PJ.02-W2-14.5 IGS-to-SRAP SPR-INTEROP.OSED - Part II - SAR for V3

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AART

AIRPORT AIRSIDE AND RUNWAY THROUGHPUT

This Safety Assessment Report (SAR) is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 874477 under European Union's Horizon 2020 research and innovation programme.

Abstract

This document specifies the results of the safety assessments carried out in SESAR2020 Wave 2 by PJ02-W2-14.5 IGS-to-SRAP (Increased Glide Slope to Secondary Runway Aiming Point) Solution by the European Organisation for the Safety of Air Navigation (EUROCONTROL).

This Safety Assessment Report (SAR) represents the Part II of the SPR-INTEROP/OSED (Safety and Performance - Interoperability Requirements/ Operational Service and Environment Definition) and contributes to the SPR-INTEROP/OSED Part I and TS/IRS (Technical Specifications/ Interface Requirement Specification) documents.

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1 Executive Summary

This document contains the Specimen Safety Assessment for a typical application of the Project 02 Solution 14 IGS-to-SRAP (Increased Glide Slope to a Second Runway Aiming point). The report presents the assurance that the Safety Requirements for the V1-V3 phases are complete, correct and realistic, thereby providing all material to adequately inform the PJ02-W2-14.5 IGS-to-SRAP SPR-INTEROP/OSED.

This Safety Assessment Report (SAR) represents the Part II of the SPR-INTEROP/OSED (Safety and Performance - Interoperability Requirements/ Operational Service and Environment Definition) and contributes to the SPR-INTEROP/OSED Part I and TS/IRS (Technical Specifications/ Interface Requirement Specification) documents.

This safety analysis is based on the work done by project P06.08.08 in SESAR 1 and by PJ02.02 IGS-to-SRAP in SESAR2020 Wave 1, contained in the corresponding SARs [13] [15]. The current version of the document contains updates with the work done for the IGS-to-SRAP enhanced approach procedures concept in SESAR 2020 Wave 2.

2 Introduction

2.1 Background

PJ02-W2-14.5 IGS-to-SRAP is based upon work, deliverables and achievements that have been made available by SESAR I and SESAR2020 Wave 1, namely by the following projects:

- P06.08.08 – Enhanced Arrival Procedures Enabled by a Ground Based Augmentation System (GBAS);
- P06.08.05 – GBAS Operational Implementation;
- PJ02.02 – Enhanced Arrival Procedures.

2.2 General Approach to Safety Assessment

A Broader approach

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

- a new *success approach* which is concerned with the safety of the IGS-to-SRAP concept, in the absence of failure; and
- a conventional *failure approach* which is concerned with the safety of the IGS-to-SRAP concept, in the event of failure within the end-to-end System

These two approaches are applied to the derivation of safety properties at each of two successive stages of the development of the IGS-to-SRAP concept, as follows:

Safety specification at Service Specification Level

This is defined as what the new concepts have to achieve at the Air Traffic Management (ATM) operational level in order to satisfy the requirements of the airspace users - *i.e.* it takes a “black-box” view of the new method of operations and includes what is “shared” between the users and the Air Traffic Service (ATS) Providers.

From a safety perspective, the user requirements are expressed in the form of SAfety Criteria (SAC) 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 is to check the completeness of the OSED and identify possibly additional validation objectives to be revealed by the safety analysis in view of their inclusion in the Validation plans.

Safety Specification at Design Level

This describes what the new concepts are 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 “whitebox", view of the IGS-to-SRAP operations. This is more generally called the Design-level Model and is expressed in terms of human and machine "actors" that deliver the functionality.

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 phase of the development lifecycle. The purpose here is to feed the SPR/INTEROP/OSED with a complete and correct set of safety requirements. Furthermore, if relevant, interact with the validation exercises so as to include additional validation objectives and obtain validation feedback regarding certain proposed safety requirements.

2.3 Scope of the Safety Assessment

The PJ02-W2-14.5 IGS-to-SRAP safety assessment will make extensive use of outcomes from previous P06.08.08 GBAS enhanced arrival procedures SAR [6] and PJ02.02 IGS-to-SRAP SAR [15]. The starting point of the safety assurance activities for PJ02-W2-14.5 IGS-to-SRAP is driven by the safety validation status at the end of SESAR2020 Wave 1.

The following parts of the safety assessment lifecycle are covered by the current issue of the Safety Plan and consequently of the safety assessment work to be undertaken and finally documented in the SAR:

- **V1** - through initial identification of safety implications of the Change and the definition of Safety Criteria (fully covered within this document and further summarized in the Safety Assessment Report)

- **V2 & V3**- through establishing Safety Objectives (SO) to deliver the Safety Criteria and the derivation of Safety Requirements at Design Level (SRDs) to satisfy the SOs (based on combined safety analysis of the design, data analysis for wake encounter risk and safety-related measurements, observations and debriefing of the validation exercises).
  The safety assessment for Safety Requirements derivation will align with the design maturity (i.e. successive inclusion of OIs). The safety assessment will be conducted to the level of granularity decided by the Project for the OSED/SPR/INTEROP and TS/IRS documents for the design of the Functional system for the Solution (encompassing people, procedures & airspace and equipment).
  The SRDs are derived during the V2 (initial SRDs) and V3 (detailed SRDs) phases of the development lifecycle. The purpose is to feed the SESAR Solution PJ02-W2-14.5 IGS-to-SRAP SPR-INTEROP/OSED Part I with a complete and correct set of safety requirements. Furthermore, where relevant, the requirements inform the validation exercises with respect to the inclusion of related additional validation objectives for which validation feedback is required

The PJ02-Solution 14.5 IGS-to-SRAP addresses the following OI:

- AO – 0331 - Increased Glide Slope to a Second Runway Aiming Point (IGS-to-SRAP)

Note that only the capacity-constrained airport environments will be addressed.

For IGS-to-SRAP a full set of configurations under the scope of the Solution (depending on runway configurations[1] and runway operating modes[2]) needs to be defined by the Project and included in the OSED (might be wider than the scope of the validation exercises; the safety assessment has to align to the wide scope of the Solution.

The Safety assurance activities will be conducted in line with the SESAR 2020 Safety Policy [9], SESAR SRM [1] and accompanying Guidance [2].

2.4 Layout of the Document

Section 1 presents the executive summary of the document

Section 2 provides the background of the IGS-to-SRAP concept, the general approach to safety assessment in SESAR and the scope of this safety assessment

Section 3 provides the operational concept overview and the scope of the change, summarises the solution operational environment and key properties together with the stakeholders' expectations and derives the Safety Criteria

Section 4 addresses the safety specification at Service level, through the definition of SRSs

Section 5 addresses the safe design of the solution, through the derivation of SRDs and link to validation results

Section 6 presents the achievability of the Safety Criteria

Section Error! Reference source not found. lists the acronyms and terminology

Appendix A presents the methodology used to derive the Functionality & Performance SOs based on the NOV5 EATMA diagram

Appendix B presents the NSV4 EATMA Models

Appendix C presents the consolidated list of SOs

Appendix D presents the consolidated list of SRDs with traceability to the Safety Objectives

Appendix E presents the results of the initial P06.08.08 HAZID updated with the SESAR 2020 developments

Appendix F presents the results of the PJ02.02 SAF/HP workshop, which took place on the 28th and 29th of March 2018, at EUROCONTROL HQ

[1] RWY configurations: Single runway, Independent parallel runways, Closely spaced parallel runways (CSPR), Dependent parallel runways.

[2] RWY operating modes: segregated mode, mixed mode

Appendix G presents the results of the workshop with pilots from Air France and CDG ATCOs, which took place on the 28th of January 2019 in the frame of SESAR 2020

Appendix H presents the list of Assumptions and safety Issues

Appendix I outlines the Accident Incident Models (AIM) relevant for PJ02-W2-14.2 IGS-to-SRAP and their associated Risk Classification Schemes

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3 Setting the Scene of the safety assessment

3.1 Operational concept overview

Increased Glide Slope (IGS) to Second Runway Aiming Point (SRAP)

Applying an Increased Glide Slope (above the approach angle in use to the first runway threshold and up to 4.49°) to a second Aiming Point further down the runway (as specified in the published chart) will enable inbound aircraft to reduce the noise footprint (environmental benefit) around the airport and possibly reduce runway occupancy time and/or taxi-in time depending on local runway/taxiway layout. Unlike the Increased Second Glide Slope concept (which applies to the first runway threshold), increasing the glide slope to a second runway aiming point should prevent a potential reduction of airport capacity and potentially increasing it through optimization in wake turbulence separations.

Compared to benefits gained from the Second Runway Aiming Point concept (using the same glide path angle for both glide slopes), increasing the glide slope to a second runway aiming point enables a potential increase of airport capacity through optimization in wake turbulence separations.

For further detail on the operational concept see the PJ.02-W2-14.05 SPR-INTEROP/OSED Part I [16].

Note that the main evolutions expected in PJ02-W2-14.5 IGS-to-SRAP compared to PJ02-02 Wave 1 OSED/SPR/INTEROP are related to:

- RWY Markings and Approach lighting system
- Non-nominal Use Cases
- PAPI/VASI

3.2 Scope of the change

The **Reference scenario** for the safety assessment is aligned as far as possible to the reference scenarios used by the validation exercises. It is represented by the current final approach operations conducted with a nominal (3°) and continuous glide path angle, with a single threshold, based on the various available technologies: ILS, GBAS CAT I, RNAV or SBAS.

Main changes in the Aircraft operating method

- Operators and pilots intending to conduct any approach operations should fill the appropriate flight plan suffixes and the on board navigation data must be current and include the appropriate procedures, including the new IGS-to-SRAP procedure (that must be selectable from a valid navigation database and not prohibited by a company instruction or NOTAM).

  Note that the IGS-to-SRAP procedure emphasizes the specificities regarding the landing distance. On a destination airport with two runway aiming points, the landing distance computation at dispatch may be performed on the longest landing runway with no wind. If the runway conditions change at landing (wind, dry/wet, contaminated etc.), the flight crew must perform a new landing distance computation.

- Before commencing the descent to the airport destination, the crew will check the approach and runway in use at destination. The IGS-to-SRAP procedure is selected as any other approach procedure (coded in the NavDB and associated to a published chart). After the selection of the IGS-to-SRAP procedure in the FMS, the on board system automatically extracts approach data from the navigation database and displays it to the pilot.

  With IGS-to-SRAP, once informed by ATC of the intended approach procedure which defines the requested landing aiming point, the flight crew may perform an in-flight landing performance assessment if the landing conditions changed compared with the landing computation at dispatch, or if they have not prepared the intended approach procedure at dispatch.

- Before capturing the final approach segment, the flight crew must verify the correctness of the IGS-to-SRAP data from the Navigation Database, crosschecking them with the approach chart.

- The final approach segment should be intercepted before the FAP in order for the aircraft to be correctly established on the final approach course before starting the descent, to ensure terrain and obstacle clearance.

- The final descent is continuous with a defined approach slope until reaching the minima. The descent profile should at least contain one fix (for example the FAP or a fix further down) where the pilots compare the crossing altitude with the required crossing altitude indicated on the approach chart.

  The crew has to respect the Standard Operational Procedure defined for IGS-to-SRAP operations if any (described in the FCOM). That concerns particularly the aircraft configurations deployment in order to be stabilized in speed and thrust level no later than 1000ft. The crew must also comply with the ATC speed constraints if any. The approach can be flown with various levels of automation: with AP/FD, with FD only and without AP/FD (using only the raw data).

- On the visual segment below the minima, additional cockpit aids may be provided to the pilot to achieve correctly the manual flare manoeuvre.

- Missed approaches flown as usual.

Main changes in the ATC operating method

- Aircraft that are approaching an aerodrome are informed about the IGS-to-SRAP procedure in use, in addition to the standard final approach instrument procedure, through the automatic terminal information service (ATIS).

- The information about aircraft performance and status might be shared between aircraft and ATC thanks to datalink. Datalink can be a good candidate to improve operations, nevertheless it is <u>not identified as compulsory</u>.

  With IGS-to-SRAP, for the second runway aiming point, the crew should take into account weather information, landing distance, aircraft performance and status (weight) (parameters affecting the needed landing distance).

- IGS-to-SRAP procedure requests can be initiated by ATC only.
- During final approach, ATCO can provide the aircrew of the follower with information about the aiming point of the leader aircraft, in order to improve the situation awareness of the follower aircraft.
- ATCO can be supported by tools to check any discrepancy from the nominal path in the final approach segment.
- ATC intervention to adjust speed and maintain separation needs to take into account aircraft speed limitation in flying an increased glide slope.
- Missed Approaches/Go-arounds: if the leader on the nominal ILS glide slope goes around and the follower is on the IGS-to-SRAP glide slope and the two a/c are separated at under the reference (e.g. RECAT-EU) minima, the follower shall also be instructed to go-around – see SR2.052 for full procedure. Additionally, the Height Loss value must be recomputed for Enhanced Arrival operations according to ICAO PANS OPS Doc 8168 - Volume II - Chapter 1.4.8.8.3.1.

The airport infrastructure (RWY markings, Visual approach slope indicator systems, Approach lighting systems), ground and airborne capabilities required for enabling IGS-to-SRAP procedures are listed in the next section “Solution operational environment & Key properties”.

3.3 Solution Operational Environment and Key Properties

This sub-section describes the key properties of the Operational Environment that are relevant to the IGS-to-SRAP safety assessment (information summarized from the OSED [16]).

3.3.1 Airspace and Airport Characteristics

IGS-to-SRAP can be applied to any size of airports (Large, Medium, Small) and any complexity of TMA (High, Medium, Low Complexity) (as per sub operational environments defined in B.04.01 D42 SESAR2020 Transition Validation [10]). However, the validation will be focused on medium and large (**capacity-constrained**) airports and TMA with Medium/High Complexity.

Any airport layout from single to multiple runways with simple or complex taxiway structures.

Any RWY configurations: Single runway, Independent parallel runways, Closely spaced parallel runways, Dependent parallel runways.

Any RWY operating modes: segregated mode, mixed mode.

3.3.2 Aerodrome service

Marking & lighting in accordance to ICAO Annex 14/EASA regulation. More specifically:

RWY Markings & Approach lighting systems: with IGS-to-SRAP there is a need to provide aircrew with a clear visual reference to the specific runway aiming point. The visual reference could be constituted of additional markings for aiming points, touch down zones and additional lighting system related to the same threshold that could be physical or virtual (displayed to ATCO and aircrew).

Visual approach slope indicator systems (VASI) / Precision Approach Path Indicator (PAPI): there is a need for a second VASI/PAPI to support IGS-to-SRAP operations.

3.3.3 Airspace Users – Flight Rules

All airspace users conducting CAT I approach operations (mainline and business aircraft).

3.3.4 Traffic Levels and complexity

In Reference: level of traffic in peak hours as per the reference RWY throughput at the capacity-constrained airports (Large, Medium)

With IGS-to-SRAP: level of traffic in peak hours as per the increased RWY throughput enabled by the Solution.

3.3.5 Terrain Features and Obstacles

Obstacle protection surfaces need to be determined for each displaced glide path (in terms of slope and/or aiming point) and corresponding Missed Approach procedures. For the solution, procedure design criteria (ICAO 8168) may need modifications.

3.3.6 Separation Minima

In Reference:

- The ICAO radar separation standards for arrivals include MRS which prevents aircraft collision and WT separation which is intended to protect aircraft from adverse WTEs. For MRS that is typically 3NM although can be 2.5NM under certain conditions prescribed in ICAO Doc 4444 or as prescribed by the appropriate ATS authority. For WT separation that involves distance-based WT separations based on WT categories as per e.g. ICAO or RECAT-EU 6 category.

With the IGS-to-SRAP Solution:

- Under certain conditions, and for certain aircraft pairs the WT separations will be reduced/removed due to successive aircraft flying different descent profiles on final approach (e.g. small jet flying upper glide approach, thus facilitating access of these aircraft to major airports) (the current MRS still applies).

3.3.7 ATC Operating modes

Both Unconstrained (closed loop) and Constrained flights (under vectoring):

- unconstrained flights will be able to follow an optimised flight profile without intervention from air traffic control;
- constrained flights need to be separated from other aircraft by ATC and spaced as required in order to obtain efficient use of the runway.

3.3.8 Final approach operations

Intermediate approach segment: Standard interception (RNP to XLS not considered). Basically based on vectoring, given the high traffic level on capacity-constrained airports. However some aircraft might conduct full RNAV approach.

Final approach segment:

- Reference: ILS or GBAS CAT I or RNAV;
- Solution: GBAS CAT I, ILS or RNAV app (based on SBAS, or APV BARO/VNAV)

Missed approach: as per the reference scenario.

