety Objectives (Integrity/reliability) and Operational Hazards for Guided Take Off in LVC

ID	Safety Objectives	Traceability
SO#2000	During Guided Take-Off in LVC based on GBAS, the frequency of occurrence of an aircraft deviating due to GBAS failure to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Remote	Hz 020 SAC#04(R.E)
SO#2005	During Guided Take-Off in LVC conducted in mixed GBAS/ILS equipage, the frequency of occurrence of an ILS aircraft deviating due to an obstructed ILS CAT III sensitive/Critical area to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Remote	Hz 021 SAC#04(R.E)

ID	Safety Objectives	Traceability
SO#2010	During Guided Take-Off optimised operations, the frequency of occurrence of a longitudinal spacing infringement on the runway leading to a runway conflict shall not be greater than **5x10-7 per movement**	Hz 022 SAC#03b(R.C)

Operational Hazard	Severity (most probable effect)
Hz 020: Failure to maintain the A/C on the runway centreline during the Guided Take-off in LVC based on GBAS	RE-SC 2b/ Imminent Runway Excursion
Hz 021: Failure to maintain the A/C on the runway centreline during the Guided Take-off in LVC based on ILS in mixed GBAS/ILS equipage operations	RE-SC 2b/ Imminent Runway Excursion
Hz 022: Failure to maintain aircraft longitudinal spacing on the runway during guided take-off in LVC	RInc-SC 3/ Runway conflict

Appendix B Consolidated List of Safety Requirements

B.1 Safety Requirements (Functionality and Performance)

B.1.1Safety Requirements in Normal Operational Conditions

SR REF **[SPR Model Element] and [applicability]**	**Safety Requirement (functionality & performance)**	**SO traceability**
SR 005 [ATIS] [CAT III APP]	ATIS shall indicate to the flight crew that GBAS approach is available at the destination aerodrome for the runway currently in use and that LVP are in force	SO#0005
SR 010 [ATIS] [CAT III APP]	ATIS shall indicate to the flight crew that GBAS and ILS approaches are both available at the destination aerodrome if mixed GBAS/ILS operation is implemented for the runway currently in use and that LVP are in force	SO#0005
SR 013 [GAST-D GS] [CAT III APP and Guided T/O]	The operational status of the GBAS landing aid shall be displayed to the Approach and Tower Controllers	SO#0010 SO#0205
SR 014 [APP ATCO] [CAT III APP]	The Approach Controller shall check the operational status of the landing aids (GBAS or GBAS and ILS) before providing the approach clearance	SO#0010
SR 015 [APP ATCO] [CAT III APP]	The Approach Controller shall provide to the flight crew the approach clearance indicating that aircraft is cleared to the GBAS approach when GBAS is the only available landing aid at the destination aerodrome	SO#0010
SR 020 [APP ATCO] [CAT III APP]	The Approach Controller shall provide to the flight crew the approach clearance considering the flight crew expected approach (GBAS or ILS) when both GBAS and ILS approach are available at the destination aerodrome	SO#0010
SR 025 [APP ATCO] [CAT III APP]	For optimised operations in LVP, the Approach Controller shall organize the arriving aircraft sequence considering the aircraft capability as indicated by flight plan information (with or without GBAS capability)	SO#0010
SR 030 [APP SUP] [CAT III APP and Guided T/O]	The approach supervisor shall inform the approach controller that optimised and mixed GBAS/ILS operation in LVP are authorised for the CAT III approach on the runway in use	SO#0010 SO#0205
SR 035 [FCRW] [CAT III APP]	Flight Crew shall inform the Approach Controller about the type of approach that she/he intent to conduct when both GBAS and ILS approach are available at the destination aerodrome considering that the preferred approach should be GBAS if aircraft is GBAS equipped	SO#0011
SR 045 [FCRW] [CAT III APP]	The Flight Crew shall read back to the Approach Controller the approach clearance (GBAS or ILS)	SO#0011
SR 046	At each frequency transfer, Flight Crew shall indicate to the	SO#0011

[FCRW] [CAT III APP]	controller the type of approach that she/he intent to conduct when both GBAS and ILS approach are available at the destination aerodrome	
SR 050 [FCRW] [CAT III APP]	The Flight Crew shall select/tune the GBAS final approach in accordance with the published procedure as soon as she/he has received the approach clearance	SO#0015
SR 055 [FCRW] [CAT III APP and Guided T/O]	The Flight Crew shall check that the GBAS station is correctly tuned by cross-checking the charted GBAS ID (Reference Path Indicator (RPI)) with the GBAS ID (RPI) displayed in the cockpit	SO#0015 SO#0200
SR 060 [FCRW] [CAT III APP and Guided T/O]	The Flight Crew shall check the aircraft GBAS CAT III capability before starting the GBAS approach	SO#0015 SO#0200
SR 065 [APP ATCO] [CAT III APP]	The Approach controller shall provide to the flight crew the clearance for the final interception by specifying the type of landing aid (“cleared for GBAS approach”)	SO#0015
SR 070 [GAST-D A/C] [CAT III APP]	The GAST-D aircraft subsystem shall intercept the GBAS final approach course in accordance with the published approach chart	SO#0015
SR 075 [FCRW] [CAT III APP]	The Flight Crew shall inform the Approach Controller when she/he is established on the GBAS final approach course (“established GBAS approach”).	SO#0015
SR 080 [GAST-D A/C] [CAT III APP]	The GAST-D aircraft subsystem shall intercept the GBAS vertical path in accordance with the published approach chart	SO#0015
SR 085 [APP ATCO] [CAT III APP]	The Approach Controller shall clear the aircraft to the GBAS approach by specifying the RNAV transition to be respected when required	SO#0020
SR 090 [RNAV Sys] [CAT III APP]	The RNAV system shall guide the aircraft in accordance with the published RNAV transition until the GAST-D aircraft subsystem intercepts the GBAS final approach course	SO#0020
SR 091 [Nav DB integrator & packer] [CAT III APP]	The processes of producing and updating the RNAV system navigation data base shall meet the standards specified in EUROCAE ED-76/RTCA DO-200A (e.g. Letter Of Acceptance or equivalent process). In particular, the navigation data base shall contain electronic navigation data with an adequate level of accuracy and integrity to ensure proper transition to the GBAS final approach segment.	SO#0020
SR 092 [Air Operator] [CAT III APP]	The Aircraft Operator shall use a navigation data base for the RNAV system which satisfies the requirements of the IR OPS (or equivalent OPS regulation) in order to meet standards of integrity that are adequate for the intended use of the electronic navigation data	SO#0020
SR 095 [APP ATCO] [CAT III APP]	The Approach Controller shall provide radar vectors to the Flight Crew to intercept the GBAS final approach course when such interception is used	SO#0025

SR 100 [FCRW] [CAT III APP]	The Flight Crew shall verify that glideslope capture is made at the altitude depicted on the chart.	SO#0030
SR 110 [APP ATCO] [CAT III APP]	When radar vectoring is used for the approach interception, the Approach Controller shall provide instructions to Flight Crew allowing the aircraft to be aligned on the final approach course at least 2Nm before FAP	SO#0035
SR 111 [APP ATCO] [CAT III APP]	When radar vectoring is used for the approach interception, the Approach Controller shall provide instructions to Flight Crew allowing the aircraft to intercept the GBAS final approach course with an angle lower than 45º.	SO#0035
SR 115 [Procedure Design] [CAT III APP]	The intermediate approach segment of the GBAS procedure shall be aligned with the final approach course and its segment length shall be sufficient to permit the aircraft to stabilize and establish on the final approach course prior to intercepting the glide path	SO#0035
SR 120 [GAST-D A/C] [CAT III APP]	The aircraft shall be established on the GBAS final approach course at a distance from the FAP sufficient to prevent GBAS glideslope capture from above	SO#0035
SR 125 [FCRW] [CAT III APP]	The Flight crew shall conduct CDO in accordance with instructions and/or limitations specified on the relevant arrival chart for a smooth capture the GBAS glideslope at the altitude depicted on the chart	SO#0040
SR 130 [APP ATCO] [CAT III APP]	The Approach Controller shall not provide radar vectoring instructions to aircraft during optimised CDO if aircraft does not support this capability	SO#0040
SR 135 [Procedure Design] [CAT III APP]	The terrain, obstacle and aerodrome data used in the design of the GBAS CAT III approach procedure shall comply with the appropriate data quality requirements of ICAO Annex 14 and 15 and respect the European Regulation N°73/2010 on the quality of aeronautical data/information.	SO#0045 SO#0165
SR 140 [Procedure Design] [CAT III APP]	The GBAS CAT III procedure shall be designed in accordance with PANS OPS criteria relative to ILS CAT III	SO#045 SO#0165 See A#0035
SR 145 [Procedure Design] [CAT III APP]	The design and validation of the GBAS CAT III procedure shall be made in accordance with the Instrument Flight Procedure process specified in ICAO Doc 9906	SO#0045 SO#0165
SR 155 [GAST-D GS] [CAT III APP and Guided T/O]	The GBAS CAT III final approach segment shall be defined by a FAS data block transmitted by the GAST-D Ground Subsystem to the GAST-D Aircraft Subsystem in accordance with ICAO annex 10 SARPS amended as per ICAO GBAS CAT II-III Development Baseline SARPS proposal dated 28 May 2010	SO#0050 SO#0200
SR 156 [Procedure designer] [CAT III APP and Guided T/O]	GBAS FAS data shall be produced by the procedure design tool in an electronic format in accordance with the FAS file format described in EUROCAE ED-114A Appendix M	SO#0050 SO#0200
SR 157	The GBAS Ground Subsystem shall implement capability to load	SO#0050

[GAST-D GS] [CAT III APP and Guided T/O]	the appropriate FAS data file delivered by the procedure design in accordance with EUROCAE ED-114A Appendix M	SO#0200
SR 160 [AIS provider] [CAT III APP]	The "Radio navigation and landing aids" AIP section shall include the following GBAS information for each airport: Type of aids: GBAS; magnetic variation; GBAS ID (Reference Path Indicator); channel number; hours of operations and the relevant geographical coordinates	SO#0045
SR 165 [AIS provider] [CAT III APP]	The GBAS CAT III approach procedure shall be published in the state AIP in accordance with ICAO Annex 4 and be identified with the title "GLS RWY xx"	SO#0045
SR 170 [AIS provider] [CAT III APP]	The promulgation of the GBAS CAT III approach procedure shall comply with the appropriate data quality requirements of ICAO Annex 15 and respect the European Regulation N°73/2010 on the quality of aeronautical data/information.	SO#0045
SR 175 [GAST-D A/C] [CAT III APP and Guided T/O]	The GAST-D aircraft subsystem shall be compliant with RTCA DO 253C complemented by 9.12 D07 "Specification Definition for mainline aircraft" and 9.12 D16 "Specification Definition for business aircraft" and be reflected in the last effective version of the Ground Based Augmentation System Positioning and Navigation Equipment ETSOs	Normal: SO#0050 SO#0060 SO#0075 SO#0080 SO#0085 SO#0200 Abnormal: SO#0300 SO#0305 SO#0310 SO#0400
SR 180 [GAST-D A/C; Flight Control] [CAT III APP]	The aircraft automatic landing system supported by GAST-D shall be approved in accordance with the applicable airworthiness EASA regulation (CS 25 airworthiness requirements and CS AWO Subpart 1 and 3 amended to consider GAST-D noise model) or equivalent airworthiness regulation (e.g. FAA AC120-XLS).	SO#0050 SO#0060 SO#0075 SO#0080 SO#0085
SR 185 [Air Operator] [CAT III APP and Guided T/O]	The Aircraft Operator shall be approved for GBAS CAT III operations in accordance with IR OPS (EU965/2012) Part SPA (LVO) or equivalent OPS regulation (E.g. FAA)	SO#0050 SO#0060 SO#0075 SO#0080 SO#0085 SO#0200
SR 187 [FCRW] [CAT III APP]	Flight crew shall make an altitude/distance check during GBAS approach between 5 Nm to 3 Nm before the threshold	SO#0050
SR 190 [TWR SUP] [CAT III APP and Guided T/O]	The Tower Supervisor shall inform the Tower Controller that optimised and mixed GBAS/ILS operation in LVP are effective on the current runway in use.	SO#0055
SR 195 [TWR ATCO] [CAT III APP and Guided T/O]	In mixed GBAS/ILS equipage operations, the Tower Controller shall instruct mobiles on the ground to prevent infringement of ILS CAT III critical and sensitive areas during CAT III ILS landing or ILS guided take-off	SO#0055
SR 200 [GAST-D GS] [CAT III APP and Guided T/O]	The GAST-D Ground Subsystem shall be compliant with ICAO Annex 10 SARPS amended as per ICAO GBAS CAT II-III Development Baseline SARPS proposal dated 28 May 2010	Normal: SO#0060 SO#0075 SO#0080 SO#0085 SO#0200 Abnormal: SO#0300 SO#0305 SO#0310 SO#0320

		SO#0325 SO#0400 SO#0405
SR 205 [Flight Inspection] [CAT III APP]	GBAS CAT III Flight Inspection shall be conducted in accordance with ICAO Doc 8071 VOL 2 to confirm ability of the GAST-D Ground Subsystem to support GBAS CAT III operations	SO#0060 SO#0075 SO#0080 SO#0085
SR 210 [GAST-D GS] [CAT III APP and Guided T/O]	GAST-D Ground Subsystem siting shall be carried out in accordance with EUROCAE ED 114 as amended by 15.3.6 D4 requirements (Ground architecture and airport installation)	SO#0060 SO#0075 SO#0080 SO#0085 SO#0200
SR 225 [ATC OPS Status] [CAT III APP]	For mixed GBAS/ILS equipage operations, the aircraft spacing between GBAS –ILS pair shall be established for each operational runway considering that GBAS landed aircraft must have vacated the ILS CAT III sensitive area before the ILS landing aircraft reaches a point at 2Nm from the threshold	SO#0070
SR 230 [APP & TWR ATCO] [CAT III APP]	The Approach and Tower Controller shall provide appropriate aircraft spacing for the considered aircraft pair which could be either GBAS-ILS or GBAS-GBAS or ILS-GBAS pair.	SO#0070 SO#0072
SR 235 [ATC OPS Status] [CAT III APP]	For optimised operations in LVP, the reduced aircraft spacing in front of a GBAS landing shall be established for each runway considering the ILS CAT III sensitive area suppression and the required Runway Occupancy Time (ROT) in Low Visibility Conditions	SO#0072
SR 245 [TWR ATCO] [CAT III APP]	Tower Controller shall provide to the Flight Crew the landing clearance when there is reasonable assurance that separation between the landing aircraft and the other aircraft on the runway (preceding landing or departure) will exist when the landing aircraft crosses the runway threshold.	SO#0090
SR 250 [TWR ATCO] [CAT III APP]	In LVP optimised operations and for GBAS landing, the Tower Controller shall provide to the Flight Crew the landing clearance when the preceding landing (GBAS or ILS) is clear of the Landing Clearance Line.	SO#0095
SR 255 [TWR ATCO] [CAT III APP]	In LVP optimised operations and for GBAS landing, the Tower Controller shall provide to the Flight Crew the landing clearance by 1nm from the threshold at the latest.	SO#0095 SO#0125 SO#0130
SR 260 [TWR ATCO] [CAT III APP]	In LVP optimised operations and for ILS landing, the Tower Controller shall provide to the Flight Crew the landing clearance by 2nm from the threshold at the latest.	SO#0095
SR 265 [TWR ATCO] [CAT III APP] SR modified (initially referring to CAT I holding position)	In GBAS only operation for CAT III, Tower controller shall verify that departing aircraft hold at the CAT III holding position	SO#0100 SO#0135 SO#0140
SR 270 [TWR ATCO] [CAT III APP]	In mixed GBAS/ILS equipage operation for CAT III, Tower controller shall verify that departing aircraft hold at the CAT III holding position whatever the actually flown approach (GBAS or ILS)	SO#0100 SO#0140