3.3.9 Ground ATM capabilities

In Reference scenario:

- Surveillance System (Approach& Final Approach path)
- VHF voice between ATC and aircraft
- Flight Data Processing System
- Arrival Manager (might be available at capacity-constrained airports but not required for the Solution)
- Advanced Meteorological Information
- A-SMGCS
- Tower CWPs (Airport Tower Supervisor, Tower Runway Controller, Tower Ground Controller, Tower Clearance Delivery Controller or Apron Manager)
    - Electronic Flight Progress Strips
    - Traffic Situation View Display
    - Meteorological Information Display
    - ATC Voice Communications
- TMA CWPs (TMA Supervisor, TMA Planning Controller, TMA Executive Departure Controller, Final Approach Controller)
    - Flight Progress Strips (Either electronic or paper)
    - Radar Situation View Display
    - ATC Voice Communications

Additional elements with the Solution:

- Datalink is not identified as compulsory. However, that can be a good candidate to still improve operations through sharing information about aircraft performance and status between aircraft and ATC;
- ATCO delivery Tool support for Arrivals (separation indicators and alerts). In its turn, this would require:
    - a reliable Approach Arrival Sequence Service that is updated upon any change in the sequence for the tool to correctly display TDIs;
- Approach Path Monitoring;
- Indication and possibility of the ATCO to record the type of approach that has been instructed;

- Local environment weather information and wind forecasting and monitoring capabilities.

3.3.10 Aircraft ATM capabilities

With the Solution:

- ILS, RNAV, MLS or GLS capability (designed according to ILS-look alike concept) – this already exists and is currently used to support GBAS CAT I approach operations conducted with a nominal (3°) and continuous glide path angle.
- Indication of type of approach that has been instructed.

3.3.11 CNS Aids

With GBAS: Satellite navigation coverage/performance for GBAS CAT I, as defined for the approach service in accordance with ICAO Annex 10 i.e. GBAS approach service type GAST-C GBAS. Final approach interception is made inside the GBAS coverage area.

With ILS: as per today

With RNAV: as per today

3.4 Stakeholders' expected benefits with potential Safety impact

According to the SESAR2020 Grant agreement, the IGS-to-SRAP concept provides benefits principally by:

Environment:

The increased glide slope (– 3.0° to - 4.49°) provides a steeper final approach segment which reduces the size of noise contours location around the airport. This means that the number of people around the vicinity of the airport exposed to aircraft noise should decrease.

Aircraft flying to the second runway aiming point will fly higher and will start descending later than a flight to the standard runway threshold. This will reduce the noise contours around the airport and should reduce the number of people exposed to aircraft noise.

The average fuel burn (due to flying time) will have to be determined locally since it depends on each implementation. It will either remain the same when the local separation minima is the same as the separation minima computed for IGS-to-SRAP, increase when the local separation minima is smaller than IGS-to-SRAP minima and decrease when the local separation minima is greater than the IGS-to-SRAP minima.

Capacity:

Second aiming point operations may contribute to a reduction of Runway Occupancy Time (by reducing the distance between the actual Touchdown Zone and the chosen/preferred Runway Exit) and enables reducing the wake turbulence separations (if the follower is on a higher glide slope than the leader). On average, since the gain in wake separation is greater than the loss, it is expected that this will positively contribute to the runway throughput.

<u>**Safety and Human Performance:**</u>

The IGS-to-SRAP operations introduce a more complex wake separation scheme to be applied and more complex ATCO tasks (multiple glide path angles and runway aiming points to monitor, more complex sequence, etc.) which could negatively impact the delivery accuracy in constrained environments (i.e. high traffic pressure), ATCO workload and SA. However, it is expected that a separation delivery tool would mitigate this. Therefore, no impact is expected on the Safety and HP KPAs.

3.5 Safety Criteria

3.5.1 Identification of relevant hazards inherent to aviation

A pre-condition for performing the safety assessment for the introduction of a new Concept is to understand the impact it would have in the overall ATM risk picture. The SRM Guidance D and E [2] provides a set of Accident Incident Models (AIM - one per each type of accident) which represents an integrated risk picture with respect to ATM contribution to aviation accidents.

In order to determine which AIM models are relevant for the PJ02-W2-14.5 IGS-to-SRAP Solution, this sub-section presents the relevant aviation hazards (that pre-exist in the operational environment before any form of de-confliction has taken place) that have been identified in the Safety Plan for SESAR2020 Wave 1 PJ02.02 (using Guidance F.2.2 of [2]) and which continue to be applicable within the current scope. The relevant pre-existing hazards, together with the corresponding ATM-related accident types and AIM models are presented in Table 1.

Pre-existing aviation Hazards [Hp]	ATM-related accident type& AIM model
Hp#1. “Situation in which the intended trajectory of an aircraft is in conflict with terrain or an obstacle during an approach”	Controlled Flight Into Terrain (CFIT) & associated AIM model I.1
Hp#2 “Situation in which the intended 4D trajectories of two or more aircraft are in conflict during interception& final approach”	Mid-Air Collision (MAC) during interception & final approach - no AIM model available (will be partially supported by WTA model on Final Approach below)
Hp#3 “Adverse wake encounter on Final Approach”	Wake Turbulence-induced Accident (WTA) on Final Approach & associated AIM model I.3
Hp#4 “Situation in which the intended trajectory of a landing aircraft is conflicting with another aircraft or vehicle on the runway area”	Runway Collision (RC) & associated AIM model I.4
Hp#5. “Situation in which the aircraft veer off, undershoot or overrun off the runway surface during landing”	Runway Excursion (RE) & associated AIM model I.5

Table 1. Pre-existing hazards relevant for Final Approach

3.5.2 Initial determination of the Operational Services to Address the Pre-existing Hazards

The following ATM/ANS Services are provided to aircraft for approach and landing to address the above pre-existing aviation hazards sufficiently to satisfy the Safety Criteria. They are detailed in Table 2 below.

ID[3]	Air Navigation Service Objective	Pre-existing Hazard
	Approach and Landing	
SAD	Establish separation between arrival flows and departing flows (including missed approach situations) in the considered environment	**Hp#2** (MAC risk)
SP1	Maintain arrival flow separation	**Hp#2** (MAC risk) **Hp#3** (Wake 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#2** (MAC risk) **Hp#3** (Wake risk)
SPT2	Separate aircraft from terrain/obstacles during the final approach	**Hp#1** (CFIT risk)
SP2a	Maintain spacing/separation between aircraft on the same final approach path	**Hp#2** (MAC risk) **Hp#3** (Wake risk) **Hp#4** (Rw collision risk)
SP2b	Maintain separation between aircraft on different final approach path for the same runway end	**Hp#2** (MAC risk) **Hp#3** (Wake risk)
FLD	Facilitate landing and deceleration on the runway	**Hp#5** (RE risk)
SP3	Maintain aircraft separation on the Runway Protected Area (RPA)	**Hp#4** (Rw collision risk)

Table 2: ATM/ANS services and Pre-existing Hazards relevant to the Solution scope

[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;

3.5.3 Preliminary identification of system-generated hazards prior to Change introduction

Based on the PJ02.02 Safety Assessment [15] conducted in SESAR 2020 Wave 1, the following operational hazards are identified as being potentially impacted by the Change.

Hazards generated by the Reference system [Hr]	Impacted (new/modified) & justification
Hz#02 Insufficient spacing at interception between aircraft pair flying IGS-to-SRAP and Standard approach or between aircraft conducting the same IGS-to-SRAP approach	No change compared to Wave 1
Hz#04 Vertical deviation of either a/c in a pair where the leader is on the lower glide slope (standard or A-IGS) and the follower is on the higher IGS-to-SRAP glide slope leading to imminent WT separation infringement	No change compared to Wave 1
Hz#05 Lateral or vertical deviation from the IGS-to-SRAP approach leading to a flight towards terrain	No change compared to Wave 1
Hz#06a An aircraft on IGS-to-SRAP approach with insufficient landing distance available	No change compared to Wave 1
Hz#06b An aircraft on IGS-to-SRAP approach landing with excessive vertical speed leading to hard landing	No change compared to Wave 1
Hz#07 Fail to prevent wake separation infringement	No change compared to Wave 1
Hz#08 Interception and landing to the incorrect aiming point going undetected with a risk of runway excursion during IGS-to-SRAP approach	No change compared to Wave 1

3.5.4 Safety Criteria definition

SAfety Criteria (SAC) define the acceptable level of safety (i.e. accident and incident risk level) to be achieved by the IGS-to-SRAP Solution under assessment, considering its impact on ATM/ANS functional system and its operations.

The SAC setting is driven by the analysis of the impact of the Change on the relevant AIM models (models identified in section 3.5.1) and it needs to be consistent with the SESAR safety performance targets defined by PJ 19.04.

Two sets of safety criteria are formulated:

- A first one aimed at ensuring an appropriate Separation design i.e. definition of WT separation minima which, if correctly applied in operations, guarantees safe operations on final approach segment and respectively on initial common approach path;

- A second one aimed at ensuring correct Final Approach path Intercepted and Flown, Separation delivery (i.e. that the defined WT separation minima or the minimum surveillance separation -MSS are correctly applied for separation delivery by ATC) and RWY separation.

SEPARATION DESIGN

A SAC is defined such as to encompass all types of operations/RWY configuration in which a pair of aircraft can be found, driven by the WT accident on Final Approach AIM model.

- on risk of WT Encounter[4] on Final Approach (see in AIM WT on Final Approach model from Appendix I the outcome of precursor WE6S "Imminent wake encounter under fault-free conditions" not mitigated by barrier B2 "Wake encounter avoidance"):

IGS-to-SRAP-SAC#WT-1: The probability per approach of a wake turbulence encounter of a given severity for a given traffic pair for any type of operations/RWY configuration in which that pair of aircraft can be found spaced on Final Approach segment at the WT minima adapted in order to account for the IGS-to-SRAP concept shall not increase compared to the same traffic pair spaced at reference distance WTC-based minima conducted on a nominal (3°) and continuous final approach path angle, with a non-displaced threshold, in reasonable worst-case conditions*.

* Reasonable worst-case conditions recognized for WT separation design.

Once the Design has met the SAC above, the following safety issue still remains to be addressed:

Safety issue: The frequency of wake turbulence encounters at lower severity levels might increase due to the reduced wake turbulence separation minima. As the frequency of wake turbulence encounters at each level of severity depends on local traffic mix, local wind conditions and intensity of application of the concept (e.g. proportion of time, proportion of aircraft), there is a need to find a suitable way for controlling the associated potential for WT-related risk increase.

An additional SAC is defined in order to cap the safety risk from the case where the correctly defined WT separation minima are not correctly applied, with potential for a severe wake encounter higher than if those minima were correctly applied.

- on risk of Imminent wake encounter under unmanaged under-separation (see WE 6F in AIM WTA Final Approach model):

IGS-to-SRAP-SAC#WT-F1: The probability per approach of an imminent wake encounter under unmanaged under-separation on Final Approach for any type of operations/RWY configuration in which a pair of aircraft can be found shall be no greater in operations with applicable WT

[4] In case of aircraft inability to recover from a severe wake encounter a wake accident will occur (encompassing loss of control or uncontrolled flight into terrain; that is not related to the Controlled Flight into Terrain accident and associated AIM model)

> minima adapted in order to account for the IGS-to-SRAP concept than in current operations, applying reference distance WTC-based minima on a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

The strategy intended for meeting the IGS-to-SRAP-SAC#WT-F1 relies upon qualitatively showing that the use of the separation supporting tool will involve a significant reduction of the frequency of unmanaged under-separations which will compensate for the risk increase brought in by the higher probability of an imminent wake encounter associated to those unmanaged under-separations.

FINAL APPROACH PATH INTERCEPTED&FLOWN, SEPARATION DELIVERY and RWY SEPARATION

A set of SACs are defined in order to ensure that the Final Approach path is correctly intercepted and flown (encompassing safe landing and RWY vacation), that the adapted WT separation minima or the MSS minima are correctly applied for separation delivery and that the runway separation is ensured, i.e. that the right Functional System in terms of People, Procedures, Equipment (e.g. new airborne functionalities, ATC separation delivery tool …) is designed such as to enable safe operations in the concept.

FINAL APPROACH PATH INTERCEPTED&FLOWN (encompassing safe landing & RWY vacation)

- on risk of Controlled Flight Towards Terrain (see CF4 following failure of B4: Flight Crew Monitoring in AIM CFIT model from I.1):

> **IGS-to-SRAP-SAC#CFIT-1:** The likelihood of "Controlled Flight Towards Terrain" on final approach segment during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- on risk of Flight towards terrain commanded by Pilot (see CF5 following failure of B5: Pilot trajectory management barrier in AIM CFIT model):

> **IGS-to-SRAP-SAC#CFIT-2:** The likelihood of Flight towards terrain commanded by Pilot on final approach segment during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- on risk of Flight towards terrain commanded by Airborne Systems (see CF6 following failure of B6: FMS/RNAV/Flight control management barrier in AIM CFIT model fromI.1):

> **IGS-to-SRAP-SAC#CFIT-3:** The likelihood of Flight towards terrain commanded by Airborne Systems on final approach segment during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- on risk of Flight towards terrain commanded by ATC (see CF7 following failure of B7: ATC Flight trajectory management barrier in AIM CFIT model):

> **IGS-to-SRAP-SAC#CFIT-4:** The likelihood of Flight towards terrain commanded by ATC on final approach segment during IGS-to-SRAP operations shall not increase compared to current

operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- on risk of Flight towards terrain commanded by ANS (see CF8 following failure of B8: Route/Procedure design and publication barrier in AIM CFIT model from):

IGS-to-SRAP-SAC#CFIT-5: The likelihood of Flight towards terrain commanded by ANS on final approach segment during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- On risk of Runway excursion following stabilised touchdown in Touchdown Zone (TDZ) (see Failure of Crew/AC for RWY deceleration/stopping action barrier following stabilised touchdown in TDZ in AIM RWY Excursion model from I.5):

IGS-to-SRAP-SAC#RWE-1: The likelihood of Runway excursion following stabilised touchdown in TDZ during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- On risk of Runway excursion following touchdown outside TDZ (see Failure of Crew/AC for RWY deceleration/stopping action barrier following touchdown outside TDZ in AIM RWY Excursion model from I.5):

IGS-to-SRAP-SAC#RWE-2: The likelihood of Runway excursion following touchdown outside TDZ during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- On risk of Runway excursion following unstable touchdown (e.g. hard landing) (see Failure of Crew/AC for RWY deceleration/stopping action barrier following unstable touchdown in AIM RWY Excursion model from I.5):

IGS-to-SRAP-SAC#RWE-3: The likelihood of Runway accident following unstable touchdown (e.g. hard landing) during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- On risk of Touchdown outside TDZ (see Failure to manage short Final&Flare barrier following Stable or Unstable approach in AIM RWY Excursion model from I.5):

IGS-to-SRAP-SAC#RWE-4: The likelihood of Touchdown outside TDZ during IGS-to-SRAP operations shall not increase compared to ILS CAT I operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- On risk of Unstable touchdown e.g. Hard landing (see Failure to manage short Final&Flare barrier following Stable or Unstable approach in AIM RWY Excursion model):

IGS-to-SRAP-SAC#RWE-5: The likelihood of Unstable touchdown (e.g. Hard landing) during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

- on risk of Unstable approach (following Failure to manage stabilization on Final Approach barrier in AIM RWY Excursion model):

> **IGS-to-SRAP-SAC#RWE-6:** The likelihood of Unstable approach during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous final approach path angle, with a non-displaced threshold.

<u>SEPARATION DELIVERY</u>

The correct application of WT separation minima need to account for the additional separation constraints imposed by the Surveillance separation (during interception and along the final approach path).

- on risk of Unmanaged under-separation (WT or radar) during interception and final approach when WT separation minima adapted to the enhanced arrival procedure are applicable (see WE 7F.1 in AIM WT on Final Approach model and account for MSS minima):

> **IGS-to-SRAP-SAC#WT-F2:** The probability per approach of Unmanaged under-separation (WT or radar) during interception & final approach when WT separation minima adapted to the IGS-to-SRAP procedure are applicable shall be no greater than in current operations applying reference distance WTC-based minima on a nominal (3°) and continuous glide path angle, with a non-displaced threshold.

- on risk of Imminent infringement (WT or radar) during interception and final approach (see WE 8 in AIM WT accident on Final Approach model and account for MSS minima):

> **IGS-to-SRAP-SAC#WT-F4:** The probability per approach of Imminent infringement (WT or radar) during Interception & final approach shall be no greater when WT separation minima adapted to the IGS-to-SRAP procedure are applicable than in current operations applying reference distance WTC-based minima on a nominal (3°) and continuous glide path angle, with a non-displaced threshold.

- on risk of Crew/Aircraft induced spacing conflicts (spacing conflicts induced by Crew/Aircraft and not related to ATC instructions for speed adjustment) during interception and final approach (see WE 10/11in AIM WT accident on Final Approach model):

> **IGS-to-SRAP-SAC#WT-F5:** The probability per approach of Crew/Aircraft induced spacing conflicts during interception & final approach shall be no greater when WT separation minima adapted to the IGS-to-SRAP procedure are applicable than in current operations applying reference distance WTC-based minima on a nominal (3°) and continuous glide path angle, with a non-displaced threshold.

<u>RUNWAY SEPARATION</u>

- on risk of Imminent Inappropriate Landing (see in AIM RWY collision model the precursor RP4C which might be caused by e.g. spacing management by APP ATCO without considering ROT constraint and which outcome is mitigated by B3A: Runway Monitoring involving e.g. a Go Around instructed by TWR ATCO):

IGS-to-SRAP-SAC#R-1: The probability per approach of Imminent Inappropriate Landing during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous glide path angle, with a non-displaced threshold.