SR 275 [FCRW] [CAT III APP]	The aircraft shall vacate the runway, as fast as possible, at a specific runway exit point when required by the Tower Controller and if accepted by the Flight Crew	SO#0105 Hz 004; Hz 008 & Hz 021
SR 280 [TWR ATCO] [CAT III APP]	In LVP optimised operations with mixed GBAS/ILS equipage and during an ILS landing, the Tower controller shall request the flight crew of the preceding landing to report when she/he has passed the CAT III Line if doubt exists on the exact location of the aircraft on the ground	SO#0110
SR 285 [TWR ATCO] [CAT III APP]	During a GBAS CAT III landing in optimised operation, the Tower controller shall request the flight crew of the preceding landing to report when she/he has passed the CAT I Line if doubt exists on the exact location of the aircraft on the ground	SO#0110
SR 290 [FCRW] [CAT III APP]	In LVP optimised operations and when required by the Tower controller, the flight crew shall report to the controller that the runway is vacated when the entire aircraft has passed a point which is the CAT I line during a GBAS landing or the CAT III line during an ILS landing.	SO#0110
SR 295 [Rwy Safety Net] [CAT III APP]	In LVP optimised operations with mixed GBAS/ILS equipage and during an ILS CAT III landing, the Runway safety Net, if fitted, shall alert the Tower Controller when a mobile is inside the ILS CAT III Critical and Sensitive Area (CSA)	SO#0120
SR 300 [Rwy Safety Net] [CAT III APP]	During a GBAS CAT III landing in optimised operation, the Runway safety Net, if fitted, shall not alert the Tower Controller when a mobile is outside the landing clearance line area but inside the ILS CAT III Critical and Sensitive Area (CSA)	SO#0120
SR 301 [Rwy Safety Net] [CAT III APP]	During a GBAS CAT III landing in optimised operation, the Runway safety Net, if fitted, shall alert the Tower Controller when a mobile has infringed the landing clearance line	SO#0120
SR 310 [TWR ATCO] [CAT III APP]	In LVP optimised operations with mixed GBAS/ILS equipage and for an ILS CAT III landing, the Tower Controller shall provide the landing clearance to the flight crew when the preceding landing aircraft has passed the ILS CAT III Critical and Sensitive Area (CSA)	SO#0130
SR 315 [Grd Surv; ATC OPS Status] [CAT III APP]	The landing clearance line shall be established no closer than 77,5m from runway centreline on runways where Super Heavy aircraft operate.	SO#0145
SR 320 [Grd Surv; ATC OPS Status] [CAT III APP]	The landing clearance line shall be established no closer than 60m from runway centreline on runways where Super Heavy aircraft do not operate.	SO#0145
SR 325 [Grd Surv; ATC OPS Status] [CAT III APP]	When considering the landing clearance line, the current holding positions (positioned in accordance to Annex 14 not closer to 90m from runway centre line or 107.5 m when Super Heavy aircraft operate) up to a distance of 900m after the threshold shall be maintained.	SO#0145
SR 330 [FCRW] [CAT III APP]	Flight Crew shall monitor operational conditions and technical capabilities at the Decision Height (DH) or at the Alert Height (for operations conducted with no DH) to decide if GBAS CAT III	SO#0150

	approach can be continued	
SR 335 [FCRW] [CAT III APP]	During GBAS CAT III approach conducted with DH, Flight Crew shall execute a missed approach at DH if visual references not acquired	SO#0155
SR 340 [FCRW] [CAT III APP]	During GBAS CAT III approach conducted with no DH, Flight Crew shall execute a missed approach at or below the Alert Height in case of aircraft capability and/or performance degradation impacting the CAT III landing and if visual references not acquired	SO#0160
SR 345 [Procedure Design] [CAT III APP]	For parallel runway operations, nominal tracks of the two missed approach procedures shall diverge by at least 30° and the associated missed approach turns shall be specified as "as soon as practicable".	SO#0166
SR 350 [ATC OPS Status] [CAT III APP]	In LVP optimised operations, the aircraft spacing between different aircraft pairs (GBAS-GBAS, ILS-GBAS and GBAS-ILS) shall be established to ensure that the need for issuing go-around is minimised.	SO#0170
SR 355 [FCRW] [CAT III APP]	During GBAS CAT III approach, Flight Crew shall execute a missed approach if excessive lateral and/or vertical deviation are detected	SO#0170
SR 360 [FCRW] [CAT III APP]	When the aircraft capability downgrade from CAT III to CAT I due to GBAS, Flight Crew shall either execute a missed approach immediately or continue the approach down to CAT I minima and execute a missed approach if CAT I visibility conditions are not met.	SO#0520
SR 365 [Procedure Design] [CAT III APP]	Arrival and Departing routes in TMA shall be designed to reduce the risk of separation infringement when considering the possibility of having multiple and simultaneous missed approaches following a GBAS failure	SO#0600
SR 370 [Procedure Design] [CAT III APP]	GBAS Missed approaches for a given aerodrome shall be designed to reduce the risk of separation infringement when considering the possibility of having multiple and simultaneous missed approaches following a GBAS failure	SO#0600
SR 375 [APP & TWR ATCO] [CAT III APP]	ATC contingency procedures in terminal area shall be defined to address the situation where multiple GBAS missed approaches are executed simultaneously following a GBAS failure	SO#0600
SR 400 [Flight Control] [Guided T/O]	The directional guidance for take-off in low visibility supported by GAST-D shall be approved in accordance with applicable airworthiness EASA regulation (CS 25 airworthiness requirements and CS AWO Subpart 4 amended to consider GAST-D noise model) or equivalent regulation (e.g. FAA).	SO#0200
SR 405 [Flight Inspection] [Guided T/O]	Flight Inspection shall be conducted in accordance with ICAO Doc 8071 VOL 2 to confirm the ability of the GAST-D Ground Subsystem to support Guided Take-Off operations considering that GBAS Signal shall be received by the Aircraft during taxi-in operation.	SO#0060 SO#0200

SR 410 [TWR ATCO] [Guided T/O]	The Tower Controller shall check the operational status of the landing aids (GBAS or GBAS and ILS) before providing the Take-Off clearance	SO#0205
SR 415 [TWR ATCO] [Guided T/O]	For optimised operations in LVP, the Tower Controller shall organize the departing aircraft sequence considering the aircraft capability as indicated by flight plan information (with or without GBAS capability)	SO#0205
SR 420 [TWR ATCO] [Guided T/O]	The Tower Controller shall provide the Take-Off clearance to the flight crew indicating that aircraft is cleared for a GBAS Take-Off or an ILS Take-Off.	SO#0205
SR 425 [FCRW] [Guided T/O]	The Flight Crew shall read back to the Tower Controller the Take-Off clearance	SO#0205
SR 430 [TWR ATCO] [Guided T/O] SR modified (initially referring to CAT I holding position)	During a guided Take-Off at an aerodrome with GBAS only operations, Tower controller shall verify that other departing aircraft hold at the CAT III holding position	SO#0050
SR 435 [TWR ATCO] [Guided T/O]	During a guided Take-Off in mixed GBAS/ILS operations, Tower controller shall verify that other departing aircraft hold at the CAT III holding position whatever the guided Take-Off (GBAS or ILS)	SO#0210
SR 440 [FCRW] [Guided T/O]	During a guided Take-Off in LVC based on GBAS or ILS, Flight Crew shall abort the take-off if excessive lateral deviation are detected and lateral path correction impossible	SO#0550
SR 445 [AIS provider] [Guided T/O]	The GBAS channel number to be used by the flight crew for guided take-off shall be provided on aerodrome publication (e.g. departure chart)	SO#0200

B.1.2 Safety Requirements in Abnormal Operational Conditions

SR REF [SPR Model Element] and [applicability]	Safety Requirement (functionality & performance)	SO traceability
SR 500 [GAST-D GS]; [Maintenance Activity]; [Engineering Activity] [CAT III APP; Guided T/O]	The GAST-D Ground Station siting requirements shall include measures taking into account the effect of ionospheric disturbances.	SO#0300 SO#0305 SO#0310 SO#0400
SR 505 [GAST-D GS]; [Maintenance Activity]; [Engineering Activity] [CAT III APP] and [Guided T/O]	Antenna height shall be determined on the basis of generic multipath considerations and risk of jamming and on-site activities	SO#0315 SO#0320 SO#0325 SO#0405

SR REF [SPR Model Element] and [applicability]	Safety Requirement (functionality & performance)	SO traceability
SR 510 [ANSP Frequency Manager] [CAT III APP] and [Guided T/O]	Regulatory material in line with the applicable standards shall be defined and applied to ensure the operation of aeronautical equipment is free from radio frequency interference in the ARNS frequency range.	SO#0315 SO#0320 SO#0325 SO#0405
SR 515 [Maintenance Activity]; [GAST-D GS] [CAT III APP] and [Guided T/O]	The GBAS service provider shall define interference monitoring and control procedures, such that: a. The interference environment at the reference receivers' sites is proven to be lower than the nominal interference environment, before the start of operations, and b. The GBAS GAST-D service is cancelled whenever the interference environment at the reference receivers sites is higher than the nominal interference environment.	SO#0315 SO#0320 SO#0325 SO#0405
SR 520 [ANSP Engineering Activity]; [Flight Inspection]; [Maintenance Activity]; [GAST-D GS] [CAT III APP] and [Guided T/O]	Interference assessment shall be conducted by means of: a. Ground tests shall be conducted during siting of the ground subsystem to verify the level of RFI complies with ED-114A App. E b. Flight tests during flight check of all GBAS approaches supported by a GBAS ground facility	SO#0315 SO#0320 SO#0325 SO#0405
SR 525 [Maintenance Activity]; [APP/TWR ATCo] [CAT III APP] and [Guided T/O]	If interference is confirmed, maintenance procedures shall ensure that the approach procedure be removed from operational status and pending corrective action and appropriate authorities be notified.	SO#0315 SO#0320 SO#0325 SO#0405
SR 530 [Maintenance Activity]; [GAST-D GS] [CAT III APP] and [Guided T/O]	Airport maintenance procedures shall include the maintenance and repairing of fencing/ barriers, if they exist, designed to block interfering signals	SO#0315 SO#0320 SO#0325 SO#0405
SR 535 [GAST-D GS] [CAT III APP] and [Guided T/O]	The GBAS GNSS receiver antennas shall have as little horizontal surfaces as possible. If slanted surfaces are used, these should have a sufficient angle relative to horizontal plane to allow snow to slide off	SO#0060 SO#0080 SO#0085 SO#0200
SR 540 [GAST-D GS] [CAT III APP] and [Guided T/O]	The antenna height shall be adapted to local snow conditions.	SO#0060 SO#0080 SO#0085 SO#0200

SR REF [SPR Model Element] and [applicability]	Safety Requirement (functionality & performance)	SO traceability
SR 545 [Maintenance Activity] [CAT III APP] and [Guided T/O]	Snow removal and prevention procedures shall be put in place to prevent build-up of snow: a. Above ¾ of the mast height inside the inner LOCA b. Above 3 degrees as seen from the antenna base in the intermediate LOCA c. In areas where snow is likely, GBAS GNSS receiver antennas shall be polished each autumn.	SO#0060 SO#0080 SO#0085 SO#0200
SR 550 [ANSP Engineering Activity] and [GAST-D GS] [CAT III APP] and [Guided T/O]	The GNSS Antennas shall not be sited in areas with poor drainage, or, alternatively, the GNSS ground subsystem design shall allow siting in water accumulation zones without performance impact.	SO#0060 SO#0080 SO#0085 SO#0200
SR 555 [ANSP Engineering Activity] and [GAST-D GS] [CAT III APP] and [Guided T/O]	The ANSP shall check that local meteo parameter (rainfall, wind, snow, etc) values do not surpass those indicated in specifications	SO#0060 SO#0080 SO#0085 SO#0200
SR 560 [ANSP Engineering Activity] [CAT III APP] and [Guided T/O]	Siting activities (data logging) shall be carried out during normal operation of the airport, and all operational modes shall be considered for impact on the GBAS Ground Subsystem. If missed approaches do not occur during siting, they shall be assessed on a theoretical basis.	SO#0060 SO#0080 SO#0085 SO#0200
SR 565 [ANSP Engineering Activity] [CAT III APP] and [Guided T/O]	The GBAS service provider shall define co-ordination procedures with the airport authority regarding GBAS siting and building activities in the vicinity of the GBAS equipment. The airport authority shall validate such procedures.	SO#0060 SO#0080 SO#0085 SO#0200
SR 570 [ANSP Engineering Activity] and [Maintenance Activity] [CAT III APP] and [Guided T/O]	The GBAS service provider shall define a building restricted area management process which should contain, at least: a. Awareness of GBAS Ground Subsystem installations when planning new infrastructure; b. A pre-installation evaluation to see if constructions may adversely affect the GBAS SiS; and Maintenance procedures which shall ask for re-assessments of GBAS parameters if construction in the vicinity of the airport is detected.	SO#0060 SO#0080 SO#0085 SO#0200
SR 575	The GBAS GS manufacturer shall define a minimum number of	SO#0060

SR REF [SPR Model Element] and [applicability]	Safety Requirement (functionality & performance)	SO traceability
[GAST-D GS] [CAT III APP] and [Guided T/O]	installed antennas/receivers for achieving a GAST D performance level . Antenna separations shall be determined based on multipath and ionospheric gradient monitoring risks.	SO#0080 SO#0085 SO#0200
SR 580 [GAST-D GS] and [ANSP Engineering Activity] [CAT III APP] and [Guided T/O]	The GBAS ground subsystem design shall include measures to avoid unsafe operation due to excessive multipath. A multipath assessment shall be performed for each GAST-D site. *Note: see SR200 as well.*	SO#0060 SO#0080 SO#0085 SO#0200
SR 585 [Procedure design] [CAT III APP]	The GBAS II/III approach missed procedure shall be either: a)based on conventional navaids, or b) based on GNSS. In this case, the GBAS CAT II/III operational approval shall require operators to define and implement (at least) one extraction contingency procedure per approach.	SO#0340
SR 590 [Air Operator] and [Flight Crew] [CAT III APP]	If a GBAS CAT II/III missed approach is based on GNSS, the airspace user's operating procedures shall be updated and flight crews shall be trained to conduct extraction contingency procedures in case of common GBAS and GNSS loss.	SO#0315 SO#0320 SO#0325 SO#0340 SO#0405
SR 595 [Procedure design]; [AIS Provider]; [Air Operator];[Flight Crew] [CAT III APP]	If a GBAS CAT II/III missed approach is based on GNSS, the GBAS service provider shall promulgate in the AIP the need for a contingency extraction procedure and the conditions to be complied with by local GBAS CAT II/III operators.	SO#0315 SO#0320 SO#0325 SO#0340 SO#0405
SR 600 [Air Operator] and [Flight Crew] [CAT III APP]	Airspace users' GBAS CAT II/III flight planning procedures, and flight crew training, shall ensure in preflight phase that sufficient conventional means are available to navigate and land, at least, at an alternate aerodrome in the case of loss of GNSS-based navigation.	SO#0330
SR 640 [GAST-D GS], [GAST-D A/C], [Display & Guidance]; [Flight Crew] [CAT III APP]	The Flight Crew shall be alerted in case of GBAS approach unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances and shall execute a Go-around.	SO#0300
SR 645 [GAST-D GS]; [APP/TWR ATCo] [CAT III APP]	The APP and TWR ATCOs shall be alerted of GBAS approach unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances	SO#0300
SR 650 [GAST-D GS], [GAST-D	The Flight Crew shall be alerted in case of of GBAS landing unavailability (including detectable GBAS hazardously misleading	SO#0305

SR REF [SPR Model Element] and [applicability]	Safety Requirement (functionality & performance)	SO traceability
A/C], [Display & Guidance]; [Flight Crew] [CAT III APP]	indication) due to ionospheric disturbances.and shall execute a Go-around.	
SR 655 [GAST-D GS]; [APP/TWR ATCo] [CAT III APP]	The APP and TWR ATCOs shall be alerted of GBAS landing unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances.	SO#0305
SR 660 [Display & Guidance]; [Flight Crew] [CAT III APP]	The Flight Crew shall be trained in go-arounds from positions other than DA/MDA and the designated Stabilised Approach Gate.	SO#0305
SR 665 [GAST-D GS], [GAST-D A/C], [Display & Guidance]; [Flight Crew] [CAT III APP]	The Flight Crew shall be alerted in case of of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances.and shall execute a Go-around	SO#0310
SR 670 [GAST-D GS]; [APP/TWR ATCo] [CAT III APP]	The APP and TWR ATCOs shall be alerted of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to ionospheric disturbances.	SO#0310
SR 675 [GAST-D GS], [GAST-D A/C], [Display & Guidance]; [Flight Crew] [CAT III APP]	The Flight Crew shall be alerted in case of of GBAS approach unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference and shall execute a Go-around	SO#0315
SR 680 [GAST-D GS]; [APP/TWR ATCo] [CAT III APP]	The APP and TWR ATCOs shall be alerted of GBAS approach unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference.	SO#0315
SR 685 [GAST-D GS], [GAST-D A/C], [Display & Guidance]; [Flight Crew] [CAT III APP]	The Flight Crew shall be alerted in case of GBAS landing unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference and shall execute a Go-around.	SO#0320
SR 690 [GAST-D GS]; [APP/TWR ATCo] [CAT III APP]	The APP and TWR ATCOs shall be alerted of GBAS landing unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference.	SO#0320
SR 695 [GAST-D GS], [GAST-D A/C], [Display & Guidance]; [Flight Crew] [CAT III APP]	The Flight Crew shall be alerted in case of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference and shall execute a Go-around.	SO#0325

SR REF [SPR Model Element] and [applicability]	Safety Requirement (functionality & performance)	SO traceability
SR 700 [GAST-D GS]; [APP/TWR ATCo] [CAT III APP]	The APP and TWR ATCOs shall be alerted of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference.	SO#0325
SR 705 [GAST-D GS], [GAST-D A/C], [Display & Guidance]; [Flight Crew] [Guided T/O]	The Flight Crew shall be alerted in case of GBAS guided take-off unavailability before main wheel lift-off (including GBAS hazardously misleading indication) due to ionospheric disturbances and shall abort the take-off.	SO#0400
SR 710 [GAST-D GS]; [APP/TWR ATCo] [Guided T/O]	The TWR ATCOs shall be alerted of GBAS rollout unavailability (including detectable GBAS hazardously misleading indication) due to GPS or VHF interference.	SO#0400
SR 715 [GAST-D GS], [GAST-D A/C], [Display & Guidance]; [Flight Crew] [Guided T/O]	The Flight Crew shall be alerted in case of GBAS guided take-off unavailability before main wheel lift-off (including GBAS hazardously misleading indication) due to GPS or VHF interference and shall abort the take-off.	SO#0405
SR 720 [GAST-D GS]; [APP/TWR ATCo] [Guided T/O]	The TWR ATCO shall be alerted of GBAS approach unavailability before main wheel lift-off (including GBAS hazardously misleading indication) due to GPS or VHF interference.	SO#0405

B.1.3 Safety Requirements(Mitigation to System generated Hazards)

Reference [SPR Model Element]]	Mitigation to System generated Hazards	Hazards traceability
SR 800 [Maintenance activity]	When Maintenance tasks/actions can potentially affect the integrity performance of the Ground Subsystem, these actions/tasks shall be categorized as Level B maintenance tasks. See Appendix G for more guidance	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 805 [Maintenance activity]	When Maintenance tasks/actions can potentially affect the continuity of service performance of the Ground Subsystem, these actions/tasks shall be categorized as Level A maintenance tasks. See Appendix G for more guidance	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 810 [Maintenance	ANSP shall define procedure, training and competence scheme allowing to reach Level A and Level B maintenance task categories applicable to	Hz 003 Hz 005

Reference [SPR Model Element]]	**Mitigation to System generated Hazards**	**Hazards traceability**
activity]	GBAS CAT III ground subsystem See Appendix G for more guidance	Hz 006 Hz 007 Hz 020
SR 815 [Maintenance activity]	Maintenance personnel shall be trained on GBAS area (LOCA) management	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 820 [APP/TWR ATCO]	If LOCA has an impact on operations (e.g. part of taxiway including in LOCA), the Tower Controller shall be trained to manage this area	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 825 [APP/TWR ATCO]	Procedure shall be defined to prevent the ATCO approach deselection when an aircraft is on the final approach or is landing	Hz 003 Hz 005 Hz 006 Hz 007 Hz 020
SR 830 [Flight Crew]	Operational Procedure shall be defined and Flight Crew shall be trained to inform ATCO in case of reversion from a GBAS approach to ILS approach	Hz 004
SR 835 [ANSP]	An ATC local assessment shall be conducted to determine the acceptability of the aircraft spacing reduction of 1Nm in front of GBAS landing (and eventually to determine a greater reduction) supported by an operational transition phase applied in non-LVP visibility condition	Hz 004 Hz 008
SR 840 [Flight Crew]	Operational Procedure shall be defined and Flight Crew shall be trained to inform ATCO in case of reversion from GBAS to ILS Guided Take-Off	Hz 021
SR 845 [APP/TWR SUP]	For mixed GBAS/ILS equipage operations, the aircraft spacing between arrival and departure shall be established for each operational runway	Hz 008 Hz 021 Hz 022
SR 850 [APP/TWR SUP]	For mixed GBAS/ILS equipage operations, the aircraft spacing between GBAS-ILS departing aircraft shall be established for each operational runway	Hz 022
SR 855 [APP/TWR ATCO]	For optimised operations in LVP, the Tower Controller shall provide appropriate aircraft spacing between arrival and departure for the considered aircraft pair which could be either GBAS-ILS or GBAS-GBAS or ILS-GBAS pair	Hz 021 Hz 022
SR 860 [GAST-D GS]	The GBAS Ground Subsystem shall include a capability to perform plausability checks during new FAS data file loading as identified in EUROCAE ED-114A Appendix M	Hz 002;Hz 003; Hz 005; Hz 006; Hz 007; Hz 020

B.2 Safety Requirements (Integrity)

Reference	Safety Requirement (Integrity/reliability)	Hazards
SIR#001 [GAST D GS]	A GAST D Ground Subsystem integrity failure shall not occur more frequently than $1x10^{-9}$ in any landing	**Hz 003** **Hz 006** Hz 002 Hz 005 Hz 007 Hz 020
SIR#002 [GAST D Aircraft Subsystem]	A GAST D Aircraft Subsystem integrity failure shall not occur more frequently than $1x10^{-9}$ in any landing	**Hz 003** **Hz 006** Hz 002 Hz 005 Hz 007 Hz 020
SIR#003 [GAST D GS]	A GAST D Ground Subsystem continuity of service failure shall not occur more frequently than $2x10^{-6}$ during any 15 sec interval	**Hz 003** **Hz 006** Hz 005 Hz 007 Hz 020
SIR#004 [GAST D Aircraft Subsystem]	A GAST D Aircraft Subsystem continuity of service failure shall not occur more frequently than $2x10^{-6}$ during any 15 sec interval	**Hz 003** **Hz 006** Hz 005 Hz 007 Hz 020
SIR#005 [RNAV and Conv nav Syst]	A RNAV/RNP airborne system failure to follow the transition shall not occur more frequently than $1x10^{-7}$ per approach	**Hz 002**
SIR#006 [Aircraft automatic landing system]	An A/C automatic landing system integrity failure shall not occur more frequently than $1x10^{-9}$ in any landing	**Hz 003** **Hz 006** Hz 005 Hz 007 Hz 020

Reference	Safety Requirement (Integrity/reliability)	Hazards
SIR#007 [Aircraft automatic landing system]	An A/C automatic landing system continuity of service failure shall not occur more frequently than $1x10^{-7}$ during any 15 sec interval	**Hz 003** **Hz 006** Hz 005 Hz 007 Hz 020
SIR#008 [Aircraft roll-out guidance system]	An A/C roll-out guidance system integrity failure shall not occur more frequently than $1x10^{-9}$ in any landing	Hz 007
SIR#009 [Aircraft roll-out guidance system]	An A/C roll-out guidance system continuity of service failure shall not occur more frequently than $1x10^{-7}$ during any 15 sec interval	Hz 007
SIR#010 [Aircraft roll-out guidance system]	An A/C take-off guidance system integrity failure shall not occur more frequently than $1x10^{-7}$ in any take-off	Hz 020
SIR#011 [Aircraft roll-out guidance system]	An A/C take-off guidance system continuity of service failure shall not occur more frequently than $1x10^{-5}$ during any 60 sec interval	Hz 007

Appendix C Assumptions, Safety Issues, Recommendation, Limitations & Validation items

C.1 Assumptions log

The following Assumptions were necessarily raised during the safety assessment:

Assumption ref [origin]	Safety Assumption	Validation
	CAT III approach and Landing	
A#0001 [OSED level]	For GBAS only operation, ILS CAT III critical and sensitive areas do not need to be protected	GBAS OSED [5]
A#0002 [OSED level]	For mixed mode runway operation (arrival/departure), the Obstacle Free Zone (OFZ) shall be protected when a departing aircraft holds the CAT I holding position, if holding 900 meters or more down the runway	ICAO Annex 14
A#0003 [OSED level]	GBAS siting on the aerodrome prevents detrimental impact on GAST D operations in particular prevention of correlated multipath effects when mobiles (aircraft or vehicles) circulate on the aerodrome surface.	GBAS Ground Architecture & airport installation [25]
A#0010 [OSED level]	For CAT III parallel approaches, ATC uses radar surveillance to monitor the interception of the parallel final approaches	PANS-ATM (current ATC procedures for independent parallel approaches)
A#0015 [OSED level]	Despite the CAT III optimised operations and the possible reduction of aircraft spacing in LVC, ATC still applies minimum radar separation and wake turbulence separation on the final approach	PANS-ATM (current ATC procedures)
A#0020 [OSED level]	ATC uses radar surveillance to monitor separation between aircraft flying CAT III parallel approaches	PANS-ATM (current ATC procedures for independent parallel approaches)
A#0025 [OSED level]	For CAT III parallel approaches and when an aircraft is observed penetrating the NTZ, the aircraft on the adjacent final approach track shall be instructed by ATC to immediately climb and turn to the assigned altitude/height and heading in order to avoid the deviating aircraft	PANS-ATM (current ATC procedures for independent parallel approaches)
A#0030 [OSED level]	For CAT III optimised operations, ATC uses an airport surveillance system for the runway conflict prevention(e.g. A-SMGCS level 1)	To be validated for each local implementation
A#0035 [OSED level]	The obstacle clearance during a GBAS CAT III approach is the same compared to ILS CAT III	Not fully validated Current PANS-OPS criteria for ILS approach applies to GBAS but specific criteria might be specified in the future by ICAO IFPP
A#0045 [SPR level]	ATC updates ATIS to provide the relevant landing aid information for the runway currently in use (GBAS only or both GBAS and ILS) and the LVP conditions (RVR)	Normal procedure for ATC

Assumption ref [origin]	Safety Assumption	Validation
A#0050 [SPR level]	Flight crew is responsible for the approach choice when both GBAS and ILS approach are available at the destination aerodrome	Basic airmanship
A#0055 [SPR level]	Optimised operations are always implemented at the destination aerodrome when GBAS is the only available landing aid	To be verified for each implementation
A#0060 [SPR level]	The Flight Plan system is updated to process the GBAS capability as specified in FPLN field 10.	New ICAO flight Plan form (2012)
A#0061 [SPR level]	The aircraft GBAS audio identification function is not available	Acceptable considering that flight-crew miss-tuning will be detected by the check of the Reference Path Identifier procedure (SR#055) and that audio ident is not transmitted by the ground station and therefore not used to indicate e.g. an ongoing maintenance activity on the ground station
A#0063 [SPR level]	The aircraft capability to fly the RNAV transition of the GBAS approach is indicated on the approach chart (e.g. RNP 1, GNSS required, RF required,…)	Charting in accordance with ICAO Annex 4 and PBN manual (Doc 9613)
A#0064 [SPR level]	RNAV transition (RNAV/RNP initial/intermediate approach segments) are designed in accordance with PANS-OPS criteria amended by ICAO letter SP65/4-13/24 (14 June 2013) if RF leg are used.	Future ICAO PANS-OPS criteria for design of RF leg
A#0065 [SPR level]	The Flight Crew respect the RNAV system guidance during the RNAV transition of the GBAS approach	Basic airmanship
A#0070 [SPR level]	The Flight Crew respect the radar vectors and prepare the transition for the interception of the GBAS final approach course	Basic airmanship
A#0071 [SPR level]	Maintenance of ATS systems is conducted by Air Traffic Safety Electronics Personnel (ATSEP) qualified and trained in accordance with the European Commission Regulation No 1035/2011 laying down common requirements for the provision of air navigation services which, in its Annex II Section 3.3 sets out "Safety requirements for engineering and technical personnel undertaking operational safety related tasks". ATSEP in charge of GBAS equipment have obtained the appropriate qualification in Navigation discipline.	Compliance with European Commission Regulation No 1035/2011
A#0075 [SPR level]	Aircraft speeds during a GBAS approach and landing operation are identical to ILS approach and landing operations when considering identical conditions (wind, temperature, weight, CG…),	Validated by Airframer