- on risk of Runway conflict due to premature landing (see in AIM RWY collision model the precursor RP2C which might be caused by e.g. TWR ATCO failure to correctly monitor the RWY and which outcome is mitigated by B2: ATC Runway Collision Avoidance involving last moment detection by TWR ATCO with or without RIMCAS):

IGS-to-SRAP-SAC#R-2: The probability per approach of Runway conflict due to premature landing during IGS-to-SRAP operations shall not increase compared to current operations conducted with a nominal (3°) and continuous glide path angle, with a non-displaced threshold.

- on risk of Runway incursion (see in AIM RWY collision model the precursor RP3) due to ATCO decreased situation awareness&overload in relation to RWY increased throughput enabled by the Concept, affecting the Landing management (barrier B7), Take-off management (barrier B8), ATC RWY entry management (barrier B4) and RWY Monitoring (barrier B3A).:

A-SAC#R-3: The probability per approach of Runway incursion shall not increase during IGS-to-SRAP operations (due to ATCO decreased situation awareness&overload in relation to RWY increased throughput enabled by the Concept) compared to current operations conducted with a nominal (3°) and continuous glide path angle, with a non-displaced threshold.

Other Safety Issues

The following Safety issue has been identified in relation to the SACs definition:

Safety issue: The frequency of wake turbulence encounters at lower severity levels might increase due to the reduced wake turbulence separation minima. As the frequency of wake turbulence encounters at each level of severity depends on local traffic mix, local wind conditions and intensity of application of the concept (e.g. proportion of time, proportion of aircraft), there is a need to find a suitable way for controlling the associated potential for WT-related risk increase.

4 Safety specification at ATS service level

4.1 Overview of activities performed

This section addresses the following activities:

- derivation of SOs in view of mitigating the relevant risks inherent to aviation in normal conditions of operations– section 4.2
- assessment of the adequacy of the ATS operational services provided by the Solution under abnormal conditions of the Operational Environment & derivation of necessary SOs – section 4.3
- assessment of the adequacy of the ATS operational services provided by the Solution in the case of internal failures and mitigation of the Solution functional system-generated hazards through derivation of SOs – section 4.4
- verification of the operational safety specification process (mainly about obtaining Backing evidence from the properties of the processes by which Direct Evidence was gleaned) – section 4.5.

4.2 Mitigation of Risks Inherent to Aviation – Normal conditions

4.2.1 Operational Services to Address the Pre-existing Hazards

The following operational services are provided to aircraft for approach and landing to address the above pre-existing aviation hazards such that the SAfety Criteria are sufficiently satisfied. They are detailed in Table 2 below.

ID[5]	Operational Service	Pre existing Hazard
Approach and Landing		
FCF	Facilitate capture of the Final approach	**Hp#1** (CFIT risk) **Hp#2** (MAC on Final Approach risk) **Hp#3** (WTA on Final Approach risk)

[5] SP= SeParate aircraft with other aircraft; SPT= SeParate aircraft with Terrain; FCF= Facilitate Capture of the Final approach; FLD= Facilitate Landing & Deceleration;

SPT	Separate aircraft from terrain/obstacles during the final approach	**Hp#1** (CFIT risk)
SP2	Maintain spacing/separation between aircraft on the same or on different final approach paths for same runway end, encompassing the final approach interception phase	**Hp#2** (MAC on Final Approach risk) **Hp#3** (Wake on Final Approach risk) **Hp#4** (Rwy collision risk)
FLD	Facilitate landing and deceleration on the runway	**Hp#5** (Rwy Excursion risk)
SP3	Maintain aircraft separation on the Runway Protected Area (RPA)	**Hp#4** (Rwy collision risk)

Table 3: Operational services and Pre-existing Hazards relevant to the Solution scope

Note: the following operational services in the initial & intermediate approach phase are not affected by the change represented by the Solution:

- Separate aircraft from terrain/obstacles during the initial/intermediate approach
- Establish separation between arrival flows and departing flows (including missed approach situation) in the considered environment
- Maintain arrival flow separation in the initial approach phase (prior to interception).

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

The purpose of this section is to derive functionality & performance Safety Objectives (as part of the success approach) in order to mitigate the pre-existing aviation risks under normal operational conditions (i.e. those conditions that are expected to occur on a day-to-day basis) such as to meet the defined Safety Criteria.

The safety Objectives in this section (functionality and performance) were derived by making use of the OSED Use Cases and their representation through the EATMA Process Models as defined by the OSED [16].

The following working method has been applied to derive the functionality & performance Safety Objectives (as part of the success approach) for Normal operations:

Step 1:

- For each Use Case (described via an EATMA Process Model):
  - For each Activity:
    - Identify to **which operational service(s)** that Activity contributes to,
    - Identify whether the Activity **is new or modified**, and what is the change,

- Whether necessary, refine the information by highlighting specific information flows produced or consumed by the Activity,
- Based on the findings above (i.e. new or modified Activity), retain (or not) the Activity and the related information as a relevant input to the Safety Objectives derivation.

Step 2:

- Consolidate the information outcome from Step 1 above according to Use Cases and Operational services
- For each Use Case:
  - For each Operational service:
    - Check whether the identified change(s) **is (are) safety relevant** (i.e. could the change impact the efficiency of a safety barrier or the occurrence of a safety precursor? The previously identified operational services are a necessary but not a sufficient indication, given their link to the AIM models),
    - Derive one or several Safety Objectives in order to describe the safety-relevant changes in the delivery of that operational service by the Solution.

The detailed application of the method presented above is provided in Appendix A. This appendix also shows to which operational services each activity contributes to and whether it involves a change or not.

Table 4 presents the consolidated list of functionality & performance Safety Objectives (SO) under normal operational conditions for the ATC-initiated IGS-to-SRAP approaches. The link to the Safety Criteria is shown in the last column for each SO, via the relevant Use Case and operational service that are concerned with the change and allowed the SO derivation.

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
SO 001	Approach Executive Control shall be able to check the conditions for the new ATC-initiated IGS-to-SRAP approach, propose the expected approach to the flight crew and, in the event of a refusal from the flight crew, cancel the ATC-initiated IGS-to-SRAP approach and propose a standard approach instead	**[NOV5-EAO 03] IGS-to-SRAP Published Approach**	Facilitate capture of the Final approach Facilitate landing and deceleration on the runway	**IGS-to-SRAP - SAC#F2** (AIM MAC FAP MF5.1 and MF5.2, in relation to aircraft unable to capture final approach path due to inadequate related capability) AIM RWE model: **IGS-to-SRAP - SAC#RWE-1, IGS-to-SRAP - SAC#RWE-2, IGS-to-SRAP - SAC#RWE-3,**

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
				IGS-to-SRAP - SAC#RWE-4, IGS-to-SRAP - SAC#RWE-5, IGS-to-SRAP - SAC#RWE-6,
SO 002	The Flight Crew shall be able to assess the feasibility of the proposed ATC-initiated IGS-to-SRAP approach, prepare and brief it if feasible, or reject it if not feasible	**[NOV5-EAO 03] IGS-to-SRAP Published Approach**	As above	As above
SO 004	Approach Executive Control shall be able to sequence, merge and space aircraft such that the different benefits of ATC-initiated IGS-to-SRAP could be taken into account	**[NOV5-EAO 03] IGS-to-SRAP Published Approach**	Maintain arrival flow separation	Non-optimal sequence would result in progressive TMA overload, with need for putting arrivals on holding patterns **IGS-to-SRAP - SAC#F2** (to account for potential degradation of B4, B5, B5a, B7 and B8 when the ATCO is overloaded) (no WT risk identified here as the Approach Control is supposed to respect the WT separation minima when facilitating the capture of the final approach path)

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
SO 003	Approach Executive Control shall be able to facilitate capture of the Final approach path whilst ensuring adequate spacing for the ATC-initiated IGS-to-SRAP approach clearance, such that the flight crew can start the approach	**[NOV5-EAO 03] IGS-to-SRAP Published Approach**	Facilitate capture of the Final approach	**IGS-to-SRAP - SAC#WT-1** (AIM Wake FAP WE 6S); **IGS-to-SRAP - SAC#WT-F1** (AIM Wake FAP WE 6F); **IGS-to-SRAP - SAC#WT-F2** (AIM Wake FAP WE7F.1); **IGS-to-SRAP - SAC#WT-F4** (AIM Wake FAP WE8); **IGS-to-SRAP - SAC#WT-F5** (AIM Wake FAP WE10/11) **IGS-to-SRAP - SAC#F1** (AIM MAC FAP MF4); **IGS-to-SRAP - SAC#F2** (AIM MAC FAP MF5.1 and MF5.2)
SO 005	Approach Executive Control shall be able to monitor and manage spacing/separation on final approach, taking into account the cohabitation of aircraft on ATC-initiated IGS-to-SRAP with aircraft on standard approach	**[NOV5-EAO 03] IGS-to-SRAP Published Approach**	Maintain spacing/separation between aircraft on the same or on different final approach paths for same runway end	As above
SO 006	Tower Runway Control shall be able to monitor spacing/separation on final approach, taking into account the new separating methods or the new landing threshold introduced by the ATC-initiated IGS-to-SRAP	**[NOV5-EAO 03] IGS-to-SRAP Published Approach**	Maintain spacing/separation between aircraft on the same or on different final approach paths for same runway end	**IGS-to-SRAP - SAC#WT-1** (AIM Wake FAP WE 6S); **IGS-to-SRAP - SAC#WT-F1** (AIM Wake FAP WE 6F); **IGS-to-SRAP - SAC#WT-F2** (AIM Wake FAP WE7F.1); **IGS-to-SRAP - SAC#WT-F4** (AIM Wake FAP WE8); **IGS-to-SRAP - SAC#WT-F5** (AIM Wake FAP WE10/11)

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
				IGS-to-SRAP - SAC#R-1 (AIM RWY Col RP2.4); **IGS-to-SRAP - SAC#R-2** (AIM RWY Col RP2.1).
SO 007	Flight Crew shall be able to safely fly the IGS-to-SRAP procedure (encompassing flight path conformance, speed stabilization, thrust level and landing in the prescribed touchdown zone)	**[NOV5-EAO 03] IGS-to-SRAP Published Approach**	Separate aircraft from terrain/obstacles during the final approach Facilitate landing and deceleration on the runway	AIM CFIT model: **IGS-to-SRAP - SAC#CFIT-1;** **IGS-to-SRAP - SAC#CFIT-2;** **IGS-to-SRAP - SAC#CFIT-3;** **IGS-to-SRAP - SAC#CFIT-4;** **IGS-to-SRAP - SAC#CFIT-5;** AIM RWE model: **IGS-to-SRAP - SAC#RWE-1;** **IGS-to-SRAP - SAC#RWE-2;** **IGS-to-SRAP - SAC#RWE-3;** **IGS-to-SRAP - SAC#RWE-4;** **IGS-to-SRAP - SAC#RWE-5;** **IGS-to-SRAP - SAC#RWE-6;** **IGS-to-SRAP - SAC#RWE-7**
SO 010	Spacing between aircraft pair conducting the standard approach and ATC-initiated IGS-to-SRAP shall consider the Runway Occupancy Time of the leader and any possible catch-up effect which	**[NOV5-EAO 03] IGS-to-SRAP Published Approach**	Maintain spacing/separation between aircraft on the same or on different final approach paths for same runway end	**IGS-to-SRAP - SAC#R-1** (AIM RWY Col RP2.4)

ID	Safety Objective *(success approach)*	Use Case	Operational Service	Related SAC# (AIM Barrier or Precursor)
	might happen after DF (compression)			

Table 4 Safety Objectives (success approach) for IGS-to-SRAP approaches

4.3 Mitigation of Risks Inherent to Aviation - Abnormal conditions

The purpose of this section is to assess the ability of the IGS-to-SRAP concept to work through (robustness), or at least recover from (resilience) any abnormal conditions, external to the Concept and not under control, that might be encountered relatively infrequently.

This section identifies the abnormal conditions that are relevant for IGS-to-SRAP and proposes the list of additional Safety Objectives in order to mitigate the risk related to the identified abnormal conditions.

The abnormal conditions identified for each OI are shown in Table 5.

ID	Abnormal Scenario
1	Flight no longer IGS-to-SRAP compatible
2	Engine failure
3	Go-around of leader on lower glide when follower is on the higher glide and when the pair is separated close to the reduced separation minima
4	Runway surface slope
5	Ice impacting engine thrust
6	Contaminated runway

Table 5 Abnormal Conditions for IGS-to-SRAP operations

Safety Objectives to address the abnormal conditions for IGS-to-SRAP operations in Table 5 are listed in Table 6 below.

ID	Description	Abnormal Scenario
SO 101	The aircraft shall no longer fly the expected or cleared approach if it is no longer compatible with the weather conditions, energy management and shall coordinate with ATC for another approach	1
SO 102	Aircraft shall keep on respecting the vertical profile of the IGS-to-SRAP approach in case of one engine failure or shall execute a missed approach	2

SO 103	During IGS-to-SRAP operations, ATC shall safely handle the situation where an aircraft on the lower glide executes a missed approach which will cross the trajectory of a follower aircraft on the upper glide, especially when the pair is separated close to the reduced separation minima	3
SO 104	Aircraft shall land in the touchdown zone for the IGS-to-SRAP approach considering the combination of the significantly Increased Glide Slope angle, the runway aiming point and the possible slope of the runway surface (downslope and upslope runways) with or without approach slope indicator (VASI/PAPI)	4
SO 105	Aircraft shall respect the vertical profile of the IGS-to-SRAP approach in case of icing conditions impacting the engine thrust or shall execute a missed approach	5
SO 107	During IGS-to-SRAP operations, the calculated required landing distance (accounting for updated weather and runway surface conditions) of the aircraft shall be compatible with the landing distance available for IGS-to-SRAP operations.	6

Table 6: List of Safety Objectives (success approach) for Abnormal Operations

4.4 Mitigation of System-generated Risks (failure conditions)

This section concerns IGS-to-SRAP operations in the case of internal failures of the Functional system. Before any conclusion can be reached concerning the adequacy of the safety specification of IGS-to-SRAP 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 operational services described in section 4.2.1 and to derive Safety Objectives (failure approach) to mitigate against these effects.

4.4.1 Identification and Analysis of System-generated Hazards

The identification and analysis of the system-generated hazards in this section is based on the analysis done in SESAR 1, namely in P06.08.08 Enhanced Arrival Procedures Enabled by GBAS. The SESAR 1 analysis has afterwards been updated to reflect the developments of PJ02.02 and PJ02-W2-14.2.

A Safety/HP workshop was performed in PJ02.02, which enabled to get updated & more mature safety relevant information related to the ATC-initiated IGS-to-SRAP concept.

The hazards, already defined in SESAR 1, were updated to reflect the PJ02.02 safety workshop. A screening of the hazards was performed and it has been decided that the developments from Wave 2 do not have an impact on the hazards at this level. The impact of the Wave 2 developments is rather on the operational procedures developed to deal with the non-nominal situations created by some of the hazards, which will be captured later on in section 5 in the design analysis.

The following tables provide the consolidated list of the identified Operational Hazards, with their operational effects, the mitigations protecting against effect propagation and the allocated severity, updated and validated in the frame of PJ02.02. The severity allocation was based on the severity classification schemes of the relevant Accident Incident Models (AIM) as per the guidance to SRM [2] (Guidance E) and which are included in Appendix I.