Assumption ref [origin]	Safety Assumption	Validation
A#0080 [SPR level] From abnormal conditions	Frequency coordination activities are performed by the ANSPs to avoid radio frequency interference in the NAV frequency range (108 – 118 MHz), including ILS/GBAS interference.	To be verified for each implementation
A#0085 [SPR level] From abnormal conditions	GBAS GAST D equipment always contains RFI mitigations (e.g. an RFI monitor).	To be verified when GAST-D MOPS are published.
A#0090 [SPR level] From abnormal conditions	The snowfall required for causing a GBAS SIS loss of continuity always triggers the airport's standard procedures for capacity decrease handling and alternate airports re-routing.	To be verified for each implementation
A#0095 [SPR level] From abnormal conditions	The volume of volcanic ash in the atmosphere required for causing GBAS SIS losses of continuity or availability always prevents GBAS flights to be conducted.	To be verified for each implementation
A#0100 [SPR level] From abnormal conditions	If earthquake damages displace threshold position in a precision approach runway, CAT II/III operations are stopped.	To be verified for each implementation
A#0105 [SPR level] From abnormal conditions	If AMAN is used to sequence arrival traffic for CAT III approach optimised operations: a. The ANSP has updated the AMAN sequencing criteria to allow for a greater separation between GBAS-ILS pairs than between ILS-GBAS or GBAS-GBAS pairs. b. ATCos using AMAN have been informed of the greater separation between GBAS-ILS pairs than between ILS-GBAS or GBAS-GBAS pairs. c. The ATC AMAN procedures have been updated with the greater separation between GBAS-ILS pairs.	To be verified for each implementation
A#0110 [SPR level] From abnormal conditions	Conventional navaids supporting GBAS CAT II/III missed approaches comply with the applicable requirements in ICAO Annex 10 and are regularly flight-inspected and maintained according to EU regulation 1035/2011 (or equivalent).	Conventional navigation providers are certified by their local Authority.
A#0115 [SPR level] From abnormal conditions	If a GBAS CAT II/III missed approach is based on GNSS, aircraft operators have received operational approvals corresponding to the PBN navigation specification(s) used in the Missed approach.	Aircraft Operators have received the necessary supplementary operational approvals from their local Authority.
A#0120 [SPR level] From abnormal conditions	All GBAS CAT II/III capable aircraft are equipped with inertial navigation systems providing accurate navigation on the missed approach on a short term basis.	To be verified for each implementation See limitation LIM#0003 below.
A#0125 [SPR level] From abnormal	All iono events which can impact both the GBAS GAST-D and GNSS-based RNAV/RNP missed	To be verified for each implementation

Assumption ref [origin]	Safety Assumption	Validation
conditions	approach guidances can be considered as "very large".	
A#0200 [Flight Crew] Hz 002	When selecting a flight procedure, such as RNAV/RNP STAR or transition, pilot cross-check the procedure inserted in the RNAV system with the published chart	Basic airmanship
A#0205 [Flight Crew] Hz 002	During RNAV/RNP transition, Flight crew verify that trajectory on the navigation display matches with the selected final approach and that indicated GBAS lateral deviation is converging.	Basic airmanship
A#0210 [Flight Crew] Hz 004 and Hz 008	If aircraft is too slow to vacate the runway, ATCO gives instructions to expedite runway vacation.	Normal procedure for ATC
A#0215 [Flight Crew] Hz 004 and Hz 008	During CAT III approach, the Flight Crew respect speed instructions given by ATCO	Basic airmanship
A#0220 [Flight Crew] Hz 008	During CAT III approach, the Flight Crew respect the landing clearance given by ATCO	Basic airmanship
A#0225 [Flight Crew] Hz 008	The Flight Crew reads back the Take-Off clearance and starts take-off roll immediately	Basic airmanship
Guided-Take-Off		
A#0001 [OSED level]	See above	See above
A#0005 [OSED level]	Back course take-off is not used with GBAS	GBAS could serve all QFU of an airport whereas ILS does not.
A#0040 [OSED level]	For guided Take-Off operations in LVC, ATC uses an airport surveillance system for the runway conflict prevention (e.g. A-SMGCS level 1)	To be validated for each local implementation
A#0080 to A#0100 [SPR level] From abnormal conditions	See above	See above
A#0210 [Flight Crew] Hz 021	If aircraft is too slow to vacate the runway, ATCO gives instructions to expedite runway vacation.	Normal procedure for ATC
A#0215 [Flight Crew] Hz 022	During CAT III approach, the Flight Crew respect speed instructions given by ATCO	Basic airmanship

Assumption ref [origin]	Safety Assumption	Validation
A#0220 [Flight Crew] Hz 022	During CAT III approach, the Flight Crew respect the landing clearance given by ATCO	Basic airmanship
A#0225 [Flight Crew] Hz 022	The Flight Crew reads back the Take-Off clearance and starts take-off roll immediately	Basic airmanship
A#0230 [Flight Crew] Hz 021	During a guided Take-Off in mixed GBAS/ILS operations, Flight Crew of the departing aircraft hold at the CAT III holding position whatever the navaid supporting the guided Take-Off (GBAS or ILS)	To be validated for each local implementation
A#0235 [Flight Crew] Hz 022	During CAT III approach, the Flight Crew respect the line-up clearance given by ATCO	Basic airmanship

C.2 Safety Issues log

The following Safety Issues were necessarily raised during the safety assessment:

Issue ref [origin]	Safety Issue	Status
	CAT III approach and Landing	
I#002 [SPR leve]	The phraseology to be used for GBAS approaches (GBAS or GLS) shall be clarified at ICAO level and should be determined to prevent any confusion with other landing aids (ILS or MLS).	Open to be solved at ICAO level
I#003 [SPR level]	It should be determined if a GAST-D Ground Station failure mode could lead to a situation where two aircraft flying a parallel approach might diverge from their trajectories and be on convergent paths when the station is serving both approaches.	Open to be solved in 15.3.6 T33
	Guided-Take-Off	
I#001 [OSED level]	It should be clarified if optimised operation for guided take-off in LVC is required	Closed. No optimised operation for guided Take-Off

C.3 Recommendation log

The following Recommendations were necessarily raised during the safety assessment:

Rec ref [origin]	Safety Recommendation	Status
	CAT III approach and Landing	
REC#0001 [OSED level]	It is recommended that the aircraft guidance remains coupled to the FMS/RNAV system for the capture of the GBAS approach path if ATC vectoring is not provided by ATC	Open to be considered by Project 06.08.08 for SESAR Solution#09 (Enhanced terminal operation with automatic RNP transition to xLS and LPV).

Rec ref [origin]	Safety Recommendation	Status
REC#0002 [OSED level]	For GBAS parallel approaches, the Final Approach Point(FAP) could be located at different position/altitude to establish strategic separation between the two approaches flows	This REC became a Safety Objective (SO#0510) when radar vectoring is not used to intercept the final approach tracks of parallel approaches.
REC#0003 [OSED level]	It is recommended that aircraft displays the distance to runway-end after passing the runway threshold to ease ROT reduction. Other means are also possible, for instance brake-to vacate or "countdown" lights before a runway exit or specific guidance lights towards the suitable exits.	Open
REC#0004 [OSED level]	It is recommended that the aircraft guidance remains coupled to the FMS/RNAV system during the missed approach procedure if the missed approach is based on RNAV/RNP.	Open
REC#0006 [OSED level]	For CAT III optimised operations, it is recommended that a Final Approach Runway Occupancy system (e.g. FAROS) alert an approaching aircraft when a risk of runway occupancy by a vehicle or another aircraft is detected.	Open
REC#0007 [SPR level]	Naming and phraseology used for GBAS should be consistent for flight crew and controllers when considering radiotelephony communications, charting information, ATC displayed information and flight deck indication.	Open to be considered at ICAO level
REC#0020 [SPR level] From abnormal conditions	Depending on ionospheric conditions, the risk of exposure to scintillations should be taken into account in the GAST-D Ground Station monitor design.	Open
REC#0021 [SPR level] From abnormal conditions	The stability of the ground antenna foundation should be considered with respect to the selected ionospheric gradient monitoring scheme.	Open (to be assessed for each implementation). It should be assessed by a soil assessment prior to the installation.
REC#0022 [SPR level] From abnormal conditions	MET and AIS providers should undertake specific studies in order to assess the feasibility of space weather forecast integration into the NOTAM system , to prevent usage of GBAS for Cat III operations in case of very large ionospheric storm.	Open
REC#0023 [SPR level] From abnormal conditions	GAST-D Ground Station architecture should take the risk of interference into account such that the Ground Station is robust against interference on a limited number of receivers.	Open
REC#0024 [SPR level] From abnormal conditions	GAST-D Ground Station site selection should take the risk of jamming into account, i.e. antennas should be sited at as far as possible from public areas such as roads.	Open (to be assessed for each implementation).

Rec ref [origin]	Safety Recommendation	Status
REC#0025 [SPR level] From abnormal conditions	Local airport development plans should be considered in the development of local GAST-D Ground Station siting procedures.	Open (to be assessed for each implementation).
REC#0026 [SPR level] From abnormal conditions	In order to support problem investigation and maintenance, the GAST-D Ground Station should output the signal-to-noise ratio for each satellite.	Open This data can be useful when determining if a particular outage is caused by the environment or by receiver anomalies.
REC#0027 [SPR level] From abnormal conditions	If interference is suspected, ground maintenance procedures should define the conditions of investigation efforts and pre-commissioning surveys of the interference environment.	Open The suspected area should be probed and spectrum analysis accomplished to define its geographical extent; GNSS and GBAS parameters such as signal/noise ratio, lateral and vertical protection levels, and DOP should be documented.
REC#0028 [SPR level] From abnormal conditions	Airport maintenance procedures should include the development of additional mitigation methods, such as barrier construction or reference receiver relocation, in case interference sources cannot be removed.	Open From 15.3.6 D20 GAST D conops, section 12.4.1.2 "Environment Specific Maintenance Procedures (RFI and multipath"
REC#0029 [SPR level] From abnormal conditions	If the soil is considered to be insufficiently drained, and additional draining is not practicable, a layer of minimum 25 cm of gravel should be added in the inner LOCA	Open (to be assessed for each implementation).
REC#0030 [SPR level] From abnormal conditions	Care should be taken during siting, to avoid areas where snow tends to build up, or areas which are used as snow deposits.	Open (to be assessed for each implementation).
REC#0031 [SPR level] From abnormal conditions	Reflecting surfaces in the vicinity of the GNSS antennas, multipath should be avoided. LOCA should be respected.	Open (to be assessed for each implementation). In particular correlated multipath should be avoided
REC#0032 [SPR level] From abnormal conditions	When an Arrival Sequence Manager is used to sequence arrival traffic for CAT III approach optimised operations, the ANSP should conduct a specific Arrival Sequence Manager failure case analysis to determine the assurance level to which it should be developed.	Open (to be assessed for each implementation). The Arrival Sequence Manager is only an "advisory" tool for ATCos.

Rec ref [origin]	Safety Recommendation	Status
REC#0033 [SPR level] From abnormal conditions	ANSPs with GBAS CAT II/III procedures and/or Authorities should produce guidelines for operators to: a.Design extraction procedures in GBAS CAT II/III operations. b.Coordinate with the local ANSP and/or local authorities the implementation of extraction contingency procedures.	Open
Guided-Take-Off		
REC#0005 [OSED level]	It is recommended that aircraft displays the distance to runway-end to enhance situational awareness during guided take-off in LVC	Open
REC#0008 [SPR level]	For departure with guided take-off, Flight Crew and Tower Controller should include in the clearance (departure/Push back/Taxi clearances) and during the read back the navaid type (GBAS or ILS) used for the guided take-off	Open
REC#0020 to 0031 [SPR level] From abnormal conditions	See above	See above

C.4 Operational Limitations log

The following Operational Limitations were necessarily raised during the safety assessment:

Lim ref [origin]	Limitation	Status
CAT III approach and Landing		
LIM#0001 [OSED level]	Independent parallel runway operations with different GBAS glide path angle could be implemented at the airport but the optimum glide path angle for CAT III remains 3° for pilots	To be verified for each local implementation
LIM#0002 [OSED level]	PANS-ATM (para. 6.7.3.2.1.f) requires the use of vectoring to intercept the final approach track for parallel runway operations	SO#0510 is not consistent with PANS-ATM because it authorizes RNP capture of the final approach tracks for parallel approaches. PANS-ATM should be updated if RNP capture is used for parallel approach Project 06.08.08 for SESAR Solution#09 (Enhanced terminal operation with automatic RNP transition to xLS and LPV) could be a good candidate to address this limitation.
LIM#0003 [SPR level] From abnormal	Some CAT-II approved aircraft are not equipped with INS/IRS and may have difficulties to follow a safe extraction	Open

Lim ref [origin]	Limitation	Status
conditions	procedure in case of common basic GNSS and GBAS guidance loss (see A#0115).	
Guided-Take-Off		
	None	

C.5 Validation Items

The following Validation Items were necessarily raised during the safety assessment and have been considered:

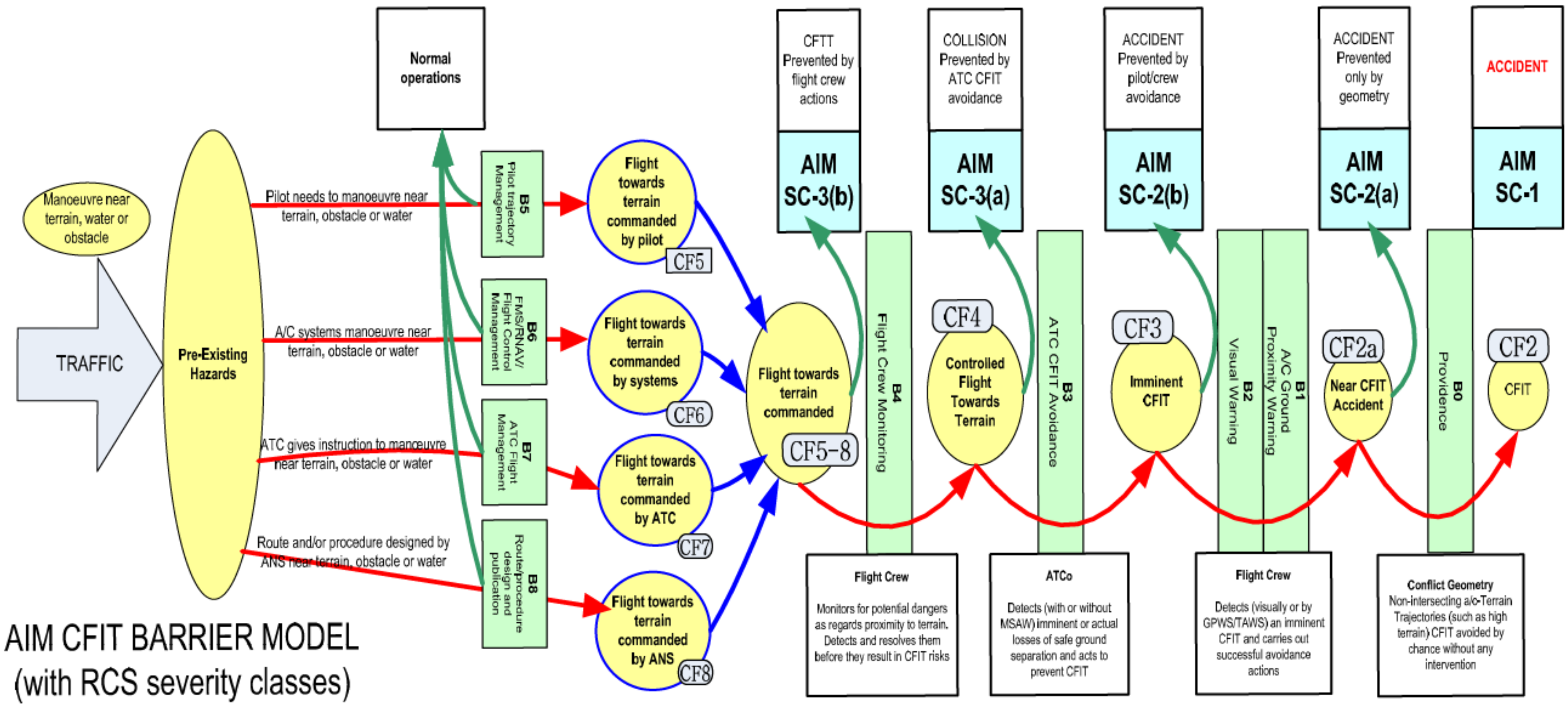
Val ref/ Associated SO	Validation Items	Status
CAT III approach and Landing		
VAL#001 (SO#0020)	It should be validated that the capture of the final approach supported by RNP is safe and efficient (with respect to the RNP corridor)	OPEN 06.08.05 validation exercise VP 166 was not fully conclusive on this aspect. It is proposed that this validation item be addressed through SESAR Solution#09 by Project 06.08.08 (Enhanced terminal operation with automatic RNP transition to xLS and LPV).
VAL#0002 (SO#0070; SO#0335)	In CAT III approach mixed GBAS/ILS equipage operation, appropriate spacing between aircraft pairs (GBAS-ILS; GBAS-GBAS and ILS-GBAS) should be validated to prevent ILS CAT III sensitive area infringement by a preceding aircraft during an ILS landing	CLOSED for segregated runway. Addressed by 06.08.05 validation exercise –VP 563. It was shown that less separation infringement were recorded compared to the baseline scenario. LIMITATION identified for mixed mode runway operations. Indeed, it was shown that more separation infringements were recorded compared to the baseline scenario. GBAS in LVP operations for mixed mode runway operations might however not bring any significant gain in runway throughput since the results indicate that the spacing cannot be reduced as much as expected. The results led to recommendations on the procedures that the magnitude of reduced spacing for GBAS operations should be assessed and determined locally as it is dependent on the local procedures and environment.

Val ref/ Associated SO	Validation Items	Status
VAL#0004 (SO#0095)	For optimised operations, the late landing Clearance shall be provided at a distance to the runway threshold which does not impair the aircraft ability to prepare the landing. This aspect should be validated during validation exercise	CLOSED Addressed by 06.08.05 validation exercise –VP 563 The latest landing clearance shall be provided at 1Nm from the threshold
VAL#0005 (SO#0120)	It should be validated if Runway safety nets are suitable for optimised operations and mixed GBAS/ILS equipage operation or if they should be modified.	OPEN Addressed by 06.08.05 validation exercise –VP 563 but only one RIMCAS alert was recorded (runway incursion). No conclusion can therefore be drawn on the controller feedback
VAL#0006 (SO#0125 to SO#0145)	The landing clearance line concept should be validated for: *segregated runway operation (arrival) with GBAS optimised operations *segregated runway operation (arrival) with mixed GBAS/ILS equipage operations *mixed mode runway operation (arrival/departure) with GBAS optimised operations *mixed mode runway operation (arrival/departure) with mixed GBAS/ILS equipage optimised operations	CLOSED Addressed by 06.08.05 validation exercise –VP 563
VAL#0007 (SO#0170)	During optimised operations, the go-around rate (without considering failure) shall not be greater than in ILS CAT III only operations (without considering failure) in similar operational environment and weather conditions.	CLOSED Addressed by 06.08.05 validation exercise –VP 563
VAL#0008 (SO#0035)	For non CDO operations, it should be checked if a 2Nm (or 30 sec) straight and level flight segment prior to final approach track intercept is necessary.	OPEN 06.08.05 validation exercise VP 166 was not fully conclusive on this aspect. It is proposed that this validation item be addressed through SESAR Solution#09 by Project 06.08.08 (Enhanced terminal operation with automatic RNP transition to xLS and LPV).
VAL#0009	To prevent any detrimental impact on GAST-D operations, it should be determined if ATC measures are necessary in LVP to control the access of GBAS areas on the ground based on LOCA (Local Object Consideration Areas)	OPEN waiting 15.03.06 validation exercise VP-236 A specific activity on this topic is planned and will be conducted in the frame of the 15.3.6 Validation exercise VP-236. Additional work is also envisaged within the scope of a 15.3.6 project extension that is under discussion at the moment.

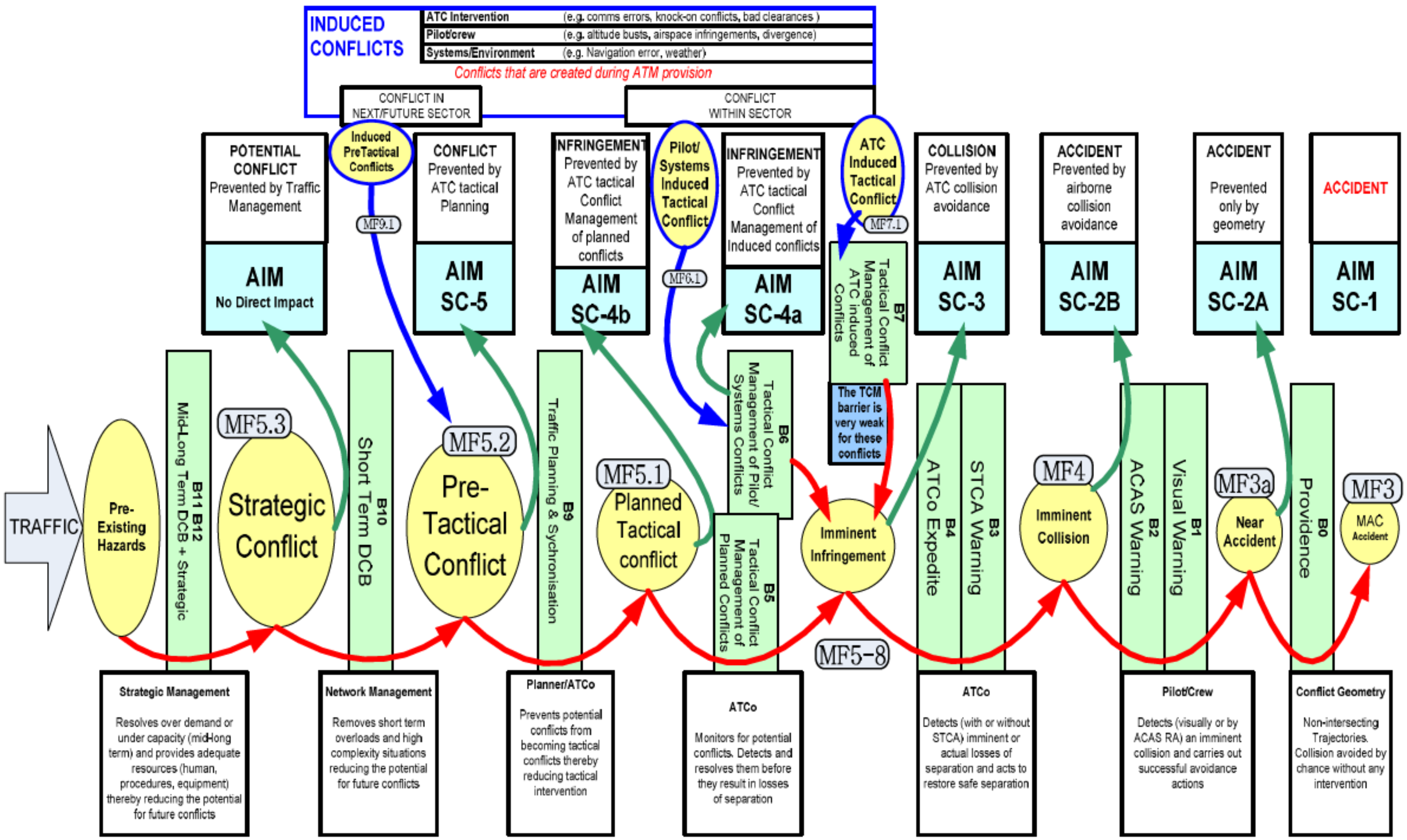
Val ref/ Associated SO	Validation Items	Status
VAL#0010 (SR#0235)	Aircraft spacing reduction of 1Nm in front of GBAS shall be validated	CLOSED Addressed by 06.08.05 validation exercise –VP 563. The validation results led to recommendations on the procedures that the magnitude of reduced spacing for GBAS operations should be assessed and determined locally as it is dependent on the local procedures and environment.
VAL#0011 (SR#0255 and SR#0260)	Possibility to provide the latest landing clearance at different points for ILS (2Nm) and GBAS (1Nm) should be validated	CLOSED Addressed by 06.08.05 validation exercise –VP 563
Guided-Take-Off		
VAL#0009	See above	OPEN waiting 15.03.06 validation exercise VP-236

Appendix D Outline of Accident Incident Model (AIM)

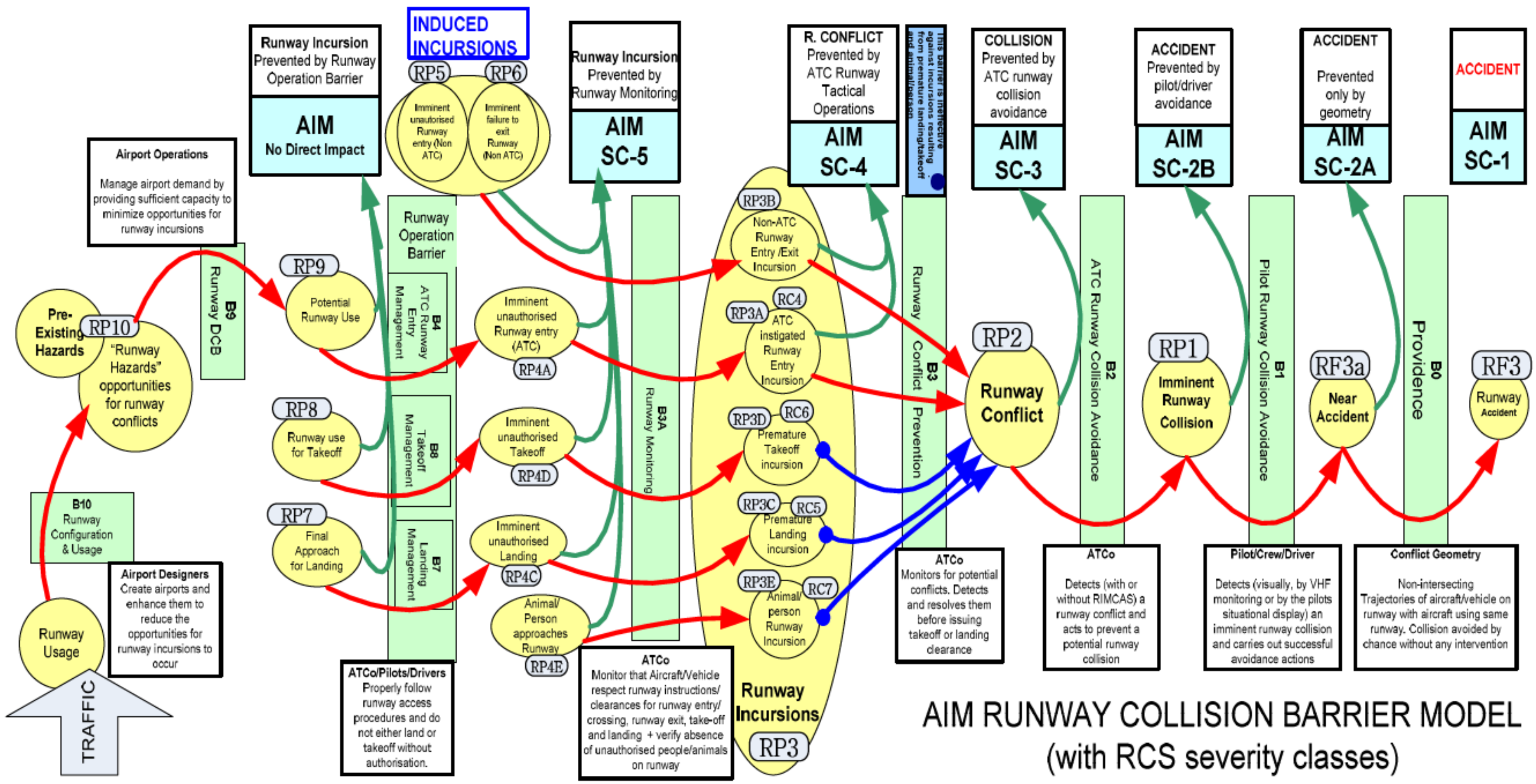
D.1 AIM for CFIT



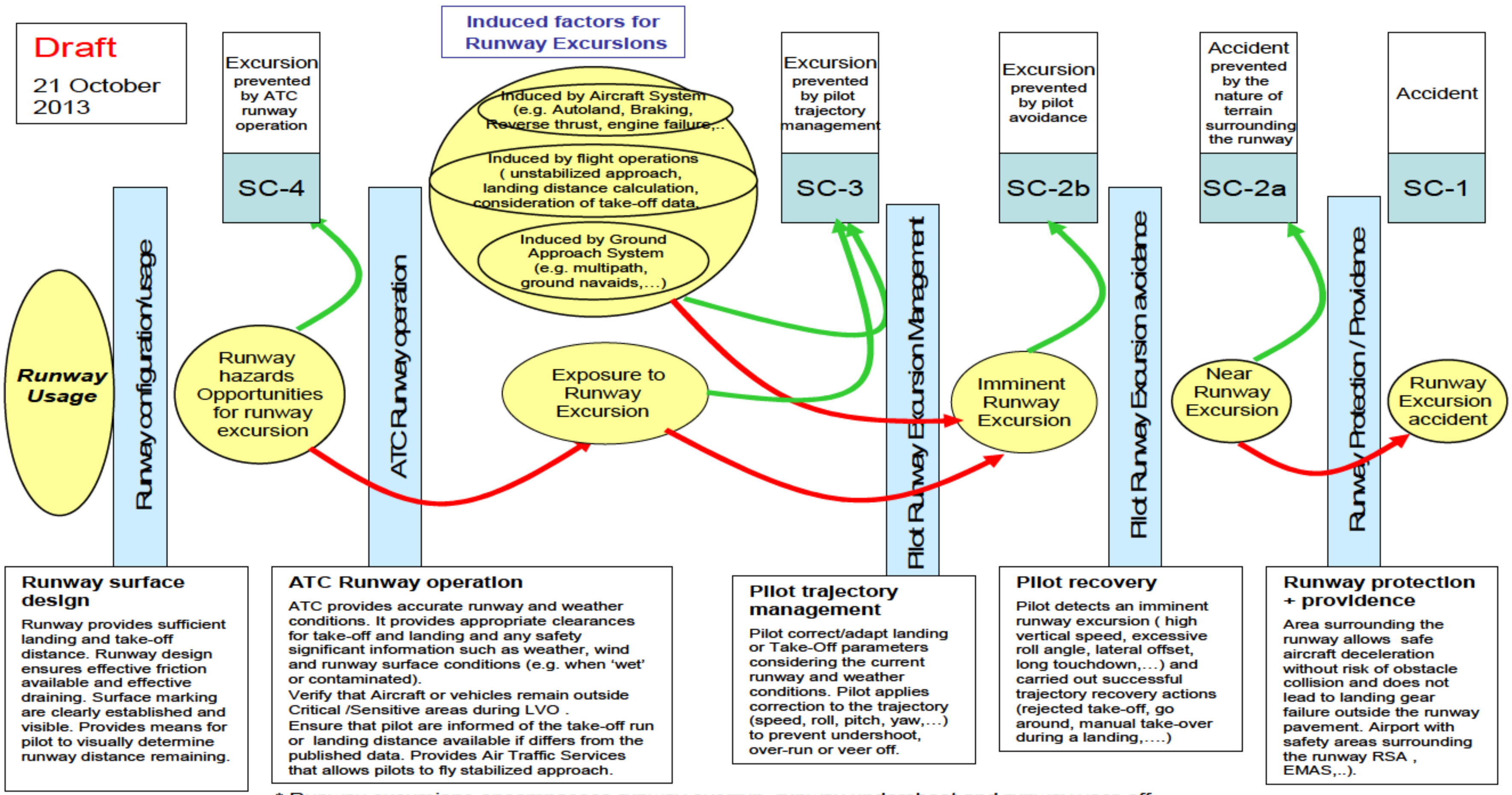
D.2 AIM for Mid Air Collision (MAC)