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ID	Hazard Description	High level causes (derived from Success SO)	Operational effect	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
Hz#02	Insufficient spacing at interception between aircraft pair flying IGS-to-SRAP and Standard approach or between aircraft conducting the same IGS-to-SRAP approach	IGS-to-SRAPIGS-to-SRAPIGS-to-SRAPNote, with ORD tool, the lack of indicator is addressed as per Sol-01 Hz#01a and the corrupted indicator as per Sol-01 Hz#05 Note: Incorrect aircraft type/WTC in FPL – no change from standard approach (in case of ORD tool, included as cause of indicator corruption)	It corresponds to a situation where an unmanaged under separation was prevented by the ATC separation recovery (imminent infringement)	*** ATC Collision Prevention Barrier** ATC detects the loss of separation using radar information and instructs one aircraft to deviate immediately from its current trajectory ***Wake encounter recovery** - Follower aircraft initiates a break-off in case of WT encountered	**Wk FA SC3b**
Hz#03	Wrong spacing management on Final Approach between two aircraft of which at least one flies an increased glide slope angle		It corresponds to a situation where an unmanaged under separation was prevented by the ATC separation recovery (imminent infringement)	*** ATC Collision Prevention Barrier** ATC detects the loss of separation using radar information and instruct one aircraft to deviate	**Wk FAP SC3b**

ID	Hazard Description	High level causes (derived from Success SO)	Operational effect	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
	(involving a/c reduced reactivity to decelerate)			immediately from its current trajectory ***Wake encounter recovery** - Follower aircraft initiates a missed approach/brake-off in case of WT encounter	
Hz#04	Vertical deviation of either a/c in a pair where the leader is on the lower glide slope and the follower is on the higher IGS-to-SRAP glide slope leading to imminent WT separation infringement	Vertical deviation of one aircraft from the instructed & correctly selected approach – derived from SO 005, SO 006, SO 007 Aircraft flying an approach different from the instructed one AND Go around not executed before or at DH Without ORD Tool: Aircraft flying an IGS-to-	It corresponds to a situation where an unmanaged under separation was prevented by the ATC separation recovery (imminent infringement)	*** ATC/Controller** - ATCO detects the loss of separation using radar information and instructs one aircraft to deviate immediately from its current trajectory *** Aircraft/Pilot** - Follower aircraft initiates a missed approach/brake-off in case of WT encounter	**Wk FAP SC3b**

ID	Hazard Description	High level causes (derived from Success SO)	Operational effect	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
		SRAP approach different from the instructed one – Not detectable via the Path Deviation Alert			
Hz#05	Lateral or vertical deviation from the IGS-to-SRAP approach leading to a flight towards terrain	Aircraft flying an approach different from the instructed one (flies IGS-to-SRAP instead of standard threshold) and standard threshold is closed – derived from SO 002 Deviating Laterally or vertically from a correct IGS-to-SRAP approach path – derived from SO 007 Approach Path corruption (FAS DB for GLS, FMS procedure for RNAV)	It corresponds to a situation where a controlled flight towards terrain was prevented by flight crew monitoring	*** Aircraft/Pilot** - Pilot monitors lateral and vertical deviation - Pilot reacts following TAWS alert- see SR2.038 for the impact of IGS-to-SRAP on TAWS logic - Pilot initiates a missed approach if there is no Glide indication and if there is no PAPI. As an alternative and if weather conditions permit, flight crew could revert to visual approach if at least one of the visual references for the intended runway is distinctly visible (Elements of the approach light system; the threshold markings; the threshold lights; the threshold	**CFIT SC3b**

ID	Hazard Description	High level causes (derived from Success SO)	Operational effect	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
				identification lights; the visual glide slope indicator; the touchdown zone or touchdown zone markings; the touchdown zone lights; or the Runway edge lights) - see SR2.023, SR2.041, SR2.051 for second aiming point lighting/markings *** ATC/Controller** -ATCO detects the deviation (via APM for example) and informs pilot	
Hz#06 a	An aircraft on IGS-to-SRAP approach with insufficient landing distance available	Incorrect procedure design of the location of IGS-to-SRAP (not compatible with specific a/c) Aircraft flying IGS-to-SRAP instead of standard	It corresponds to a situation where an unstable approach or a touchdown outside TDZ does not end up to being a runway excursion due to the breaking and deceleration action of the crew (imminent runway excursion)	*** Aircraft/Pilot** - The runway excursion is avoided by the pilot by efficiently decelerating the a/c or by executing a go-around (please see SR2.200 related to training for managing landings with significant increased glide slope angle and SR2.021	**RE SC2b**

ID	Hazard Description	High level causes (derived from Success SO)	Operational effect	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
		approach and go-around not initiated Long landing due to early flare of a/c conducting IGS-to-SRAP approach or FC on conventional approach incorrectly following VASI/PAPI of the IGS-to-SRAP Aircraft correctly following the IGS-to-SRAP approach path is not able to decelerate to the stabilised approach speed And Go around not executed		related to the energy management function)	
Hz#06 b	An aircraft on IGS-to-SRAP approach landing with excessive vertical	Landing with excessive vertical speed due to late flare	It corresponds to a situation where an unstable approach or a touchdown outside TDZ does not end up to being a runway excursion due to the breaking and deceleration action of the crew (imminent runway excursion)	*** Aircraft/Pilot** - The runway excursion is avoided by the pilot by efficiently decelerating the a/c or by executing a go-	**RE SC2b**

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ID	Hazard Description	High level causes (derived from Success SO)	Operational effect	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
	speed leading to hard landing	Aircraft deviating from the correctly selected IGS-to-SRAP approach path Aircraft correctly following the IGS-to-SRAP approach path is not able to decelerate to the stabilised approach speed And Go around not executed		around (please see SR2.200 related to training for managing landings with significant increased glide slope angle and SR2.021 related to the energy management function)	
Hz#07	Fail to prevent wake separation infringement	<u>Without ORD Tool</u>: Aircraft flying an IGS-to-SRAP approach different from the instructed one – Not detectable via APM (Approach Path Monitoring) – Not detectable via APM (Approach Path Monitoring) - derived from SO 007 Insufficient spacing at interception between aircraft pair flying IGS-to-	It corresponds to a situation where an under-separation not managed within safe margins has occurred <u>Only without ORD tool support</u>: since the controller did not update the system with the new clearance and the FC is flying the first expected clearance (i.e. the one that is actually in the system), the APM will not be efficient in this case and the fact that the controller will apply the separation rules for the instructed approach could go undetected.	*** ATC Collision Prevention Barrier** ATCO detects the loss of separation and instructs one aircraft to deviate immediately from its current trajectory *** Wake encounter recovery**	**Wk SC3a**

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ID	Hazard Description	High level causes (derived from Success SO)	Operational effect	Mitigations protecting against propagation of effects	Severity *(most probable effect)*
		SRAP and Standard approach not mitigated by go-around – derived from SO 003		- A/C initiates a break-off in case of WT encountered	
Hz#08	Interception and landing to the incorrect aiming point going undetected with risk of runway excursion during IGS-to-SRAP approach	Aircraft flying an approach different from the instructed one (i.e. IGS-to-SRAP instead of Standard) AND Go around not executed before or at DH – derived from SO 003 and SO 007 Without ORD Tool: Aircraft flying an IGS-to-SRAP approach different from the instructed one – Not detectable via the Path Deviation Alert	It corresponds to a situation where an approach is attempted on the wrong runway aiming point Only without ORD tool support: since the controller did not update the system with the new clearance and the FC is flying the first expected clearance (i.e. the one that is actually in the system). The APM will not be efficient in this case and the fact that the controller will apply the separation rules for the instructed approach could go undetected.	*** Aircraft/Pilot** - Pilot detects that A/C is approaching the wrong aiming point - Pilot executes a touch and go if needed *** ATC** - TWR ATCO detects the aircraft is flying towards the wrong runway aiming point (see SR2.312)	**RE SC3b**

835 **Title?**

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4.4.2 Derivation of Safety Objectives (integrity/reliability)

This section derives Safety Objectives (addressing integrity/reliability) to limit the frequency with which the system-generated hazards could occur using the relevant Risk Classification Schemes (WT on FAP, MAC on FAP, RE, CFIT, RWY Col).

The following table provides the consolidated list of Safety Objectives (integrity/reliability) for the different operational concepts.

ID	Safety Objective	Related Hazard	Severity
SO 202	The frequency of occurrence of insufficient spacing at interception between aircraft pair flying IGS-to-SRAP and Standard approach or between aircraft conducting the same IGS-to-SRAP approach shall not be greater than 2E-03 per approach	Hz#02	Wake-SC3b
SO 203	The frequency of occurrence of wrong spacing management on Final Approach between two aircraft of which at least one flies an increased glide slope angle (IGS-to-SRAP, involving a/c reduced reactivity to decelerate) shall not be greater than 2E-03 per approach	Hz#03	Wake-SC3b
SO 204	The frequency of occurrence of vertical deviation of either a/c in a pair where the leader is on the lower glide slope and the follower is on the higher IGS-to-SRAP glide slope leading to imminent WT separation infringement shall not be greater than 2E-03 per approach	Hz#04	Wake-SC3b
SO 205	The frequency of occurrence of lateral or vertical deviation from the IGS-to-SRAP approach leading to a flight towards terrain shall not be greater than 2x10-7 per approach	Hz#05	CFIT SC3b
SO 206	The frequency of occurrence of an aircraft on IGS-to-SRAP approach with insufficient landing distance available shall not be greater than 1x10-7 per approach	Hz#06a	RE-SC2b
SO 209	The frequency of occurrence of an aircraft on IGS-to-SRAP approach landing with excessive vertical speed leading to hard landing shall not be greater than 1x10-7 per approach	Hz#06b	RE-SC2b
SO 207	The frequency of failing to prevent wake separation infringement shall not be greater than 4E-05 per approach	Hz#07	Wake-SC3a
SO 208	The frequency of occurrence of interception and landing to the incorrect aiming point going undetected with risk of runway excursion during IGS-to-SRAP approach shall not be greater than 1x10-5 per approach	Hz#08	RE-SC3b

Table 7: Safety Objectives (integrity/reliability)

4.5 Process assurance of the Safety Specification at ATS Service level

This section describes the processes by which safety objectives were derived as well as details of the competencies of the personnel involved.

Two OHA Safety workshops were organised in April 2015 focusing on normal and abnormal conditions and in September 2015 focusing on failure aspects with the support of operational people including controllers and pilots.

A Safety-Human Performance workshop took place in March 2018, in the frame of SESAR 2020. This workshop helped clarifying outstanding concept elements and any other possible safety and human performance issues.

Additionally, a workshop with pilots from Air France and CDG ATCOs took place on the 28th of January 2019 on the Air France premises at CDG airport. The workshop helped clarifying remaining SAF/HP and concept questions for projects PJ02.02, PJ02.01 and PJ02.03.

For the development of the non-nominal procedures in Wave 2, two workshops were held on 19th November 2020 and 7th May 2021 with Paris CDG controllers to begin the development of the procedures. They were validated during the ATC Real Time Simulation and developed/enhanced where required.

5 Safe Design of the Solution functional system

5.1 Overview of activities performed

This section addresses the following activities:

- Section 5.2 - introduction of the design model (initial or refined) of the Solution functional system
- Section 5.3 - derivation of Safety Requirements (functionality & performance) at Design level (SRD) in normal conditions of operations from the SOs (functionality & performance) of section 4.2 and supported by the analysis of the initial or refined design model above
- Section 5.4 - derivation of Safety Requirements (functionality & performance) at Design level (SRD) in abnormal conditions of operations from the SRS (functionality and performance) of section 4.3 and supported by the analysis of the operations of the initial or refined design under abnormal conditions of operations
- Section 5.5 - assessment of the adequacy of the design (initial or refined) in the case of internal failures and mitigation of the Solution operational hazards (identified at section 4.4) through derivation from SOs (integrity/ reliability) of Safety Requirements (functionality & performance) and Safety Requirements (integrity&reliability) at Design level (SRD)
- Section 5.6 - realism of the refined safe design (i.e. achievability and “testability” of the SRD)
- Section 5.7 - safety process assurance at the initial or refined design level

5.2 Design model of the Solution functional system

5.2.1 P06.08.08 SPR level Model (still applicable)

The SPR-level Model in this context is a high-level architectural representation of the enhanced arrival procedures. This model is the equivalent of the SESAR 2020 NSV-4 EATMA diagrams (shown in section 5.2.2 and in Appendix B) 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 SPR level model detailed in Figure below is then described in section 5.2.1.1.

The symbols used in the model are as follows:

	ATS Human actor – ground-based
	ATS Equipment function – ground-based

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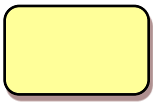
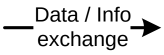
	Non-ATS Human actor – ground-based
	Human actor – airborne
	Equipment function – airborne
	Optional element
	Main data / information flow

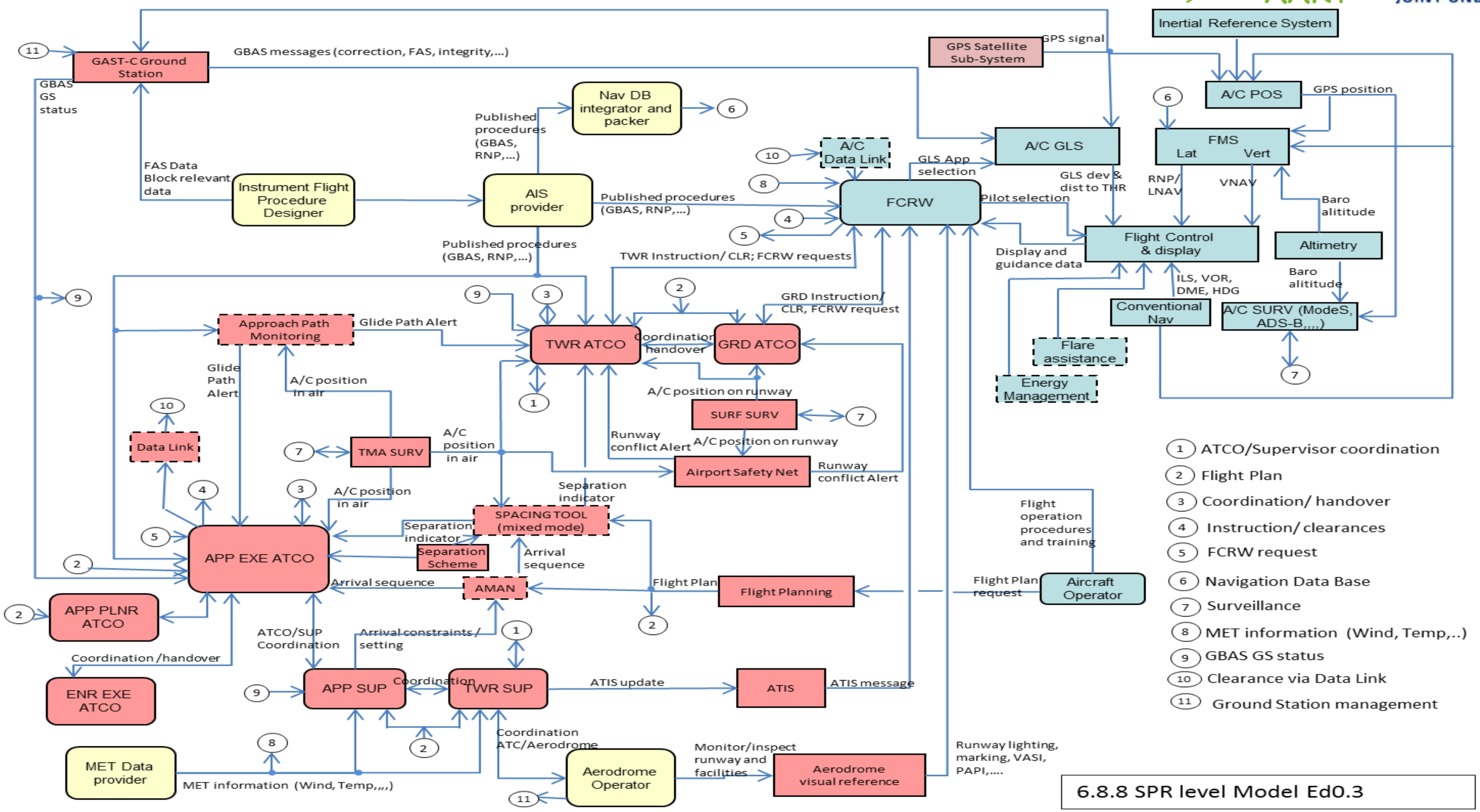


Figure Error! Reference source not found.**: Enhanced Arrival Procedures SPR level-Model**

5.2.1.1 Description of SPR-level Model

GAST-C Ground Station:

*Provides the GBAS messages to the airborne GLS function (correction message, integrity data, FAS data)

*Provides the operational status of the GBAS Ground Station

GPS Satellite Subsystem: provides GPS satellite signal to the airborne GLS function and to the airborne GPS function

Instrument Flight Procedure designer:

*provides all data relevant for the aeronautical data origination including the procedure design in accordance with the procedure design criteria

*provides all data in order to define the FAS data Block for each GLS approach

AIS provider: provides aeronautical data and aeronautical information necessary for

the operation (AIP, NOTAM,AIC) including charts and information like GLS channel number, RNP value, RF leg capability required,…

Nav Data Base Integrator and packer: provides the navigation database to be used by the FMS in the appropriate format considering the charts published by the AIS provider

MET data provider: provides the relevant Meteorological information for the approach and the landing to be considered by Flight Crew, ATC and Aerodrome operator

Aerodrome operator:

* monitors and inspects movement area and related facilities including visual references like runway marking, runway lighting, visual approach slope indicator

*determines the runway surface conditions (e.g. runway friction)

Flight Planning: provides the required information of the different flights relevant for this airspace including GBAS and RNP aircraft capability

AMAN (optional): provides an optimised arrival sequence considering constraints specific to GBAS enhanced arrival procedure (mixed-mode, modified wake separation scheme,…)

Spacing Tool (optional): computes and displays separation indicators for each pair of aircraft on the final approach. The spacing tool computes the required separation by considering the approach conducted by the leader and the follower which might be different (mixed mode of operations).

Separation Scheme: Specifies the wake turbulence scheme to be applied by the controllers during GBAS enhanced arrival procedures in particular in mixed mode (A/C on different approach paths during the final approach phase)

Approach Path monitoring (optional): alerts ATC when the aircraft does not respect the lateral and/or vertical path associated to the approach which was cleared by the controller

Airport Safety Net: alerts ATC in case of runway conflict

TMA_SURV (TMA Surveillance): provides aircraft surveillance information in air (identification, position, altitude) during the approach

SURF_SURV (Surface Surveillance): provides aircraft surveillance information on the aerodrome movement area (identification and position)

ATIS: provides relevant information for the destination aerodrome including weather, runway surface conditions, approach to be expected

Data Link (optional): A data link service which provides electronically the ATC cleared approach to the Aircraft

ENR EXE ATCO

The Enroute Executive Controller:

*is in charge of safe and efficient processing of traffic in Enroute sectors

*gives inbound clearance to follow a STAR for the destination.