D.3 AIM for Runway Incursion



D.4 Simplified Draft Barrier model for Runway Excursion used for this OFA (no AIM available for Runway Excursion)



* Runway excursions encompasses runway overrun, runway undershoot and runway veer-off

Appendix E Safety objective derivation (Functionality & Performance)

E.1 Safety Objectives (Functionality & Performance – success approach) for CAT III Approach and landing / Normal Operations

Table E.1 below describes not only the final approach part but the complete approach operation in order to assess potential issues during transitions (e.g. from approach to missed approach.

Phase of Flight/ATM service	AIM applicable accident Model and related Barrier[16]	Achieved by/ Success-case Safety Objective (SO#n):	SAC
Within the terminal airspace			
Establish separation between arrival flows and departing flows (SAD)	• **MAC accident Model :** → Tactical Planning Barrier → Tactical Conflict Resolution Barrier Note: TMA Airspace design is a key aspect of the segregation between arrival and departure (e.g. SID and STAR design).	-Vertical separation at intersections of STAR with SIDs achieved by means of published altitude restrictions -Control and separate arrival traffic from departing traffic and missed approach. No Safety Objectives are derived for above aspects because not impacted by GBAS CAT III operations. -ATIS informs landing procedures which are available for the runway in use (ILS/GBAS or GBAS only) and that LVP are in place (SO# 0005). -Approach clearance is provided to the aircraft which indicates the expected approach to be flown (SO# 0010). -For mixed GBAS/ILS equipage with optimised operations, aircraft informs ATC about the approach that will be flown: GBAS or ILS (SO# 0011).	SAC#02 (MAC)
Prior to commencing the approach – upstream IAF			
Maintain arrival flow separation (SP1)	• **MAC accident Model :** → Tactical Planning Barrier → Tactical Conflict Resolution	-Control and sequence arrival traffic while ensuring aircraft separation (minimum radar and wake vortex). In non radar environment separation is done vertically (using flight levels). In radar environment separation is	SAC#02 (MAC)

[16] Barriers of the Accident Incident Model (AIM) are described in SESAR Safety Reference Material (SRM)

	Barrier	done under radar vectoring, both laterally and vertically. No Safety Objectives are derived for above aspects because not impacted by GBAS CAT III operations.	
Initial approach – IAF to IF			
Maintain arrival flow separation (SP1)	• **MAC accident Model :** → Tactical Planning Barrier → Tactical Conflict Resolution Barrier	-Aircraft conformance to appropriate speed or heading instructions from ATC No Safety Objectives are derived for above aspects because not impacted by GBAS CAT III operations.	SAC#02 (MAC)
Separate aircraft from terrain/obstacles during the initial approach (SPT1)	• **CFIT accident Model :** → Trajectory Management Barrier (pilot; a/c systems and ATC), → Route/Procedure Design Barrier → Pilot Tactical Resolution Barrier are the applicable barriers for this service	-The initial approach segment is designed to prevent loss of separation with terrain/obstacle. -For initial approach supported by RNAV: lateral conformance with the published initial approach segment (IAF-IF) and vertical conformance with the published altitude at IAF and IF (as described by the approach chart). -For initial approach supported by vectoring: ATC provision of navigational guidance to aircraft in the form of specific headings, based on the use of an air traffic services surveillance system No Safety Objectives are derived for above aspects because not impacted by GBAS CAT III operations.	SAC#01(CFIT)
Intermediate approach – IF to FAP			
Maintain arrival flow separation (SP1)	• **MAC accident Model:** → Tactical Planning Barrier → Tactical Conflict Resolution Barrier	-Aircraft conformance to the published approach intermediate segment to prevent arrival/departure conflict (MAC) and conformance to appropriate speed instructions from ATC (Wake avoidance) -If the aircraft is vectored for the final approach interception, aircraft conformance to appropriate speed and heading instructions from ATC. No Safety Objectives are derived for above aspects because not impacted by GBAS CAT III operations.	SAC#02 (MAC)

Separate aircraft from terrain/obstacles during the intermediate approach (SPT1)	• **CFIT accident Model :** → Trajectory Management Barrier (pilot; a/c systems and ATC), → Route/Procedure Design Barrier → Pilot Tactical Resolution Barrier are the applicable barriers for this service	-The intermediate approach segment which could include RF leg is designed to prevent loss of separation with terrain/obstacle. -For intermediate approach supported by RNAV: lateral conformance to the published intermediate approach segment (IF-FAF/FAP) and vertical conformance to the published altitude at IF and FAP (as described by the approach chart). -For approach interception supported by vectoring: ATC provision of navigational guidance to aircraft in the form of specific headings, based on the use of an air traffic services surveillance system No Safety Objectives are derived for above aspects because not impacted by GBAS CAT III operations.	SAC#01(CFIT)
Just prior the FAP			
Facilitate capture of the final approach (FCF)	• **MAC accident Model:** → Tactical Conflict Resolution Barrier • **CFIT accident Model :** → Trajectory Management Barrier (pilot; a/c systems and ATC), → Route/Procedure Design Barrier → Pilot Tactical Resolution Barrier are the applicable barriers for this service	• **General** -Aircraft capture of the GBAS Lateral path before the GBAS vertical path (SO#0015) -Aircraft remains in navigation lateral mode (e.g. RNP→GBAS) for the capture of the GBAS approach path which is the preferred option for flight crew. (Recommendation REC#0001) • **In lateral:** -Aircraft lateral transition from RNP to GBAS (xLS) respecting the RNP accuracy of the published intermediate segment including possibly RF leg (SO#0020). -It should be validated that capture of the final approach supported by RNP is safe and efficient considering the RNP corridor [Validation Objective VAL#0001] -Aircraft lateral transition from heading instructions to GBAS (xLS) if aircraft is vectored to the final approach (SO#0025).	SAC#01(CFIT) SAC#02 (MAC)

		• **In Vertical:** -Aircraft vertical transition from Baro-altitude to GBAS vertical path (xLS) respecting FAP altitude constraints (SO# 0030). -For non CDO operations, a 2NM vertical stabilisation path before FAP is required to prevent unstabilised approach (SO# 0035). It should be validated if this level-off segment is still necessary [Validation Objective VAL#0008] -ATC Vectoring should not be used for aircraft conducting CDO if the aircraft cannot conduct a fully optimised CDO including vectoring (SO# 0040). • **For parallel runways operation:** -Independent parallel runway operations with different GPA could be implemented but the optimum angle remains 3° from a pilot's perspective. Aircraft could be certified in autoland for GPA from 2.5 to 3.5° (Limitation LIM#0001) - For parallel approaches and with GBAS, FAP could be located at different position/altitude to establish strategic separation between the two approach flows (Recommendation REC#0002)	
GBAS CAT III (GAST-D) Approach			
Separate aircraft from terrain/obstacles during the final approach (SPT2)	• **CFIT accident Model :** → Trajectory Management Barrier (pilot; a/c systems and ATC), → Route/Procedure Design Barrier → Pilot Tactical Resolution Barrier are the applicable barriers for this service	-The GBAS CAT III approach is designed and promulgated to prevent loss of separation with terrain/obstacle (SO#0045). -Aircraft respects the lateral and vertical path of the promulgated GBAS approach (SO#0050). -For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside of the ILS CAT III critical and sensitive areas (SO#0055). - The aircraft GBAS Total System error (TSE) shall be equivalent or better than ILS CAT III TSE (SO#0060).	SAC#01(CFIT)

		- For GBAS only operation, ILS CAT III critical and sensitive areas do not need to be protected (Assumption#0001) -To prevent any detrimental impact on GAST-D operations, it should be determined if ATC measures are necessary in LVP to control the access of GBAS areas on the ground based on LOCA (Local Object Consideration Areas) [Validation Objective VAL#0009]	
Maintain separation between aircraft on the same final approach (SP2a) → between A/C on the final approach segment → between aircraft conducting GBAS and non-GBAS approaches (mix equipage operations)	• **MAC accident Model:** → Tactical Conflict Resolution Barrier • **Wake Induced Accident Model:** → Tactical Conflict Resolution Barrier	-Aircraft conformance to the appropriate approach speed (SO#0065) - Aircraft respects the lateral and vertical path of the promulgated GBAS approach (SO#0050) - ATC procedures supports the mixed GBAS/ILS equipage operations by providing appropriate separation between aircraft pairs (GBAS-ILS pair, GBAS-GBAS pair and ILS-GBAS pair) without leading to more wake encounters (SO#0070) -In CAT III approach mixed GBAS/ILS equipage operation, appropriate spacing between aircraft pairs (GBAS-ILS; GBAS-GBAS and ILS-GBAS) should be validated to prevent ILS CAT III sensitive area infringement by a preceding aircraft during an ILS landing[Validation Objective VAL#0002] -For optimised operations, the reduced separation between aircraft takes into account the Runway Occupancy Time (ROT) in Low Visibility Condition in addition to the suppression of the ILS CAT III critical/sensitive area. (SO#0072) - It should be analyzed if the sizing factor for reducing the separation in optimised operations is the ROT or the suppression of the ILS CAT III Critical/sensitive Area	SAC#02 (MAC)
Monitor separation between aircraft on parallel approaches (SP2b)	• **MAC accident Model:** → Tactical Conflict Resolution Barrier	- Aircraft respects the lateral and vertical path of the promulgated GBAS approach (SO#0050) - For parallel approaches, the infringement rate of the Non	SAC#02 (MAC)

→ between A/C conducting parallel approaches (independent or dependent) → between aircraft conducting GBAS and non-GBAS approaches (mix equipage operations)		Transgression Zone (NTZ) is not greater with GBAS (GBAS only or mixed GBAS/ILS equipage) compared to ILS (SO#0075) -Independent parallel runway operations with different GPA could be implemented but the optimum angle remains 3° from a pilot's perspective. Aircraft could be certified in autoland for GPA from 2.5 to 3.5° (Limitation LIM#0001) -PANS-OPS (para. 6.7.3.2.1.f) requires the use of vectoring to intercept the final approach track for parallel runway operations (Limitation LIM#0002) - For parallel approaches and with GBAS, FAP could be located at different position/altitude to establish strategic separation between the two approach flows (Recommendation REC#0002)	
Facilitate landing and deceleration on the runway (FLD)	• **Prevent Landing Accident** (Runway veer-off, Runway overrun or Runway undershoot)	• **General** - Aircraft respects the lateral and vertical path of the promulgated GBAS approach (SO#0050) -Aircraft conformance to the appropriate approach speed (SO#0065) - Aircraft lands in the prescribed touch down zone(SO#0080). - Aircraft landing rollout respects the runway centre-line and decelerates to a safe taxi speed (SO#0085). -For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside the ILS CAT III critical and sensitive areas (SO#0055). - For GBAS only operation, ILS CAT III critical and sensitive areas do not need to be protected (Assumption#0001) -To prevent any detrimental impact on GAST-D operations, it should be determined if ATC measures are necessary in LVP to control the access of GBAS areas on the ground based on LOCA (Local Object Consideration Areas) [Validation Objective VAL#0009] • **CAT III missed approach initiation:** -Aircraft Monitoring of operational conditions at the Decision Height	SAC#01(CFIT) SAC#04 (R.E)

		(DH) or at the Alert Height (AH) for operations conducted with no DH (weather minima are the same compared to ILS approaches) (SO#0150) - For CAT III approach conducted with DH, aircraft transition to missed approach at DH if visual references not acquired (SO#0155) - For CAT III approach conducted with no DH, aircraft transition to missed approach in case of performance degradation/ failure with visual references not acquired (SO#0160)	
Maintain aircraft separation on the Runway Protected Area (SP3)	• **Runway Collision accident Model :** →Runway Operation Barrier for Landing management →Runway Operation Barrier for runway entry management	• **General** - Landing Clearance and associated read back is provided to the aircraft to ensure proper separation with other aircraft or vehicles on the runway (SO#0090). - For optimised operations, late landing Clearance is provided at a distance to the runway threshold acceptable for the aircraft (SO#0095 and Validation Objective VAL#0004. - All aircraft on the ground remain outside the OFZ (SO#0100). - Aircraft vacates the runway at the cleared exit point (SO#0105). -Aircraft reports when he has vacated the runway (tail leaves the runway) (SO#0110). -ATC provides whenever necessary additional information to facilitate runway vacation (SO#0115). - Aircraft displays the distance to runway-end after passing the runway threshold to ease ROT reduction. Other means are also possible, for instance brake-to vacate or “countdown” lights before a runway exit or specific guidance lights towards the suitable exits. (Recommendation REC#0003) - Runway Incursion safety net (e.g. RIMCAS) are suitable for optimised operations. An aircraft holding inside ILS CAT III Critical and Sensitive Area (CSA) during an ILS landing is considered a Runway Incursion whereas an aircraft holding at the same position during a GBAS landing is not (SO#0120).	SAC#03a (R.C) SAC_Assumption#01 (OFZ protection)

		-It should be validated if Runway safety nets are suitable for optimised operations and mixed GBAS/ILS equipage operation or if they should be modified Validation Objective VAL#0005. • **Specific to Segregated runway operation (arrival)** -For segregated runway operation (arrival only) with GBAS optimised operations, ATC provide the landing clearance to the next arrival when the preceding arrival has passed the landing clearance line (SO#0125). -For segregated runway operation(arrival) with mixed GBAS/ILS equipage optimised operations, ATC provide the landing clearance to the: *next GBAS arrival when the preceding arrival has passed the landing clearance line * next ILS arrival when the preceding arrival has vacated the ILS CAT III sensitive area (SO#0130). • **Specific to mixed mode runway (arrival/departure)** -For mixed mode runway operation (arrival/departure) with GBAS optimised operations, departing aircraft hold at the landing clearance line (SO#0135). -For mixed mode runway operation (arrival/departure) with mixed GBAS/ILS equipage optimised operations, departing aircraft hold: *at the landing clearance line for a GBAS landing *at the CAT III holding point for an ILS landing (SO#0140). -For mixed mode runway operation (arrival/departure), OFZ is protected when a departing aircraft holds the CAT I holding position, if holding 900 meters or more down the runway (Assumption#0002) • **Specific to landing clearance line** The landing clearance line is to be positioned where: *the risk of collision with obstacle is acceptable. *wing tip clearance is provided from touchdown to end of roll out along the runway (SO#0145) -The landing clearance line concept should be validated for:	

		*segregated runway operation (arrival) with GBAS optimised operations *segregated runway operation (arrival) with mixed GBAS/ILS equipage operations *mixed mode runway operation (arrival/departure) with GBAS optimised operations *mixed mode runway operation (arrival/departure) with mixed GBAS/ILS equipage optimised operations Validation Objective VAL#0006.	
Missed approach			
Separate aircraft from terrain/obstacles during the missed approach (SPT3)	• **CFIT accident Model :** → Trajectory Management Barrier (pilot; a/c systems and ATC), → Route/Procedure Design Barrier → Pilot Tactical Resolution Barrier are the applicable barriers for this service	-For RNAV guided missed approach: lateral conformance to the designed missed approach segments and vertical conformance to the defined altitudes at each missed approach waypoint (as described in the approach chart). -For non-RNAV guided missed approach: lateral conformance to the designed conventional missed approach segments (e.g. heading, NDB track, VOR radial,..) and vertical conformance with the defined altitude (as described in the approach chart). No Safety Objectives are derived for above aspects because not impacted by GBAS CAT III operations. -The Missed approach segment of a GBAS CAT III approach is designed and promulgated to prevent loss of separation with terrain/obstacle and does not rely on GBAS (SO#0165). -Aircraft remains in navigation lateral mode (e.g. GBAS → RNP) for the missed approach which is the preferred option for flight crew if the MA is based on RNAV/RNP (Recommendation REC#0004)	SAC#01(CFIT)
Establish and maintain separation between aircraft during missed approach (SP4)	• **MAC accident Model:** → Tactical Conflict Resolution Barrier	-Aircraft conformance to the published missed approach procedure No Safety Objectives are derived for above aspects because not impacted by GAST-D. - The go-around rate without considering GBAS ground Station failure is similar between ILS CAT III operations, GBAS CAT III optimised operations and mixed GBAS/ILS equipage CAT III optimised operations (SO#0170 and Validation Objective VAL#0007)	SAC#02 (MAC)

		-For independent parallel runway operations, the Missed approach track for one approach diverges by at least 30 degrees from the missed approach track of the adjacent approach (SO#0166) (from PANS-ATM)	

Table E.1: Derivation of Success-case Safety Objectives for CAT III approach and landing phase

E.2 Safety Objectives (Functionality & Performance – success approach) for Guided Take-Off in LVC / Normal Operations

Table E.2 below describes not only the guided take-off part but the complete take off operation in order to assess potential issues during transitions (e.g. from guided take-off to climb phase).

Phase of Flight/ATM service	AIM applicable accident Model and related Barrier[17]	Achieved by/ Success-case Safety Objective (SO#n):	SAC
Guided Take-off (from lime-up to main wheel lift-off)			
Facilitate Take-Off roll on the runway (FTA)	• **Prevent Landing Accident** (Runway veer-off or Runway overrun)	- Aircraft respects the lateral path for the guided take-off from the start of the take-off roll to the main wheel lift-off (SO#0200). - The aircraft GBAS Total System error (TSE) shall be equivalent or better than ILS CAT III TSE (SO#0060). -Back course take-off is not used with GBAS (Assumption#0005) -For mixed GBAS/ILS equipage operations, all vehicles and aircraft on the ground remain outside of the ILS CAT III critical and sensitive areas (SO#0055). - For GBAS only operation, ILS CAT III critical and sensitive areas do not need to be protected (Assumption#0001) -To prevent any detrimental impact on GAST-D operations, it should be determined if ATC measures are necessary in LVP to control the access of GBAS areas on the ground based on LOCA (Local Object Consideration Areas) [Validation Objective VAL#0009]	SAC#04 (R.E) SAC_Assumption#01 (OFZ protection)

[17] Barriers of the Accident Incident Model (AIM) are described in SESAR Safety Reference Material (SRM)

Maintain aircraft separation on the Runway Protected Area (RPA) (SP3)	• **Runway Collision accident Model :** →Runway Operation Barrier for Take-Off management →Runway Operation Barrier for runway entry management	- Take-Off Clearance and associated read back is provided to the aircraft to ensure appropriate separation with other aircraft and vehicles on the runway (SO#0205). - Aircraft respects the lateral path for the guided take-off from the start of the take-off roll to the main wheel lift-off (SO#0200). - The aircraft GBAS Total System error (TSE) shall be equivalent or better than ILS CAT III TSE (SO#0060). - All aircraft on the ground remain outside the OFZ during a take-off (SO#0210). - Aircraft displays the distance to runway end to enhance situational awareness during guided take-off in LVC. (Recommendation REC#0005)	SAC#03b (R.C)
Climb phase			
Separate aircraft from terrain/obstacles during the climb phase (SPT4)	• **CFIT accident Model :** → Trajectory Management Barrier (pilot; a/c systems and ATC), → Route/Procedure Design Barrier → Pilot Tactical Resolution Barrier are the applicable barriers for this service	-Aircraft respects the departure procedure (SID) and the climb gradient -Departure design and associated guidance is proven safe and reliable -Aircraft lateral deviation information for the guided take-off are automatically removed at lift off -Aircraft guided take-off deviation are replaced by departure route information at lift off No Safety Objectives are derived because not specific to GBAS	SAC#01(CFIT)
Establish and maintain separation between aircraft during climb (SP5)	• **MAC accident Model:** → Tactical Conflict Resolution Barrier	-Aircraft respects departure clearance with associated guidance and/or other restrictions (speed, heading, etc…) -Aircraft lateral deviation information for the guided take-off are automatically removed at lift off -Aircraft respects the departure procedure (SID) laterally and vertically No Safety Objectives are derived because not specific to GBAS	SAC#02 (MAC)

Table E.2: Derivation of Success-case Safety Objectives for Guided take-off operations

Appendix F OHA Table

F.1 Operational Hazards for CAT III approach and landing

Phase of flight/ ATM services	Operational Hazard	Related SO (Success approach)	Operational effects	Mitigations of effects	Severity (most probable effect)	Comparison with ILS CAT III
TMA Establish separation between arrival flows and departing flows (SAD)	No operational Hazard affecting the TMA Note: Initially a hazard was identified (Hz 001) but has been suppressed because identical to Hz 004 (see below).	SO#0005 SO#0010 SO#0011	NA	NA	NA	NA
Intermediate Approach Facilitate capture of Final Approach (FCF)	Hz 002: Failure to transition laterally and/or vertically from RNP or radar vectoring to GBAS CAT III approach	SO#0015 SO#0020 SO#0025 SO#0030 SO#0035 SO#0040	The aircraft does not intercept the GBAS final approach segment. The aircraft deviates from the planned trajectory in lateral, in vertical or in both axis	**Corrective:** * **Aircraft/Pilot** -Pilot monitors the GBAS lateral and vertical deviation indication during the transition and detects that capture of the GBAS approach path is not effective. -Pilot crosscheck -Pilot could reject the approach (MA) or try to recover the lateral and vertical path	*CFIT-SC3b / Flight Toward Terrain Commanded. → It corresponds to a situation where a controlled flight towards terrain was prevented by flight crew monitoring	When considering single approach operation, Hz 002 is applicable to current ILS operation for radar vectoring interception but not applicable for the transition from RNP to xLS because not currently implemented with ILS
			For parallel approaches, several aircraft do not intercept the GBAS final approaches e.g. if GBAS Ground station is serving two runway ends and fails	**Preventive:** * **ATC/Controller** REC#0002 (strategic separation between arrival flows) might be considered as a preventive means for such hazard. (SO#0510) Radar coverage is required at the location where parallel final approaches are intercepted (PANS-ATM assumption A#0010). **Corrective:** * **For CFIT: Aircraft/Pilot**	*For CFIT same as above. *MAC-SC4a/Tactical conflict (crew/aircraft induced). → It correspond to a situation where an imminent infringement coming from crew/aircraft induced conflict was prevented by tactical conflict management	When considering parallel approach operation, Hz 002 is partially applicable to ILS however the GBAS ground station might serve the two approaches whereas for ILS , two ILS ground stations must be installed

Phase of flight/ ATM services	Operational Hazard	Related SO (Success approach)	Operational effects	Mitigations of effects	Severity (most probable effect)	Comparison with ILS CAT III
				-See above *** For MAC: ATC/Controller** -Controller detects the deviation through radar monitoring or supported by tool and ask a diverging Go-around for the two aircraft -Controller monitors the A/C altitude and heading Note: ATCo should be more vigilant due to tighter A/C separation (specific to optimised operation)		
<u>Final Approach</u> Separate aircraft from terrain/obstacle during the final approach (SPT2)	Hz 003: Failure to follow the correct final approach path in GBAS CAT III	SO#0045 SO#0050 SO#0055 SO#0060	The aircraft deviates from GBAS final approach path during a CAT III approach	**<u>Preventive:</u>** ***ANSP/AIS** -GBAS SIS integrity and continuity performance in accordance with ICAO Annex 10 -Aircraft certified in accordance with EASA CS AWO (CAT III criteria) -DATA quality (FAS DataBlock) and Flight procedure validation and inspection (ICAO Doc 8071 and 9906). It complements SO#0050 and SO#0060. **<u>Corrective:</u>** **For integrity failure:** no corrective mitigations in LVP and at low altitude **For continuity failure:** *** Aircraft/Pilot** - Aircraft executes a missed approach. Missed approach can be executed with autopilot still engaged if possible or manually. (SO#0520). In case of GBAS system performance degradation leading to the aircraft capability downgrade from CAT III to CAT I, aircraft continue to CAT I minima or execute a missed approach. Missed approach can be	*CFIT-SC1 / CFIT. → It correspond to a situation where aircraft collides with terrain/water/obstacle.	Hz 003 is applicable to current ILS CAT III operations. However a GBAS ground station failure may affect simultaneously multiple runway-ends at the airport. Mitigations are the same compared to ILS operations (except those related to maintenance actions and CAT III downgrade due to ground system performance)

Phase of flight/ ATM services	Operational Hazard	Related SO (Success approach)	Operational effects	Mitigations of effects	Severity (most probable effect)	Comparison with ILS CAT III
				executed with autopilot still engaged if poss ble or manually. (SO#0530).		
			For parallel approaches, several aircraft deviate from GBAS final approach paths during a CAT III approach	Same mitigations as above but if detected diverging GA are necessary to prevent mid air collision.	*Same as above: CFIT-SC1 / CFIT.	Same as above
Final Approach Maintain separation between aircraft on the same final approach (SP2a)	Hz 004: Failure to maintain spacing between aircraft within the same final approach for optimised operations conducted in mixed GBAS/ILS equipage operations during CAT III approach	SO#0050 SO#0065 SO#0070 SO#0072	There is no risk of loss of separation or wake turbulence encounter because minimum radar separation and wake turbulence separation rules are still applied and are not impacted by optimised operations. However for optimised operations conducted in mixed GBAS/ILS equipage and if GBAS-ILS pairs are not correctly spaced the ILS landing aircraft might deviate from its path due to wrong ILS guidance during landing and rollout (preceding GBAS landed aircraft still in the ILS CAT III sensitive area) . Furthermore if a landing	**Preventive:** ***ATC/controller** -Despite the optimised operation and the poss ble reduction of spacing in LVC, minimum radar separation or wake turbulence separation still apply. (PANS-ATM assumption A#0015). In mixed GBAS/ILS equipage and in case that a GBAS approach was foreseen by ATC but aircraft indicates before starting the approach that he will conduct an ILS approach, either ATC verify that ILS CAT III sensitive area is clear or ask aircraft to go-around (SO#0505) * **Aircraft/Pilot** -For optimised operations conducted in mixed GBAS/ILS equipage and before starting the final approach, the aircraft shall confirm that ILS approach is conducted. (SO#0500) - Before starting the final approach, aircraft/pilot shall verify that GBAS CAT III	Final approach *CFIT-SC2b / Imminent CFIT. → It correspond to a situation where an near CFIT was prevented by pilot/airborne avoidance (e.g. Visual warning/TAWS) Landing and Roll-out: *RE-SC2b /Imminent Runway excursion → It correspond to a situation where a near Runway Excursion was mitigated by pilot avoidance (e.g. Late Go around or manual take-over during rollout)	Hz 004 is applicable to current ILS CAT III operations.

Phase of flight/ ATM services	Operational Hazard	Related SO (Success approach)	Operational effects	Mitigations of effects	Severity (most probable effect)	Comparison with ILS CAT III
			aircraft is considered by ATC as a GBAS landing whereas it is actually an ILS landing, the ILS CAT III sensitive area may not be protected leading possibly to wrong ILS guidance during landing and rollout.	approach can be conducted. If not aircraft might revert to another GBAS approach or to an ILS approach (only for mixed GBAS/ILS equipage operations). GBAS failure indication to aircraft and ATC might be different (SO#0501) **Corrective:** * **Aircraft/Pilot** -Aircraft/pilot detects instability/wrong deviation during the landing and execute a go around (Flight crew CFIT monitoring barrier) (SO#0520). - Aircraft/pilot detect instability/wrong deviation during the rollout and is able to correct the deviation (Flight crew runway excursion avoidance barrier)		
Final Approach Monitor separation between aircraft on parallel approaches (SP2b)	Hz 005: Failure to maintain the separation between aircraft on adjacent CAT III approach operations	SO#0050 SO#0075	During independent parallel approaches, the Non-transgression Zone (NTZ) is infringed by at least one aircraft. If not detected it may lead to loss of separation between aircraft conducting the parallel CAT III approaches	**Preventive:** ***ATC/controller** Radar coverage during independent or dependent parallel approaches is required (PANS-ATM assumption A#0020). **Corrective:** ***ATC/controller** When an aircraft is observed penetrating the NTZ, the aircraft on the adjacent final approach track shall be instructed to immediately climb and turn to the assigned altitude/height and heading in order to avoid the deviating aircraft. (PANS-ATM assumption A#0025).	*MAC-SC4a/Tactical conflict (crew/aircraft induced). → It correspond to a situation where an imminent infringement coming from crew/aircraft induced conflict was prevented by tactical conflict management	Hz 005 is applicable to current ILS CAT III operations. However a GBAS Ground Station failure could affect simultaneously the two final approach tracks.
Landing Facilitate landing and deceleration on the runway (FLD)	Hz 006: Failure to land in the prescribed touch-down zone in GBAS CAT III approach	SO#0050 SO#0055 SO#0060 SO#0065	The aircraft is not landing in the touch-down zone and it leads to a runway overrun, runway undershoot or runway veer-off	**Corrective:** * **Aircraft/Pilot** - Aircraft/pilot detect the short/long/offset landing and initiate a go-around or correct the trajectory (Pilot runway excursion avoidance barrier) however this barrier is consider inefficient in CAT III operation	*RE- SC1 /R.E accident → It corresponds to Runway Excursion with fatalities/injuries or where the a/c sustains damage or structural failure which affects the structural strength.	Hz 006 is applicable to current ILS CAT III operations. However a GBAS ground station failure may affect simultaneously multiple runway-ends at the airport.