APP PLNR ATCO

The Approach Planner controller:

*is in charge of preparing the flow integration by deciding an initial order between groups of aircraft from each flow

*verifies ATIS information, approach availability and weather conditions.

APP EXE ATCO

The Approach Executive controller:

*is in charge of safe and efficient processing of arrival to the runway considering the GBAS enhanced arrival procedure

* establishes and maintain the required separation during the approach until the handover to the Tower controller

APP SUP:

The Approach Supervisor:

* plans, monitors and supervises tactical traffic management in the TMA

* is aware of the MET conditions (wind on the glideslope) to decide if GBAS enhanced arrival procedure can be conducted (e.g. IGS-to-SRAP) and coordinates with the Tower Supervisor

*is aware of the status of the GBAS approach at the destination aerodrome

*is aware if mixed mode operations is active (A/C conducting standard approach and GBAS enhanced arrival procedure for the same runway end)

TWR ATCO: The Tower controller is in charge of the landing, maintains the required separation following APP ATCO handover and provides the landing clearance

TWR SUP: The Tower Supervisor is responsible for the planning of the Tower operations, monitors operations, decides on arrival and departure rates, proposes runway configuration, updates ATIS information when necessary

GRD ATCO: The Ground Controller provides taxi-in clearances and instructions to aircraft following the landing based on the foreseen runway exit

FCRW: The flight Crew conducts the approach safely considering the GBAS enhanced arrival procedure to be flown and ATC instructions

A.O: The Aircraft Operator is responsible for the aircraft operations and file flight plan considering the aircraft capability and flight crew approval

Aerodrome visual reference: provides all the necessary visual references for the approach and landing including lighting system, runway marking, visual approach slope indicator

A/C GLS: The airborne GLS equipment computes GLS deviation (lateral/vertical) and distance to threshold from the selected approach

FMS computes lateral and vertical deviation from a selected route (STAR, RNP approach,..) using data from the navigation data base.

Flight Control and Display:

*provides the flight control law for the selected mode (xLS for GLS or steering control for RNP)

*allows the selection of the different modes.

*provides display and announcements to the flight crew

Conventional Nav: provides conventional navigational information (VOR, DME, ILS,…) in accordance with the flight crew selection

A/C SURV (Aircraft Surveillance): provides aircraft information (Identity, Altitude, optionally 2D position,…) to be used by the ground-based surveillance (TMA SURV and SURF SURV)

Altimetry: provides the aircraft pressure altitude corrected by the flight crew baro-setting

A/C Pos: Provides the aircraft position based on GPS or on a mix of GPS, conventional navaids and Inertial systems.

Inertial Reference System: Provides the inertial position of the aircraft

Flare assistance (Optional): An aircraft supporting tool assisting the flight crew to initiate timely the flare manoeuvre

Energy Management (Optional): An aircraft function assisting the flight crew to assess or manage the aircraft energy level during the approach.

5.2.2 SESAR 2020 SPR level Models (EATMA NSV-4 Diagrams)

The figures in this section show the EATMA NSV4 diagrams (the equivalent of the SPR-level Model in SESAR 2020) for the IGS-to-SRAP concept from both the ground and airborne perspectives. These diagrams were used to check the completeness of the high level and the refined safety requirements against the latest developments of PJ02.02 and PJ02-W2-14.5.

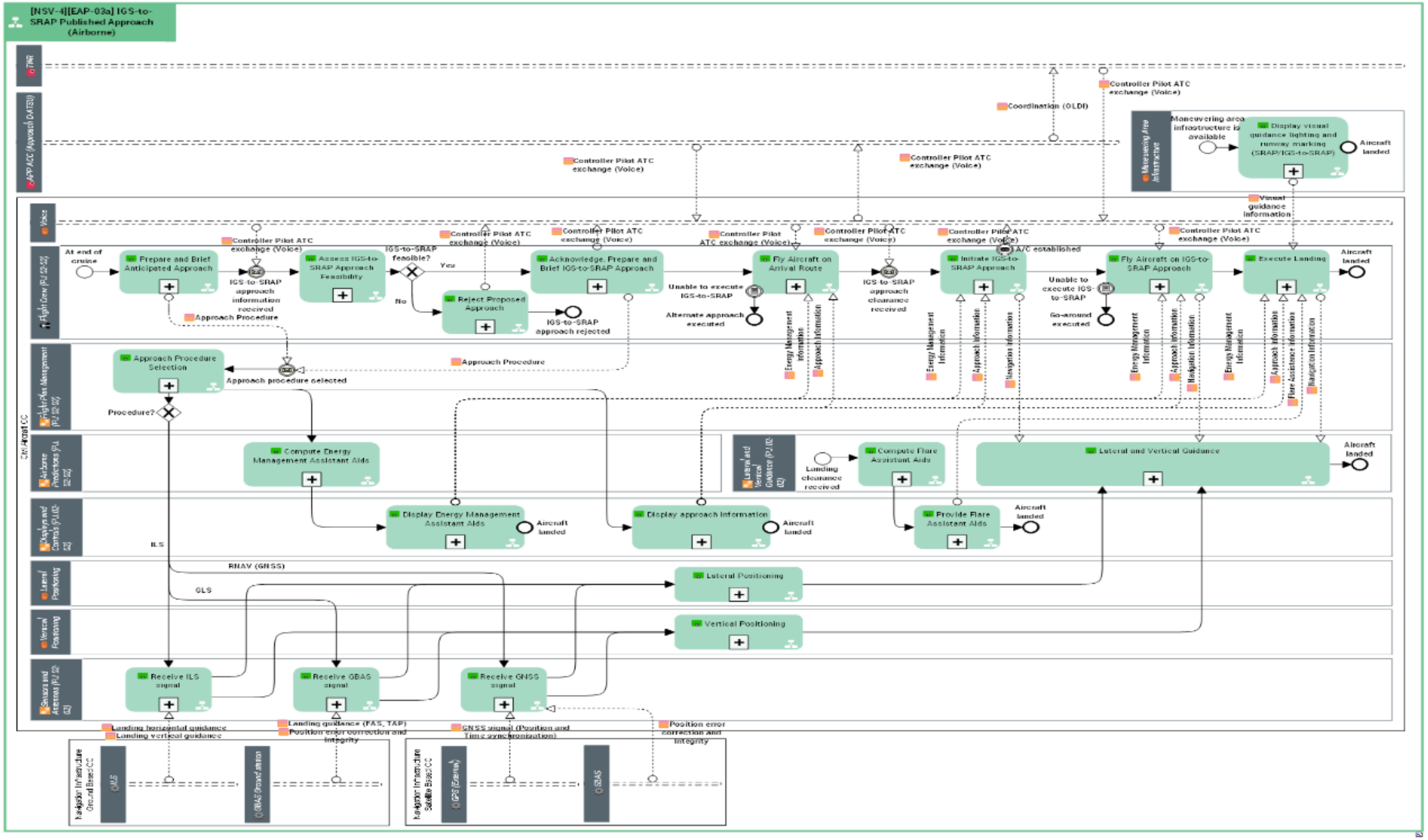


Figure 3 IGS-to-SRAP Published Approach (airborne)

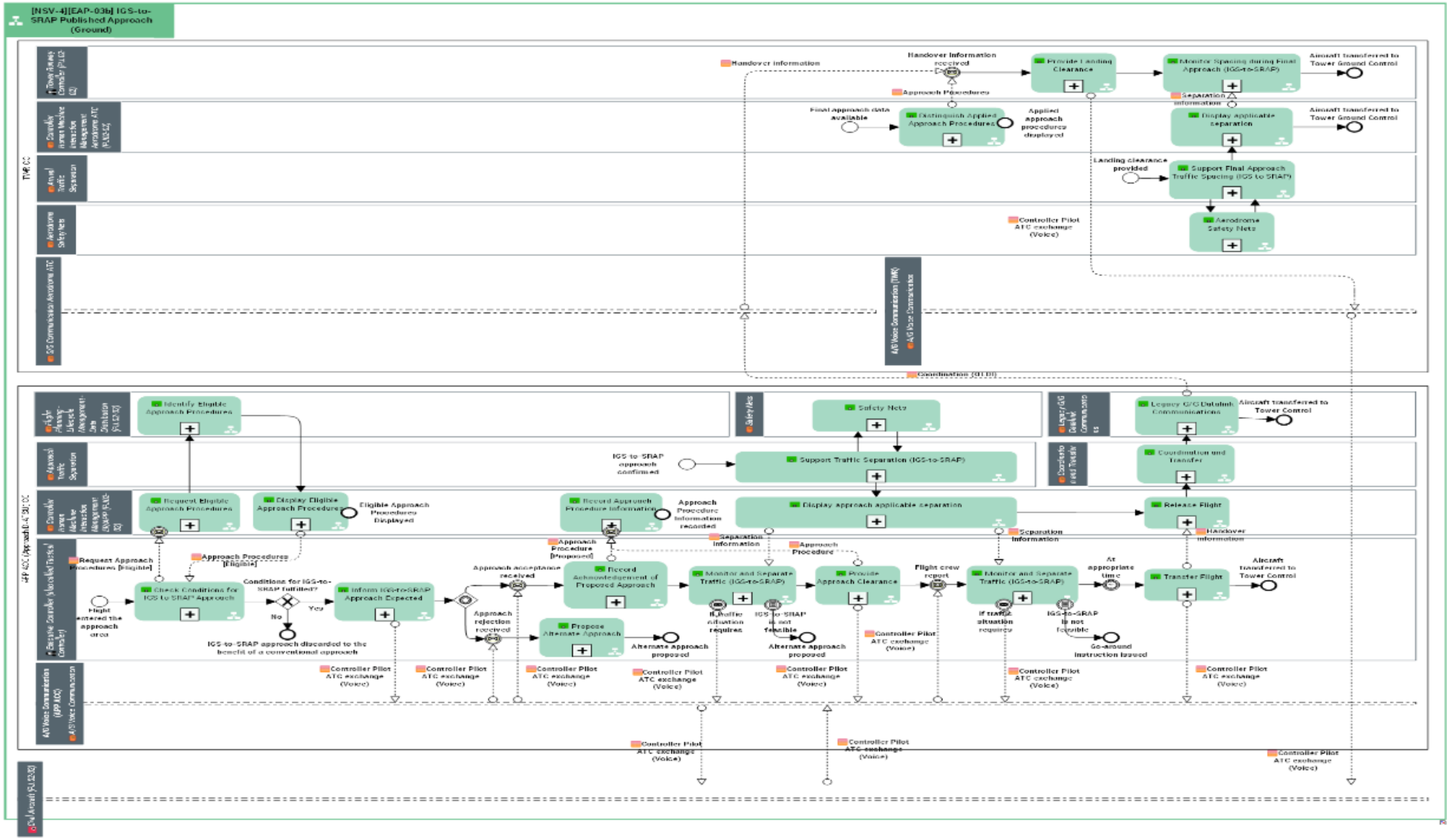


Figure 4 IGS-to-SRAP Published Approach (ground)

5.3 Deriving Safety Requirements at Design level for Normal conditions of operations

Table 8 below shows how the Safety Objectives (Functionality and Performance in Table 4) map on to the Safety Requirements which were derived with the help of the SPR-level model (section 5.2.1) and the EATMA NSV-4 diagrams (sections 5.2.2 and Appendix B).

The safety requirements address the ATM changes related to the new enhanced approach procedures (with indicators).

SO Description	SR ID	SR Description
SO 001 Approach Executive Control shall be able to check the conditions for the new ATC-initiated IGS-to-SRAP approach, propose the expected approach to the flight crew and, in the event of a refusal from the flight crew, cancel the ATC-initiated IGS-to-SRAP approach and propose a standard approach instead	SR2.001 REQ-14.5-SPRINTEROP-CTL.1006	After Flight Deck acknowledgment, Approach Executive Control shall record the expected IGS-to-SRAP approach associated to a given arrival aircraft
	SR2.004 REQ-14.5-SPRINTEROP-CTL.1001	Approach Supervision shall decide when a published IGS-to-SRAP becomes active/inactive for operations, considering the conditions for application are and remain met: 1. No operational ATC & weather limitations 2. necessary navigation guidance means are serviceable
	SR2.033 REQ-14.5-SPRINTEROP-CTL.1004	ANSPs shall reinforce through a request to Aircraft Operators the need for Flight Plans to be complete and correctly filled with aircraft navigation capabilities.
	SR2.034 REQ-14.5-SPRINTEROP-CTL.1005	At first call from an incoming traffic with APPROACH, Approach Executive Control shall provide information to the arrival aircraft about the expected approach procedure, taking in account the traffic eligibility to IGS-to-SRAP, local working methods for traffic assignment (e.g. Heavies left on conventional approach), and using related standard phraseology (e.g. BLUEBIRD 123, Expect GLS Z approach runway 28L) Then later on the approach clearance will be provided as usual

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	SR2.045 REQ-14.5-SPRINTEROP-CTL.1002	Approach / Tower Supervisors shall inform the Approach / Tower Controllers about the list of active approach procedures
SO 002 The Flight Crew shall be able to assess the feasibility of the proposed ATC-initiated IGS-to-SRAP approach, prepare and brief it if feasible, or reject it if not feasible	SR2.054 REQ-14.5-SPRINTEROP-ACFT.2103	Upon cleared for IGS-to-SRAP Approach, Flight Deck shall confirm the feasibility of the instructed IGS-to-SRAP operations under the actual flight and weather conditions
	SR2.009 REQ-14.5-SPRINTEROP-ACFT.2108	Before contacting APP Control, Flight Deck shall assess the feasibility of the probable IGS-to-SRAP operations under the expected flight and weather conditions
	SR2.057 REQ-14.5-SPRINTEROP-CTL.1203	A single IGS-to-SRAP procedure type (i.e. one glideslope angle) may be supported by different navigation guidance systems and part of or all the procedures with the same glideslope angle may be active at the same time
	SR2.041 REQ-14.5-SPRINTEROP-ACFT.2104	Flight Crew shall recall during approach briefing the possible differences in visual references (VASI/PAPI, runway aspect, etc) that are expected in IGS-to-SRAP operations
	SR2.042	Flight Crew shall be informed about discrepancies from visual aid references when not specifically adapted to increased glideslope procedures.
	SR2.043 REQ-14.5-SPRINTEROP-CTL.1003	The ANSP shall inform Airspace Users (e.g. via AIC) about the availability of IGS-to-SRAP procedure with their differences from the local conventional approaches (including applicable separation minima, location of the second aiming point, landing distance available etc.)