Phase of flight/ ATM services	Operational Hazard	Related SO (Success approach)	Operational effects	Mitigations of effects	Severity (most probable effect)	Comparison with ILS CAT III
		SO#0080				
	Hz 007: Failure to maintain the A/C on the runway centreline during the CAT III GBAS landing rollout	SO#0055 SO#0060 SO#0085	The aircraft deviates from the runway centre line during the landing rollout and it leads to a runway veer-off	**Corrective:** * **Aircraft/Pilot** - Aircraft/pilot detect the lateral deviation and correct the trajectory (Pilot runway excursion avoidance barrier) Barrier rather inefficient with speed greater than 50 kts in LVC ***Runway protection + providence** Area surrounding the runway may allow a safe aircraft deceleration without risk of obstacle collision	*RE- SC 2b/ Imminent Runway excursion → It correspond to a situation where a near Runway Excursion was mitigated by pilot avoidance (e.g manual take-over during rollout)	Hz 007 is applicable to current ILS CAT III operations. However a GBAS ground station failure may affect simultaneously multiple runway-ends at the airport.
Landing Maintain aircraft separation on the runway protected area (SP3)	Hz 008: Failure to maintain aircraft longitudinal spacing on the runway during CAT III approaches in optimised operation	SO#0090 SO#0095 SO#0100 SO#0105 SO#0110 SO#0115 SO#0120 SO#0125 SO#0130 SO#0135 SO#0140 SO#0145	The aircraft is landing very close to the preceding landed aircraft or to a departing aircraft leading to a runway conflict	**Preventive:** ***ATC/controller** Airport surveillance (e.g. A-SMGCS level 1) is available for optimised operations (Assumption A#0030). ***Safety Net:** For optimised operations, a Final Approach Runway Occupancy safety net could alert an approaching aircraft when a risk of runway occupancy by a vehicle or another aircraft is detected. (REC#0006). **Corrective:** ***ATC/controller** The runway conflict is detected by the safety net (RIMCAS) and ATC could request a go around for the landing aircraft (ATC runway collision avoidance barrier)	*RInc-SC 3/ Runway conflict → It corresponds to a runway incursion due to a premature landing concurrent with a conflicting aircraft on the runway (preceding landing) or approaching the runway (departure)	Hz 008 is applicable to current ILS CAT III operations but is impacted by optimised operations. Indeed reduced ROT could be implemented thanks to the suppression of ILS CAT III sensitive area for GBAS landing.

F.2 Operational hazards for Guided Take-Off in LVC

Phase of flight/ ATM services	Operational Hazard	Related SO (Success approach)	Operational effects	Mitigations of effects	Severity (most probable effect)	Comparison with ILS CAT III
Take-Off Facilitate Take-Off roll on the runway (FTA)	Hz 020: Failure to maintain the A/C on the runway centreline during the Guided Take-off in LVC based on GBAS	SO#0060 SO#0200	The aircraft deviates from the runway centre line during the take-off roll based on GBAS and it might lead to a runway veer-off	**Corrective:** * **Aircraft/Pilot** - Aircraft/pilot detect the lateral deviation and correct the trajectory or abort the Take-Off at high-speed (Pilot runway excursion avoidance barrier). Aircraft aborts the guided take-off in LVC if excessive lateral deviation is detected and manual take over impossible due to loss of external visual cues (centerline lights) (SO#550) ***Runway protection + providence** Area surrounding the runway may allow a safe aircraft deceleration without risk of obstacle collision	*RE-SC 2b/ Imminent R.E → It correspond to a situation where a near Runway Excursion was mitigated by pilot avoidance (e.g Aborted Take-Off)	Hz 020 is applicable to Guided take-off based on ILS. However a GBAS ground station failure may affect simultaneously multiple take-off at the airport.
	Hz 021: Failure to maintain the A/C on the runway centreline during the Guided Take-off in LVC based on ILS in mixed GBAS/ILS equipage operations	SO#0055	The aircraft deviates from the runway centre line during the take-off roll based on ILS and it might lead to a runway veer-off			Hz 021 is relative to ILS but could be impacted by mixed GBAS/ILS equipage operation where the ILS CAT III sensitive area is not always protected (e.g. for GBAS departure)
Take-Off Maintain aircraft separation on the runway protected area (SP3)	Hz 022: Failure to maintain aircraft longitudinal spacing on the runway during guided take-off in LVC	SO#0060 SO#0200 SO#0205 SO#0210	The departing aircraft is taking-off very close to the preceding departing aircraft or to a landing aircraft leading to a runway conflict	**Preventive:** ***ATC/controller** Airport surveillance (e.g. A-SMGCS level 1) is available for LVC operations (Assumption A#0040). **Corrective:** ***ATC/controller** The runway conflict is detected by the safety net (RIMCAS) and ATC could request to abort the take-off (ATC runway collision avoidance barrier)	*RInc-SC 3/ Runway conflict → It corresponds to a runway incursion due to a premature take-off concurrent with a conflicting aircraft on the runway (preceding departure) or approaching the runway (arrival)	Hz 022 is applicable also to guided take-off operations based on ILS but is impacted by the poss ble reduced ROT thanks to the suppression of ILS CAT III sensitive area for GBAS departure.

F.3 Safety Objectives (failure approach) determination

Given the severity class of the consequence of the operational hazard, the relevant Risk Classification Scheme (RCS) associated to the AIM model will provide the maximum tolerable frequency of occurrence. Then this maximum tolerable frequency of occurrence will be divided by the Number of hazards for this severity class to obtain the Safety Objectives (failure approach). The different RCS per accident type are provided in SRM Guidance E.2 [2] and the number of hazards (N) for each severity class in SRM Guidance E.3.2 [2].

However for Runway Excursion there is no AIM model therefore EASA CS AWO and CS 25.1309 have been used to determine quantitatively the Safety Objective relevant to this accident type.

Operational Hazard	Severity Class	Maximum tolerable frequency of occurrence	Number of Hazards	SO (Failure) computation
Hz 002: Failure to transition laterally and/or vertically from RNP or radar vectoring to GBAS CAT III approach	CFIT-SC3b	1.0 E-05/approach	50	*SO= 1.0 E-05 / 50 = 2.0 E-07 per approach* SO#1005: The frequency of occurrence of an aircraft erroneous capture of the GBAS CAT III final approach path leading to a flight towards terrain shall not be greater than **2x10-7 per approach**
	MAC –SC4a	1.0 E-03 per flight hour	25	*SO= 1.0 E-03 / 25 = 4.0 E-05 per flight hour* SO#1010: During parallel approaches, the frequency of occurrence of aircraft erroneous capture of GBAS CAT III final approach paths leading possibly to separation infringement between the two arrival flows shall not be greater than **4x10-5 per flight hour**
Hz 003: Failure to follow the correct final approach path in GBAS CAT III	CFIT-SC1	1.0 E-08/approach	5	*SO= 1.0 E-08 / 5 = 2.0 E-09 per approach* SO#1015: The frequency of occurrence of an aircraft deviating laterally and/or vertically from the approach path due to GBAS failure leading to flight towards terrain during a CAT III approach shall not be greater than **2x10-9 per approach**

Operational Hazard	Severity Class	Maximum tolerable frequency of occurrence	Number of Hazards	SO (Failure) computation
Hz 004: Failure to maintain spacing between aircraft within the same final approach for optimised operations conducted in mixed GBAS/ILS equipage operations during CAT III approach	CFIT-SC2b	1.0 E-06/approach	10	*SO= 1.0 E-06 / 10 = 1.0 E-07 per approach* SO#1001: During CAT III optimised operations conducted in mixed GBAS/ILS equipage, the frequency of occurrence of an aircraft deviating laterally and/or vertically from the approach path due to an obstructed ILS CAT III sensitive/Critical area shall not be greater than **2x10-7 per approach**
	RE-SC2b	Hazardous FC (EASA CS 25.1309 and CS AWO)		SO#1002: During CAT III optimised operations conducted in mixed GBAS/ILS equipage and during the rollout, the frequency of occurrence of an aircraft deviating due to an obstructed ILS CAT III sensitive/Critical area to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Extremely Remote
Hz 005: Failure to maintain the separation between aircraft on adjacent CAT III approach operations	MAC –SC4a	1.0 E-03 per flight hour	25	SO= 1.0 E-03 / 25 = 4.0 E-05 per flight hour SO#1020: During parallel approaches, the frequency of occurrence of an aircraft deviating from the approach path due to GBAS failure, leading possibly to separation infringement between the two arrival flows shall not be greater than **4x10-5 per flight hour**
Hz 006: Failure to land in the prescribed touch-down zone in GBAS CAT III approach	RE-SC1	Catastrophic FC (EASA CS 25.1309 and CS AWO)		SO#1025: During GBAS CAT III landing, the frequency of occurrence of an aircraft which does not land in the prescribed touch down zone due to GBAS failure shall not be greater than 1x10-9 per approach/Extremely Improbable
Hz 007: Failure to maintain the A/C on the runway centreline during the CAT III GBAS landing rollout	RE-SC2b	Hazardous FC (EASA CS 25.1309 and CS AWO)		SO#1030: During GBAS CAT III rollout, the frequency of occurrence of an aircraft deviating due to GBAS failure to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Extremely Remote

Operational Hazard	Severity Class	Maximum tolerable frequency of occurrence	Number of Hazards	SO (Failure) computation
Hz 008: Failure to maintain aircraft longitudinal spacing on the runway during CAT III approaches in optimised operation	Rinc-SC3	1E-5/movement	20	*SO= 1.0 E-05 / 20 = 5.0 E-07 per movement* SO#1035: During CAT III approach optimised operations, the frequency of occurrence of a longitudinal spacing infringement on the runway leading to runway conflict shall not be greater than **5x10-7 per movement**
Hz 020: Failure to maintain the A/C on the runway centreline during the Guided Take-off in LVC based on GBAS	RE-SC3	Hazardous FC (EASA CS 25.1309 and CS AWO)		SO#2000: During Guided Take-Off in LVC based on GBAS, the frequency of occurrence of an aircraft deviating due to GBAS failure to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Remote
Hz 021: Failure to maintain the A/C on the runway centreline during the Guided Take-off in LVC based on ILS in mixed GBAS/ILS equipage operations	RE-SC2b	Hazardous FC (EASA CS 25.1309 and CS AWO)		SO#2005: During Guided Take-Off in LVC conducted in mixed GBAS/ILS equipage, the frequency of occurrence of an ILS aircraft deviating due to an obstructed ILS CAT III sensitive/Critical area to a point from the runway centre line where the outboard landing gear is near the edge of the runway shall be less than 1x10-7 per approach/Remote
Hz 022: Failure to maintain aircraft longitudinal spacing on the runway during guided take-off in LVC	Rinc-SC3	1E-5/movement	20	*SO= 1.0 E-05 / 20 = 5.0 E-07 per movement* SO#2010: During Guided Take-Off optimised operations, the frequency of occurrence of a longitudinal spacing infringement on the runway leading to a runway conflict shall not be greater than **5x10-7 per movement**

Appendix G Skills and competences for maintenance personnel working on GBAS

Air Traffic Safety Electronics Personnel (ATSEP) are qualified and trained in accordance with the European Commission Regulation No 1035/2011 laying down common requirements for the provision of air navigation services which, in its Annex II Section 3.3 sets out “Safety requirements for engineering and technical personnel undertaking operational safety related tasks”. These requirements transpose the equivalent requirements of former EUROCONTROL ESARR 5.

EUROCONTROL has developed the guidance document EAM 5 / GUI 3 that is the Explanatory Material on ESARR 5 Requirements for Engineers and Technical Personnel Undertaking Operational Safety-Related Tasks. The main purpose of this document is to provide guidance about the provisions established in ESARR 5 and more specifically in its Section 5 ‘Safety Requirements’, sub section 5.3 addressing engineers and technical personnel undertaking operational safety related tasks.

Section 2.2.1.2 of this guidance material notably identifies a terminology to be used within the competence processes for engineers and technical personnel around the ECAC States:

- Qualification indicates the discipline in which an ATSEP has been trained to provide the service - Communication, Navigation, Surveillance, Data Processing.
- Equipment/System rating indicates explicitly the equipment/system on which an ATSEP will perform his safety related tasks. Maintenance is preventive, adaptive or corrective. It deals with both hardware and software issues.
- Level rated tasks represent the categorization by complexity, knowledge, skills and operational impact. Three categories will usually suffice but could be further sub-divided for highly complex or diverse systems.
    - Level A tasks. Level A maintenance tasks are primarily associated with immediate service restoration or reconfiguration (“frontpanel level”). It is appropriate for staffs that have been trained to understand the elements of equipment or system, their interrelationships and functional purpose, but does not require an in-depth knowledge of these elements.
    - Level B tasks. Level B maintenance tasks involves in-depth fault analysis at the system/equipment level (“functional level”). It is usually carried out by staff that has been trained for the more complicated maintenance tasks on the equipment/system.
    - Level C tasks. Level C maintenance tasks involves the detailed diagnosis of a software problem, of a faulty LRU (Line Replacement Unit), PCB (Printed Circuit Board) or module (“component level”). It usually requires the use of automated test equipment at a suitable location and is usually carried out by staff that has been trained in detailed fault diagnosis and repair techniques.

To be allowed to perform any maintenance actions on GBAS, ATSEP must have obtained the qualification in Navigation discipline completed by specific expertise to ensure appropriate and reliable maintenance of the GBAS ground subsystem.

In general, any erroneous maintenance actions (wrong configuration, settings or repair) could lead to degrade the integrity and continuity performance of the GBAS ground subsystem:

- Less critical are wrong maintenance actions that could potentially affect the continuity performance: for the purpose of the safety assessment it is considered to be categorized as Level A maintenance tasks.
- More critical are wrong maintenance actions that could potentially affect the integrity performance: for the purpose of the safety assessment it is considered to be categorized as Level B maintenance tasks. Typically, GBAS ground subsystem monitor threshold setting or FAS data file loading are classified as Level B maintenance tasks.

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