	SR2.046 REQ-14.5-SPRINTEROP-CTL.1101	Information about a published IGS-to-SRAP being active to a given runway QFU shall be available to the Flight Crew in order to prepare the expected approach briefing (e.g. via ATIS)
SO 003 Approach Executive Control shall be able to facilitate the capture of the Final approach path whilst ensuring adequate spacing for the ATC-initiated IGS-to-SRAP approach clearance, such that the flight crew can start the approach	SR2.008 REQ-14.5-SPRINTEROP-CTL.1006	When Approach Executive Control clears an aircraft for an approach procedure, he/she shall be able to record the cleared approach procedure for this arrival aircraft.
	SR2.013 REQ-14.5-SPRINTEROP-CTL.1104	For IGS-to-SRAP operations with complex separation minima scheme, Approach Executive Control shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD), which necessitates to electronically record the expected and cleared approach procedures
	SR2.014 REQ-14.5-SPRINTEROP-CTL.1105	For IGS-to-SRAP operations with complex separation minima scheme in high traffic environments, Approach Executive Control shall be supported by a Separation Delivery function providing indications about spacing required to account for compression (ITD) (due to difference in speed profiles of Leader and Follower after the Deceleration Fix) to be applied for achieving the separation minima at the separation delivery point
	SR2.064 REQ-14.5-SPRINTEROP-CTL.1109	The need for displaying to the Controllers the interception points respective for each procedure shall be evaluated as part of the local deployment, such that the visual references are operationally relevant and unambiguously presented without e.g. cluttering on the controller air surveillance display

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	SR2.065 REQ-14.5-SPRINTEROP-CTL.1207	For high density operations supported by Separation Delivery Function with TDIs, when IGS-to-SRAP are flown based on RNP APCH navigation, there is a need for flexibility in the final approach axis interception (e.g. using vectoring). In such cases, the ANSP shall request on the charts Flight Crew to inform Approach Controller when the aircraft is unable to use the FMS guidance for final approach axis interception
SO 004 Approach Executive Control shall be able to sequence, merge and space aircraft such that the different benefits of ATC-initiated IGS-to-SRAP could be taken into account	SR2.013 REQ-14.5-SPRINTEROP-CTL.1104	For IGS-to-SRAP operations with complex separation minima scheme, Approach Executive Control shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD), which necessitates to electronically record the expected and cleared approach procedures
	SR2.014 REQ-14.5-SPRINTEROP-CTL.1105	For IGS-to-SRAP operations with complex separation minima scheme in high traffic environments, Approach Executive Control shall be supported by a Separation Delivery function providing indications about spacing required to account for compression (ITD) (due to difference in speed profiles of Leader and Follower after the Deceleration Fix) to be applied for achieving the separation minima at the separation delivery point

	SR2.016 REQ-14.5-SPRINTEROP-CTL.1112	For IGS-to-SRAP operations, Approach Executive Control should be supported by arrival sequencing optimisation or role in assigning aircraft to an active approach procedure. In case this support is not available and when the traffic pressure is sufficiently high such that the runway throughput is penalised due to the increased separation minima introduced by IGS-to-SRAP procedures, Approach Executive Control shall apply the following general rule for arrival sequence: Heavy and Super Heavy aircraft types shall always fly on the lower glide path.
	SR2.037 REQ-14.5-SPRINTEROP-CTL.1008	After Flight Deck has been informed of an expected approach procedure, if a change is needed from ATC, Approach Executive Control shall consider the time needed for the Flight Deck to re-configure for the new approach procedure, shall inform Flight Deck at the earliest opportunity and with sufficient time before instructing final approach axis interception (special consideration should be given to the transition from ILS/GLS to RNP APCH which is demanding and time consuming for the pilot)
SO 005 Approach Executive Control shall be able to monitor and manage spacing/separation on final approach, taking into account the cohabitation of aircraft on ATC-initiated IGS-to-SRAP with aircraft	SR2.013 REQ-14.5-SPRINTEROP-CTL.1104	For IGS-to-SRAP operations with complex separation minima scheme, Approach Executive Control shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD), which necessitates to electronically record the expected and cleared approach procedures

on standard approach	SR2.014 REQ-14.5-SPRINTEROP-CTL.1105	For IGS-to-SRAP operations with complex separation minima scheme in high traffic environments, Approach Executive Control shall be supported by a Separation Delivery function providing indications about spacing required to account for compression (ITD) (due to difference in speed profiles of Leader and Follower after the Deceleration Fix) to be applied for achieving the separation minima at the separation delivery point
	SR2.017 REQ-14.5-SPRINTEROP-CTL.1205	Approach Executive Control shall apply dedicated longitudinal wake turbulence distance-based separation minima for the following combinations: ○ Leader and follower on same glideslope ○ Leader upper glide - follower lower glide ○ Leader lower glide - follower upper glide when both aircraft are descending on their respective glide slope.
	SR2.058 REQ-14.5-SPRINTEROP-CTL.1204	IGS-to-SRAP Approach separation minima shall be specified for each combination of published approach procedures with different glideslopes, taking into account the associated navigation means and corresponding vertical accuracy around the published profile, for ○ Leader and follower on same glideslope ○ Leader upper glide - follower lower glide ○ Leader lower glide - follower upper glide

	SR2.019 REQ-14.5-SPRINTEROP-CTL.1011	Applicable Contingency approach separation minima shall be available to Approach Executive Control and Tower Runway Control when controllers are supported by a separation tool.
	SR2.074 REQ-14.5-SPRINTEROP-CTL.1011	Applicable Standard approach separation minima when SRAP is active and no separation tool in use shall be available to Approach Executive Control and Tower Runway Control
SO 006 Tower Runway Control shall be able to monitor spacing/separation on final approach, taking into account the new separating methods or the new landing threshold introduced by the ATC-initiated IGS-to-SRAP	SR2.015 REQ-14.5-SPRINTEROP-CTL.1106	For IGS-to-SRAP operations with complex separation minima scheme the Tower Controller shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD)
	SR2.017 REQ-14.5-SPRINTEROP-CTL.1205	Approach Executive Control shall apply dedicated longitudinal wake turbulence distance-based separation minima for the following combinations: ○ Leader and follower on same glideslope ○ Leader upper glide - follower lower glide ○ Leader lower glide - follower upper glide when both aircraft are descending on their respective glide slope.
	SR2.058 REQ-14.5-SPRINTEROP-CTL.1204	IGS-to-SRAP Approach separation minima shall be specified for each combination of published approach procedure with different glideslopes, taking into account the associated navigation means and corresponding vertical accuracy around the published profile, for ○ Leader and follower on same glideslope

		○ Leader upper glide - follower lower glide ○ Leader lower glide - follower upper glide
	SR2.019 REQ-14.5-SPRINTEROP-CTL.1011	Applicable Contingency approach separation minima shall be available to Approach Executive Control and Tower Runway Control when controllers are supported by a separation tool.
	SR2.050 REQ-14.5-SPRINTEROP-CTL.1111	When supported by ground surveillance (with aerodrome maps), the runway markings for all active approaches shall be displayed to Tower Runway Control
SO 007 Flight Crew shall be able to safely fly the IGS-to-SRAP procedure (encompassing flight path conformance, speed stabilization, thrust level and landing in the prescribed touchdown zone)	SR2.200 REQ-14.5-SPRINTEROP-ACFT.2102	The Flight Crew shall be trained for managing and flying IGS-to-SRAP operations
	SR2.010 REQ-14.5-SPRINTEROP-CTL.1201	The IGS-to-SRAP approach chart shall be specific to one final approach path (i.e. angle / touchdown aiming point) and supporting navigation guidance mean, and shall highlight the glide path angle in case it is significantly increased (e.g. more than 3.5°)
	SR2.022 REQ-14.5-SPRINTEROP-ACFT.2102	Flight Deck shall be able to execute flare during IGS-to-SRAP operations without increasing the risk of hard landing or long landing
	SR2.023 REQ-14.5-SPRINTEROP-APT.1302	In case of IGS-to-SRAP, Flight Deck shall be able to clearly distinguish between each threshold and aiming point and be supported by appropriate landing visual aid references (e.g. location and identification of the second runway threshold and aiming point, a second PAPI)

	SR2.062 REQ-14.5-SPRINTEROP-CTL.1212	Procedure design for IGS-to-SRAP operations shall use a glide path angle limited to 4.49°.
	SR2.030 REQ-14.5-SPRINTEROP-ACFT.2104	Flight Deck shall recall during approach briefing the reduced landing distance available from the second aiming point to the expected runway exit in IGS-to-SRAP operations
	SR2.051 REQ-14.5-SPRINTEROP-APT.1303	For IGS-to-SRAP operations down to CAT I minima, Flight Deck shall be able to clearly see the approach lighting for the threshold and aiming point that they are flying to.
SO 010 Spacing between aircraft pair conducting the standard approach and ATC-initiated IGS-to-SRAP shall consider the Runway Occupancy Time of the leader and any possible catch-up effect which might happen after DF (compression)	SR2.040 REQ-14.5-SPRINTEROP-CTL.1206	If the Runway Occupancy Time (ROT) is affected by landing on an active further runway aiming point, this ROT spacing shall be taken into account in the runway separation management (ROT might become the most constraining factor due to changes in separation minima)

Table 8: Mapping of Safety Objectives to Safety Requirements

5.3.1 Dynamic Analysis of the functional system behaviour – Normal and Non-nominal conditions of operations

In Wave 2, the focus of PJ02-W2-14.5 IGS-to-SRAP was on the:

- Validation of ATC non-nominal procedures such as:
  - Interception of the Wrong Glide Path (with Glide Path Alert);
  - Missed approach by lead aircraft and possible multiple G/A management; or
  - ORD tool failure management.
- Validation of the RWY markings and the Approach lighting system for the Second Aiming Point.

As a consequence, one RTS and three Flight Simulation campaigns took place, to validate the above.

For the non-nominal procedures, two workshops were held on 19th November 2020 and 7th May 2021 with Paris CDG controllers to begin the development of the procedures. They were validated during the simulation and developed/enhanced where required.

The following are the final non-nominal situations procedures applied and validated during the non-nominal situations real time simulation:

Regarding Go-Arounds/Missed Approaches:

"When an a/c is sent for go-around or when a missed approach takes place and the IGS-to-SRAP concept is in operations, the controller shall:

- Instruct concerned aircraft to go-around as per local procedure;
- If the concerned aircraft was performing a Missed Approach / Go-around from the ILS lower glideslope with a follower on upper glide:
    - compare separation between the concerned aircraft and the following aircraft against RECAT-EU minima;
    - If less than RECAT minima: instruct go-around to the following aircraft with "Turn left/right immediately" instruction" so that the two aircraft are on diverging flightpaths."

Regarding Glide Alert:

"When there is a Glide Alert warning, the APP controller shall:

- Ask pilot to "confirm type of approach and landing runway";
- If the concerned aircraft has a RECAT-EU wake turbulence category of CAT A "Super heavy", CAT B "Upper Heavy" or CAT C "Lower Heavy" on upper glide – instruct go-around;
- For any other RECAT-EU wake turbulence category:
    - update CWP HMI to the approach procedure actually flown (to update the separation delivery tool indicators);
    - Check the position of the concerned aircraft, leading aircraft and following aircraft against their indicators;
    - If any under separated, instruct go-around to the flight which triggered the glide alert."

Regarding the loss of the ORD tool:

"In case of a total loss of the separation delivery tool, the controller shall:

- For pairs of aircraft for which the controller is confident that were ON or BEHIND the ITD and stabilised at 160kts – let them continue on final;
- For non-stabilised pairs (upper-lower, lower-upper or same slope):
    - If any S/G/H aircraft on Upper Glide → instruct go-around;
    - For **Upper - lower glide pairs**, → ensure **RECAT-EU + 3NM** minimum separation (if not possible, instruct go-around to a/c on upper glide);
    - For remaining traffic on final (i.e. lower-upper and same slope pairs) → ensure **RECAT-EU** separation minima (if not possible, instruct go-around to a/c on upper glide);
- For all aircraft that have not yet intercepted the glide and localiser:

- Progressively re-assign on conventional glide (ILS) (vectoring as appropriate if necessary)."

Table 9 below shows the new IGS-to-SRAP (including the requirements coming from the procedures presentd above) requirements as a result of Wave 2 validation activities related to non-nominal activities. No new/changed safety requirements came from the flight simulations.

SR ID	SR Description
Regarding double go-arounds	
SR2.052 REQ-14.5-SPRINTEROP-GOAR.0001	If the lead aircraft is performing a missed approach or a go-around from the lower glide slope and the follower is on the upper glide slope, Approach Executive Control or Tower Runway Control shall compare the distance between the aircraft going around and the following one, against the reference separation minima applied at the airport.
SR2.053 REQ-14.5-SPRINTEROP-GOAR.0002	When the separation between the aircraft going around and the following one is less than the reference separation minima, Approach Executive Control or Tower Runway Control shall instruct a go-around to the following aircraft, whilst ensuring the two aircraft are on diverging flight paths.
SR2.054 REQ-14.5-SPRINTEROP-GOAR.0003	Approach Executive Control and Tower Runway Control should be able to check the vertical position of an aircraft.
SR2.055 REQ-14.5-SPRINTEROP-GOAR.0004	When IGS-to-SRAP procedure is active, Flight Deck, on standard approach or IGS-to-SRAP one, shall communicate to Approach Executive Control or Tower Runway Control about a missed approach as soon as practicable.
SR2.056 REQ-14.5-SPRINTEROP-ACFT.2109	Flight Deck shall pay particular attention to the transition of frequencies from APP to TWR and shall not delay it
SR2.057 REQ-14.5-TS-GND-0013	The IGS-to-SRAP related go-around procedure shall be regularly briefed and included in the refresher training of the controllers
Regarding glide alert	
SR2.058 REQ-14.5-SPRINTEROP-GALT.0001	When a wrong glide alert is activated, Approach Executive Control shall ask Flight Crew to confirm the flown approach procedure.
SR2.059 REQ-14.5-SPRINTEROP-GALT.0002	When a wrong glide alert is activated by a Heavy aircraft wrongly on the IGS-to-SRAP procedure, and Flight Crew confirms flying a different approach procedure than the instructed one, Approach Executive Control shall instruct a go around to that aircraft.

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SR2.060 REQ-14.5-SPRINTEROP-GALT.0004	When a wrong glide alert is activated by an aircraft other than Heavy and Flight Crew confirms flying a different approach procedure than the instructed one, the Approach Executive Control shall: - Update the CWP HMI with the actually flown approach procedure - Check the position of the concerned aircraft, leading aircraft and following aircraft against their indicators - If any under separated, instruct go-around to the flight which triggered the glide alert.
SR2.061 REQ-14.5-TS-GND-0013	The Glide Alert procedure shall be regularly briefed and included in the refresher training of the controllers
SR2.062 REQ-14.5-SPRINTEROP-GALT.0003	After following the glide alert procedure, Approach Executive Control shall coordinate with Tower Runway Control about the aircraft that triggered the glide alert when IGS-to-SRAP is active.
SR2.073 REQ-14.5-SPRINTEROP-CTL.1108	The alert shall be sufficiently reliable, the level of reliability being defined locally at each airport.
Regarding total loss of the separation delivery tool	
SR2.063 REQ-14.5-SPRINTEROP-ORDF.0006	In case of loss of separation tool, Approach Executive Control or Tower Runway Control should let all aircraft from pairs which are stabilised at 160kts and on (or behind) the ITD, continue on final.
SR2.064 REQ-14.5-SPRINTEROP-ORDF.0007	In case of loss of separation tool, for all mixed slope pairs which are not stabilised at 160kts or not on (or behind) the ITD, and for which a heavy aircraft is on the upper glide, Approach Executive Control or Tower Runway Control shall instruct a go-around to the heavy aircraft.
SR2.065 REQ-14.5-SPRINTEROP-ORDF.0001	In case of loss of separation tool, for all upper-lower slope pairs without Heavy which are not stabilised at 160kts or not on (or behind) the ITD, Approach Executive Control or Tower Runway Control shall apply the addtional simplified mixed slope pairs table. It that is not possible, Approach Executive Control or Tower Runway Control shall instruct a go around to the aircraft flying the IGS-to-SRAP procedure.
SR2.066	In case of loss of separation tool, for all lower-upper and same slope pairs which are not stabilised at 160kts or not on (or behind) the ITD, Approach Executive Control or Tower Runway Control shall apply reference separation minima.

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REQ-14.5-SPRINTEROP-ORDF.0002	It that is not possible, Approach Executive Control or Tower Runway Control shall instruct a go around to the aircraft flying the IGS-to-SRAP procedure.
SR2.067 REQ-14.5-SPRINTEROP-ORDF.0003	In case of loss of separation tool, Approach Executive Control shall re-assign all the aircraft that have not yet intercepted the glide slope and localiser, to conventional approach procedure.
SR2.068 REQ-14.5-SPRINTEROP-ORDF.0004	In peak traffic, in case of loss of separation tool, the coordinator/assistant shall aid the Approach Executive Control for checking the separations between aircraft and suggesting which aircraft should be sent around.
SR2.069 REQ-14.5-SPRINTEROP-ORDF.0005	In case of loss of separation tool, Approach Executive Control should inform Tower Runway Control about the last aircraft flying the IGS-to-SRAP procedure.
SR2.070 REQ-14.5-SPRINTEROP-ORDF.0004	In peak traffic, in case of loss of separation tool, the coordinator/assistant shall aid the Approach Executive Control for checking the separations between aircraft and suggesting which aircraft should be sent around.
SR2.071 REQ-14.5-SPRINTEROP-ORDF.0005	In case of loss of separation tool, Approach Executive Control should inform Tower Runway Control about the last aircraft flying the IGS-to-SRAP procedure.
SR2.072 REQ-14.5-TS-GND-0013	The IGS-to-SRAP related ORD tool failure procedure shall be regularly briefed and included in the refresher training of the controllers
SR2.074 REQ-14.5-SPRINTEROP-CTL.1011	Applicable Standard approach separation minima when SRAP is active and no separation tool in use shall be available to Approach Executive Control and Tower Runway Control

Table 9 Additional Requirements as a result of Wave 2 validation EXEs related to non-nominal activities

5.3.2 Effects on Safety Nets – Normal conditions of operations

Although no safety nets are credited in the safety assessment, any potential impact of the enhanced arrival procedures 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 at certain locations.

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

5.3.2.1 Ground Based Safety Nets

a) RIMS (Runway Incursion Monitoring System)

IGS-to-SRAP operations could impact RIMS. Having the possibility to clear aircraft to different runway aiming points might impact the detection logic of this safety net. This has been analysed in P06.08.08 and the conclusion was as follows:

- If proper ATC procedures are put in place for the management of the multiple runway aiming points there should be no impact on RIMS but local analysis shall always be conducted to verify that.

b) STCA (Short Term Conflict Alert)

STCA might be active or not for the initial, intermediate and final approach.

In case it is active, no negative effect on its operations is foreseen for IGS-to-SRAP if proper TMA airspace design rules are applied, in particular when IGS-to-SRAP and standard operations are simultaneously conducted.

5.3.2.2 Airborne Safety Nets

a) TAWS (Terrain Avoidance Warning System)6

For IGS-to-SRAP operations, it should be checked if TAWS logic is impacted by the increased glide slope which could be set at the maximum to -4.49°. Indeed, for steep approaches (4° or greater), there is currently a TAWS option that desensitizes the alert boundaries (TAWS Mode 1 Excessive Descent Rate) to permit steeper than normal approaches without unwanted alerts.

b) ACAS (Airborne Collision Avoidance System)

No negative effect on ACAS is foreseen for IGS-to-SRAP operations if proper TMA airspace design rules are applied in particular when IGS-to-SRAP and standard operations are simultaneously conducted.

5.4 Deriving Safety Requirements at Design level for Abnormal conditions of operations

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.

5.4.1 Scenarios for Abnormal Conditions

The different scenarios relative to the abnormal conditions are listed in section 5.4.2.

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

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

107 The tables below take each of the Safety Objectives from section and derive the corresponding Safety
108 Requirements (Functionality and Performance) by considering the SPR level Model and requirements
109 already identified in that previous section.

110 Table 10 below derives the Safety Requirements (Functionality and Performance) considering the
111 Safety Objectives for abnormal conditions.

SO Description	SR ID	SR Description
SO 101 The aircraft shall no longer fly the expected or cleared approach if it is no longer compatible with the weather conditions, energy management and serviceability of enabling functions and shall coordinate with ATC for another approach	SR2.206 REQ-14.5-SPRINTEROP-CTL.1007	After an aircraft has been cleared to intercept the final approach, if Flight Deck informs ATC that they are no longer able to fly the expected approach (IGS-to-SRAP), Approach Executive Control shall instruct a go-around
	SR2.207 REQ-14.5-SPRINTEROP-CTL.1103	In case Approach Executive Control changes the expected approach procedure, he/she shall update the expected approach procedure recorded for this arrival aircraft
SO 103 During IGS-to-SRAP operations, ATC shall safely handle the situation where an aircraft on the lower glide executes a missed approach which will cross the trajectory of a follower aircraft on the upper glide, especially when the pair is separated close to the reduced separation minima		See SR2.052 and SR2.053 in Table 9.
SO 104 Aircraft shall land in the touch down zone for the IGS-to-SRAP approach considering the combination of the significantly Increased Glide Slope angle, the runway aiming point and the possible slope of the runway surface (downslope and upslope runways) with or without approach slope indicator (VASI/PAPI)	SR2.200 REQ-14.5-SPRINTEROP-ACFT.2102	The Flight Crew shall be trained for managing and flying IGS-to-SRAP operations

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SO 105 Aircraft shall respect the vertical profile of the IGS-to-SRAP approach in case of icing conditions impacting the engine thrust or shall execute a missed approach	SE2.202 REQ-14.5-SPRINTEROP-ACFT.2101	Flight Deck shall be able to decelerate the aircraft during the final approach, even under flight conditions that reduce deceleration capability (e.g. anti-ice system ON)
SO 107 During IGS-to-SRAP operations, the calculated required landing distance (accounting for updated weather and runway surface conditions) of the aircraft shall be compatible with the landing distance available for IGS-to-SRAP operations.	SR2.030 REQ-14.5-SPRINTEROP-ACFT.2104	Flight Deck shall recall during approach briefing the reduced landing distance available from the second aiming point to the expected runway exit in IGS-to-SRAP operations

Table 10: Safety Requirements to mitigate abnormal conditions for the IGS-to-SRAP concepts

5.4.3 Analysis of the functional system behaviour – Abnormal conditions of operations

No additional safety requirements.

5.5 Safety Requirements at Design level addressing Internal Functional System Failures

5.5.1 Design analysis addressing internal functional system failures

The objective of this analysis consists in determining how the system architecture (encompassing people, procedures, equipment) designed for the IGS-to-SRAP procedures can be made safe in presence of internal system failures. The method consists in apportioning the Safety Objectives derived from each hazard into system elements Safety Requirements driven by the analysis of the hazard causes.

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 but also accounting for the safety requirements derived in section 5.4.3 and during the design analysis in normal and abnormal conditions.

Quantitative Safety Requirements will not be derived in this safety assessment. This will however need to be done by the industry in the validation stages prior to implementation (i.e. V4 onwards).

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

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5.5.2 Causal Analysis

For each system-generated hazard (see chapter 4.4.1), a top-down identification of internal system failures that could cause the hazard was conducted.

The purpose of the causal analysis is to increase the detail of risk mitigating strategy through the identification of all possible causes. This way it will be possible to identify the corresponding Safety Requirements enabling to meet the Safety Objective of the Operational Hazard under consideration.

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 into a combination of failures (i.e. Basic Causes or failure of mitigations) linked by different gates: "AND" gates and "OR" gates. Once the fault tree is built, the safety objective assigned to the hazard is apportioned among the failures identified. Existing mitigations (i.e. already captured as safety requirements in sections 5.3 and 5.5.4) are identified and, where necessary, additional mitigation means are proposed in order to reduce the likelihood of occurrence of the Operational Hazard. The additional mitigation means are formalized as Safety Requirements.

5.5.2.1 Causal Analysis

A top-down identification of internal system failures that could cause each of the system-generated hazards in chapter 5.5.2 was conducted. The following sub-sections contain the results of this analysis.

5.5.2.1.1 Hz#02 (SO 202) Insufficient spacing at interception between aircraft pair flying IGS-to-SRAP and Standard approach or between aircraft conducting the same IGS-to-SRAP approach

This operational hazard occurs during any IGS-to-SRAP combined with standard approach operations.

Basic causes for such failure have been captured in the Hz#02 Fault Tree (See Figure 1).

Furthermore, a table is attached to the Fault Tree describing in more detail these basic causes and identifying the existing mitigations for preventing the occurrence of this hazard as well as deriving new required mitigations as safety requirements to satisfy the Safety Objective SO 202 associated to this operational hazard.

Requirements in italics are requirements already derived during the analysis in normal or abnormal conditions.

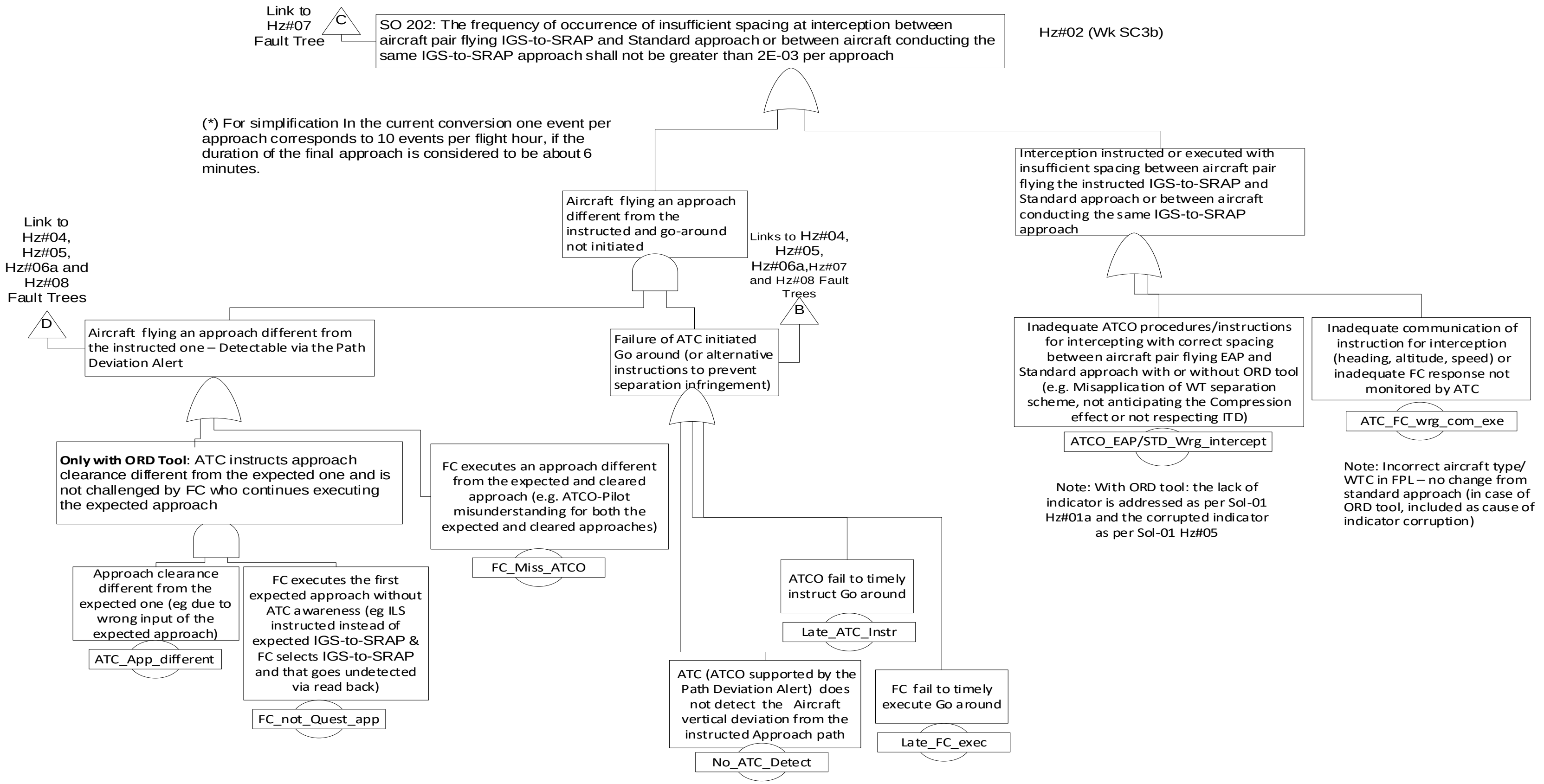

Figure 1 Hz#02 Fault Tree

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement

Aircraft flying an approach different from the instructed one or flying an incorrect IGS-to-SRAP approach path and go-around not initiated			
Aircraft flying a different approach from the instructed one or flying an incorrect IGS-to-SRAP approach path – Detectable via the Path Deviation Alert			
Only with ORD Tool: ATC instructs approach clearance different from the expected one and is not challenged by FC who continues executing the expected approach			
Approach clearance different from the expected one (e.g. due to wrong/no input of the expected approach)	ATC_App_different	INI App Controller inputs the wrong or not expected approach procedure into the system and as a result, FIN APP Controller clears an a/c for an approach different than the expected one provided by INI APP Controller.	Regarding "no input": ***SR2.001****: After Flight Deck acknowledgment, Approach Executive Control shall record the expected IGS-to-SRAP approach associated to a given arrival aircraft* ***SR2.008:*** *When Approach Executive Control clears an aircraft for an approach procedure, he/she shall be able to record the cleared approach procedure for this arrival aircraft.*
			Regarding "wrong input": It is expected that the FC will challenge the difference between the expected and the instructed approach clearances from the APP controller/s
FC executes the first expected approach without ATC awareness (e.g. ILS instructed instead of expected IGS-to-SRAP & FC selects IGS-to-SRAP and that goes undetected via read back)	FC_not_Quest_app	FC decides to fly the expected approach that was provided in the first place and this goes undetected via read-back. <u>Only with ORD tool support</u>: if the controller correctly updates the system with the new approach (e.g. IGS-to-SRAP, instead of the expected ILS) then the Path Deviation Alert will spot the error (since the FC will keep on flying the expected ILS approach). Conversely, if the controller forgets to update the system with the new approach, the Path Deviation Alert will not be able to spot the error (because the FC will actually fly what the system already knows, i.e. the expected approach), but the ORD tool will show the correctly calculated indicators which will be safely used by the controller (even though most probably the controller is unaware to which approach procedure they correspond)	Proposed mitigation: **SR2.306** Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile. ***SR2.013:*** *For IGS-to-SRAP operations with complex separation minima scheme, Approach Executive Control shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD), which necessitates to electronically record the expected and cleared approach procedures*

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			SR2.015: *For IGS-to-SRAP operations with complex separation minima scheme the Tower Controller shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD)* ***SR2.014*** *For IGS-to-SRAP operations with complex separation minima scheme in high traffic environment, Approach Executive Control shall be supported by a Separation Delivery function providing indications about spacing required to account for compression (ITD) (due to difference in speed profiles of Leader and Follower after the Deceleration Fix) to be applied for achieving the separation minima at the separation delivery point*
FC executes a different approach from the expected and cleared approach (e.g. ATCO-Pilot misunderstanding for both the expected and cleared approaches)	FC_Miss_ATCO	FC selects an approach different from the expected and cleared ones due to, e.g. ATCO-Pilot misunderstanding both the expected and cleared approaches	The proposed mitigation is **SR2.306,** about the path deviation alert
			Additional mitigation proposed: **SR2.301:** At each aircraft transfer on frequency when contacting the next ATC unit, the Flight Deck shall indicate the expected or cleared approach procedure **SR2.316:** At each aircraft transfer on frequency, Approach Executive Control or Tower Runway Control shall confirm the expected or cleared IGS-to-SRAP Approach.
Failure of ATC initiated Go around			
ATC (ATCO supported by the path deviation alert) does not detect the aircraft vertical deviation from the instructed approach path	No_ATC_Detect	APP or TWR ATCO do not detect the aircraft vertical deviation from the correctly instructed approach path	Proposed mitigation:

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			SR2.306: Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.
ATCO fails to timely instruct Go around	Late_ATC_Instr	The ATCO does not instruct a timely Go-around, at or just after interception, to an aircraft which deviated vertically from the instructed approach.	In case the ATCO does execute an untimely go-around: ***SR2.204:*** *When the lead aircraft flying on final conventional approach is executing a missed approach and a following traffic is flying on final IGS-to-SRAP spaced at or close to the separation minimum, the Approach or Tower Controller shall also instruct the following aircraft flying an IGS-to-SRAP to execute a missed approach, either with a "Turn left/right immediately" instruction or ensure that the follower is maintained above the lead traffic (taking into account a sufficient climb performance)*
FC fail to timely execute Go around	Late_FC_exec	FC fail to execute a timely Go-around, at or just after interception, while the aircraft has a vertical deviation from the instructed approach.	Proposed mitigation for increasing crew awareness of aircraft speed/energy management for approaches with increased glide slope angle: ***SR2.200*** *The Flight Crew shall be trained for managing and flying IGS-to-SRAP operations* ~~Note that energy management function is not required below certain values of the glide path angle (***SR2.021:*** *An energy management function is required to fly a glide slope in a decelerated manner above a value to be defined in function of the aircraft type (e.g. 3.5° for mainline aircraft). If energy management function is installed and activated, it will cover the full range of glide slope values*)~~
Interception instructed or executed with insufficient spacing between aircraft pair flying the instructed IGS-to-SRAP and Standard approach or between aircraft conducting the same IGS-to-SRAP approach			

Inadequate ATCO procedures/instructions for intercepting with correct spacing between aircraft pair flying IGS-to-SRAP and Standard approach or between aircraft pair conducting the same IGS-to-SRAP approach with or without ORD tool (e.g. Misapplication of WT separation scheme, not anticipating the Compression effect or not respecting ITD)	ATCO_IGS-to-SRAP/STD_Wrg_intercept	ATCO does not correctly apply the separation at interception between a pair of aircraft flying IGS-to-SRAP and standard approach or between aircraft pair conducting the same IGS-to-SRAP approach, with or without the ORD tool (e.g. Misapplication of WT separation scheme, not anticipating the Compression effect or not respecting ITD)	***SR2.058:*** *IGS-to-SRAP Approach separation minima shall be specified for each combination of published approach procedures with different glideslopes, taking into account the associated navigation means and corresponding vertical accuracy around the published profile, for* o *Leader and follower on same glideslope* o *Leader upper glide - follower lower glide* o *Leader lower glide - follower upper glide*
			SR2.017: *Approach Executive Control shall apply dedicated longitudinal wake turbulence distance-based separation minima for the following combinations:* o *Leader and follower on same glideslope* o *Leader upper glide - follower lower glide* o *Leader lower glide - follower upper glide* *when both aircraft are descending on their respective glide slope.*
			SR2.019: *Applicable Contingency approach separation minima shall be available to Approach Executive Control and Tower Runway Control when controllers are supported by a separation tool.*
			SR2.014: *For IGS-to-SRAP operations with complex separation minima scheme in high traffic environments, Approach Executive Control shall be supported by a Separation Delivery function providing indications about spacing required to account for compression (ITD) (due to a difference in speed profiles of Leader and Follower after the Deceleration*

			Fix) to be applied for achieving the separation minima at the separation delivery point
			SR2.013: *For IGS-to-SRAP operations with complex separation minima scheme, Approach Executive Control shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD), which necessitates to electronically record the expected and cleared approach procedures*
			SR2.305: The Separation Delivery Tool shall send to CWP HMI a speed conformance alert when an aircraft's ground speed exceeds its offline defined air speed - corrected by the wind value - by a predefined offline tolerance value
			SR2.302: Approach Executive Control shall consider, when establishing and maintaining separation, that aircraft ability to respect ATC speed instructions may be limited during IGS-to-SRAP operations, especially for slope angles above 3.5 degrees, and aircraft's speed might need to be reduced earlier compared to standard approach. Note: the higher the slope angle, the longer it takes for the aircraft to decelerate. However, this should not be a problem with slopes under 3.5 degrees.
Inadequate communication of instruction or inadequate FC response not monitored by ATC	ATC_FC_wrg_com_exe	ATCO instruction is not clear or FC misunderstands the clearance and it goes undetected via read-back. With ORD tool support: the ATCO will be able to see that the ITD (or FTD) is infringed and will take appropriate action. Without ORD tool support: if the ATCO applies the wrong separation minima, it would go undetected.	Without ORD tool support: This can cause an Imminent Wake Encounter under unmanaged under-separation.

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5.5.2.1.2 Hz#03 (SO 203) Wrong spacing management on Final Approach between two aircraft of which at least one flies an increased glide slope angle (involving a/c reduced reactivity to decelerate)

Basic causes for such failure have been captured in the Hz#03 Fault Tree (See Figure 2).

Furthermore, a table is attached to the Fault Tree describing in more detail these basic causes and identifying the existing mitigations for preventing the occurrence of this hazard as well as deriving new required mitigations as safety requirements to satisfy the Safety Objective SO 203 associated to this operational hazard.

Requirements in italics are requirements already derived during the analysis in normal or abnormal conditions.

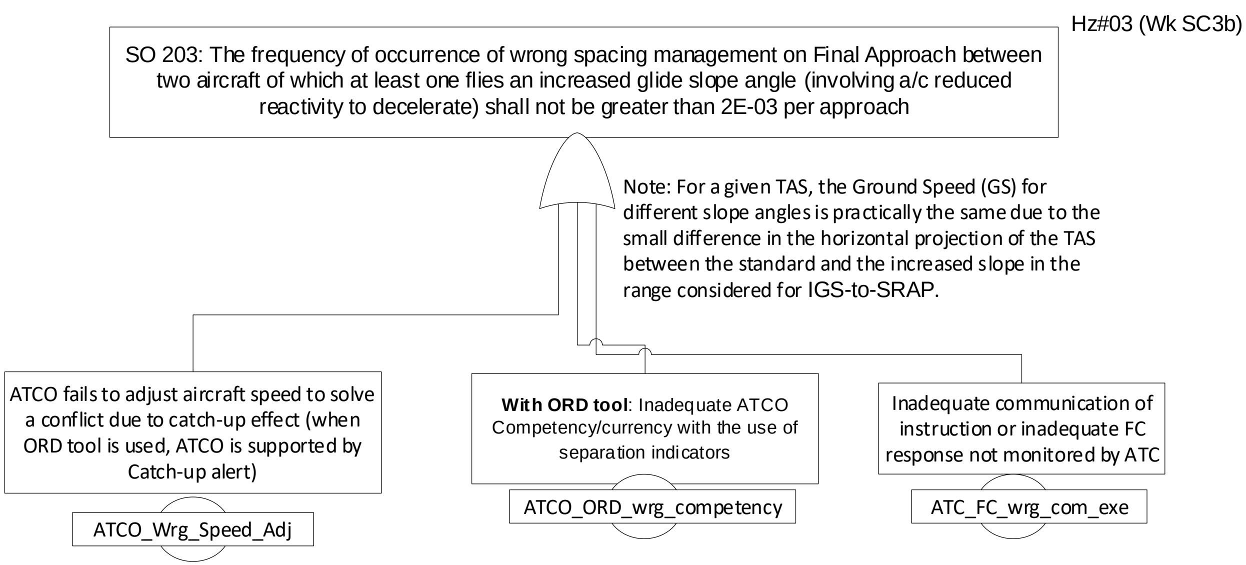


Figure 2 Hz#03 Fault Tree

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement

ATCO fails to adjust aircraft speed to solve a conflict due to catch-up effect (when ORD tool is used, ATCO is supported by Catch-up alert)	ATCO_Wrg_Speed_Adj	With or without ORD tool support, ATCO fails to adjust aircraft speed to solve a conflict due to catch-up effect	Mitigated by **SR2.302** regarding the aircraft's ability to respect speed instructions during IGS-to-SRAP operations.
			SR2.304: For IGS-to-SRAP operations with complex separation minima scheme in high traffic environments, Approach Executive Control shall be warned when an aircraft is significantly catching-up the preceding traffic with an anticipated risk of loss of separation minima.
With ORD tool: Inadequate ATCO Competency/currency with the use of separation indicators	ATCO_ORD_wrg_competency	ATCOs are not properly trained in the usage of the FTD and/or ITD indicators.	The following mitigation from PJ02.01 applies: *SR1.117 (REQ-02.01-SPRINTEROP-ARR0.1250): Approach and Tower Controllers shall be fully trained to apply the procedures for the new separation modes and to use of the Separation Delivery Tool and supporting systems (e.g. alerts) with indicators prior to deployment.*
Inadequate communication of instruction or inadequate FC response not monitored by ATC	ATC_FC_wrg_com_exe	ATCO instruction is not clear or FC misunderstands the clearance and it goes undetected via read-back. With ORD tool support: the ATCO will be able to see that the ITD (or FTD) is infringed and will take appropriate action. Without ORD tool support: if the ATCO applies the wrong separation minima, it would go undetected.	Without ORD tool support: This can cause an Imminent Wake Encounter under unmanaged under-separation.

5.5.2.1.3 Hz#04 (SO 204) Vertical deviation of either a/c in a pair where the leader is on the lower glide slope and the follower is on the higher IGS-to-SRAP glide slope leading to imminent WT separation infringement

Basic causes for such failure have been captured in the Hz#04 Fault Tree (See Figure 3).

Furthermore, a table is attached to the Fault Tree describing in more detail these basic causes and identifying the existing mitigations for preventing the occurrence of this hazard as well as deriving new required mitigations as safety requirements to satisfy the Safety Objective SO 204 associated to this operational hazard.

Requirements in italics are requirements already derived during the analysis in normal or abnormal conditions.

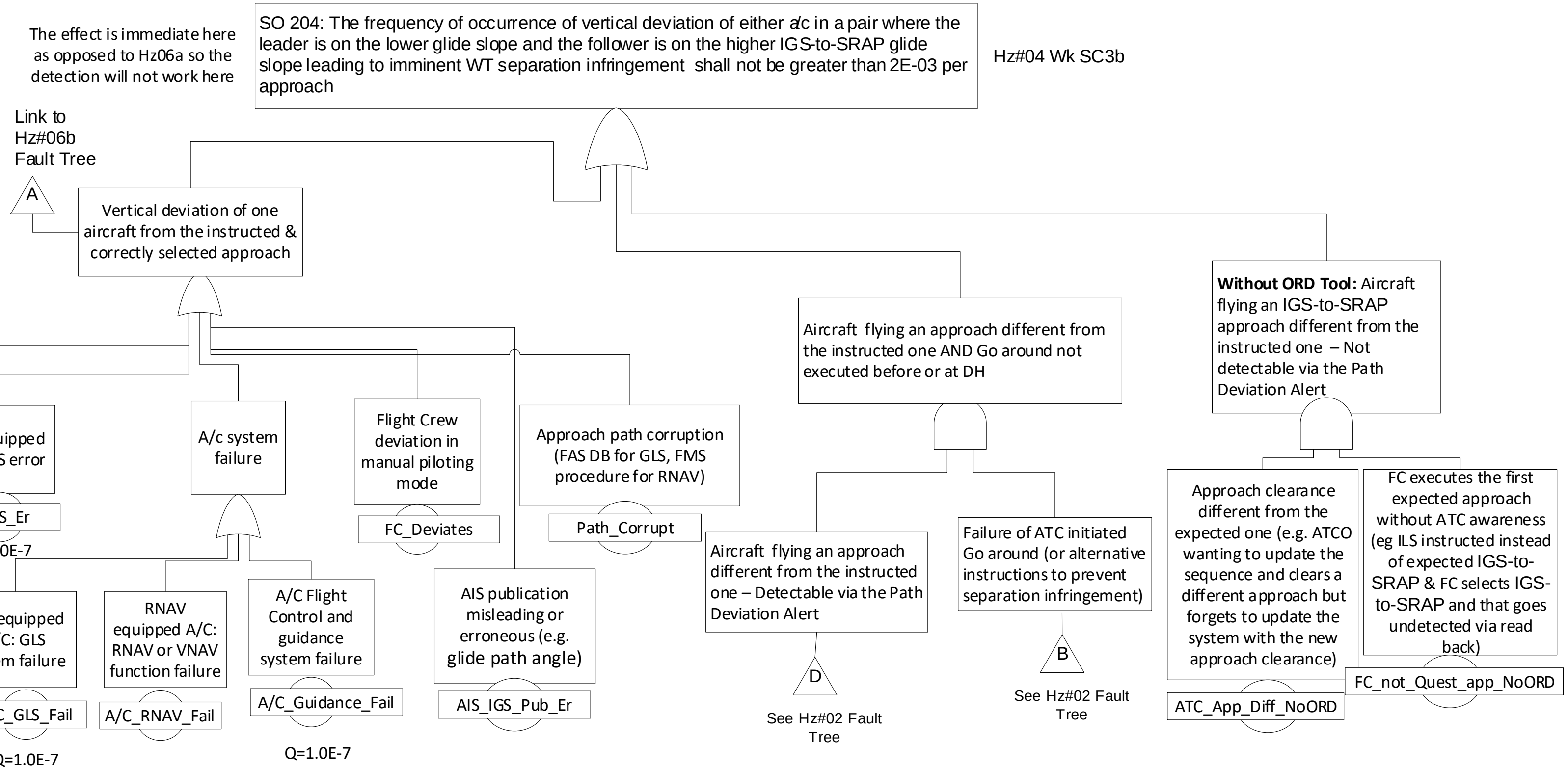


Figure 3 Hz#04 Fault Tree

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Vertical deviation of one aircraft from the instructed &correctly selected IGS-to-SRAP approach			
GLS equipped A/C: GBAS Ground Station error	GBAS_GS_Er	An undetected erroneous GBAS message (e.g. correction) is transmitted to airspace users	Mitigated by existing means: For GBAS: the quality assurance process for GBAS data coding (e.g. channel). Also, the installation of the GBAS Ground Station will be approved by the competent authority and be at least GAST-C compliant.
RNAV equipped A/C: GNSS error	GNSS_Er	An undetected erroneous GNSS message (e.g. correction) is transmitted to airspace users	The GNSS is considered an existing enabler for which integrity requirements should have already been developed.
Flight Crew deviation in manual piloting mode	FC_Deviates	In manual mode, the flight crew deviates vertically from a correctly displayed guidance	Mitigated by requirement **SR2.306** about the Path Deviation Alert Additional mitigations: **SR2.303** Flight Deck shall be supported by appropriate landing visual aid references for their flown approach procedure (e.g. PAPIs associated to the additional threshold), down to the approach minima. ***SR2.041*** *Flight Crew shall recall during approach briefing the possible differences in visual references (VASI/PAPI, runway aspect, etc) that are expected in IGS-to-SRAP operation* ***SR2.042*** *Flight Crew shall be informed about discrepancies from visual aid references when not specifically adapted to increased glideslope procedures.*
Approach path corruption (FAS DB for GLS, FMS procedure for RNAV)	Path_Corrupt	The GBAS Ground Station transmits a corrupted Final Approach Segment (FAS) or The RNAV procedure uploaded in FMS is corrupted	Mitigated by existing means: For GBAS the quality assurance process for GBAS data coding (e.g. channel). Also, the installation of the GBAS

			Ground Station will be approved by the competent authority For RNAV the quality assurance process for FMS procedure coding and loading. Additionally, the crew crosschecks the flight plan information (including final approach slope) that has been loaded into the FMS.
AIS publication misleading or erroneous (e.g. glide path angle)	AIS_IGS_Pub_Er	The AIP includes errors on the GLS or RNAV approach chart (e.g. Approach designator, glide path angle, RPID, etc.) or is misleading especially regarding the approach designator.	Regarding erroneous publication: Mitigated through the currently implemented quality assurance process to verify and validate data/elements exchanged with the procedure designer.
			Regarding misleading publication: ***SR2.010:*** *The IGS-to-SRAP approach chart shall be specific to one final approach path (i.e. angle / touchdown aiming point) and supporting navigation guidance mean, and shall highlight the glide path angle in case it is significantly increased (e.g. more than 3.5°)*
A/c system failure			
GLS equipped A/C: GLS system failure	A/C_GLS_Fail	The Aircraft GLS system provides incorrect vertical deviation despite a correct FAS Data Block	Mitigated by existing means: For GBAS the installation of the GBAS Ground Station and the on-board GLS capability will be approved by the competent authority
RNAV equipped A/C: RNAV or VNAV function failure	A/C_RNAV_Fail	The RNAV computed vertical path is incorrect despite correct FMS RNAV procedure	Mitigated by existing means: For RNAV the, the FMS (including its computing algorithm) is certified by the competent authority
A/C Flight Control and guidance system failure	A/C_Guidance_Fail	The Aircraft Control and Guidance system provides incorrect vertical guidance during the approach despite correct vertical information from the aircraft GLS system	Mitigated by existing means: GLS and FMS are considered existing certified enablers

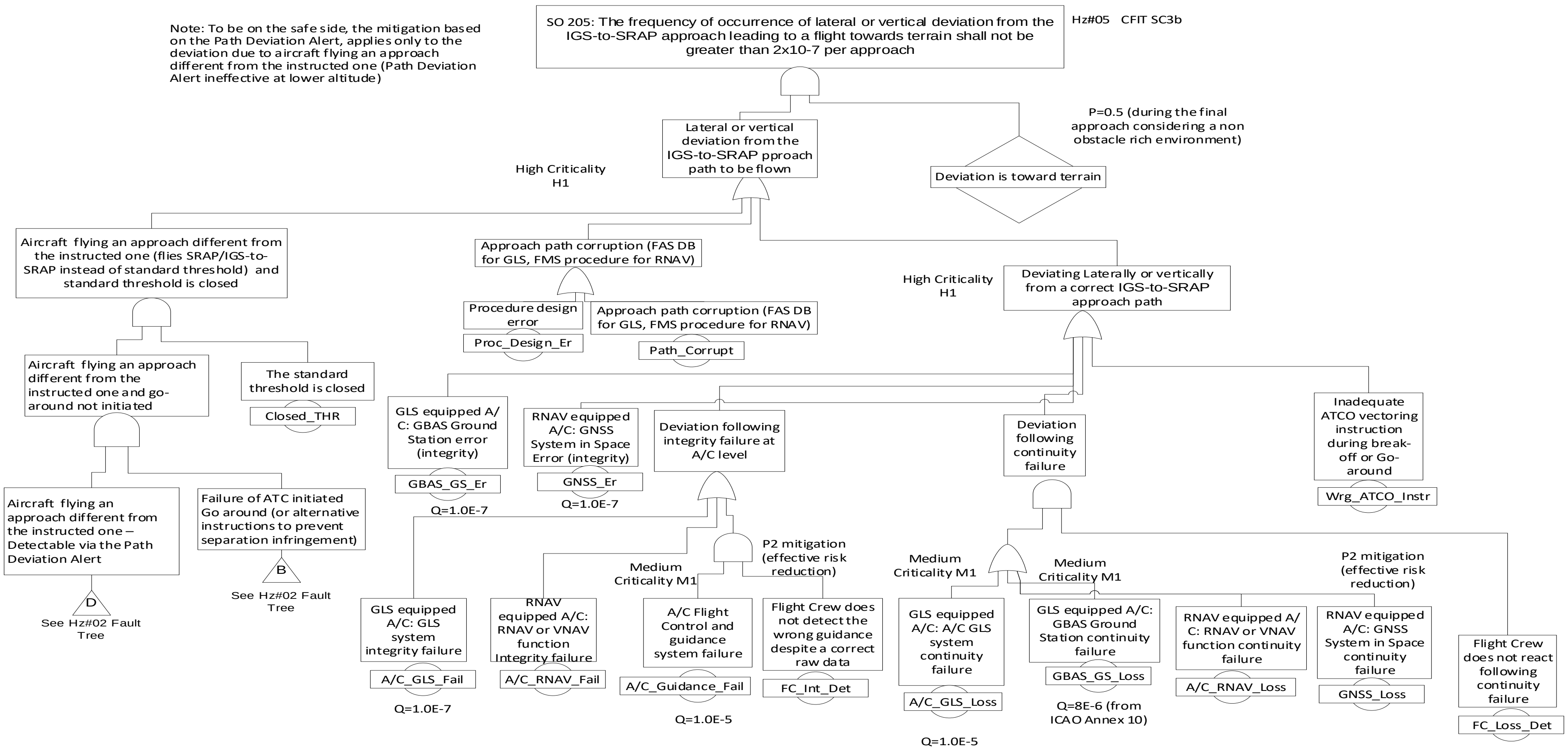
		The RNAV vertical guidance is incorrect despite correct FMS RNAV procedure and computed vertical path	
Aircraft flying an approach different from the instructed one AND Go around not executed before or at DH			
Aircraft flying a different approach from the instructed one – Detectable via the Path Deviation Alert	See Hz#02 Fault Tree		
Failure of ATC initiated Go around (or alternative instructions to prevent separation infringement)			
Without ORD Tool: Aircraft flying an IGS-to-SRAP approach different from the instructed one – Not detectable via the Path Deviation Alert			
Approach clearance different from the expected one (e.g. ATCO wanting to update the sequence and clears a different approach but forgets to update the system with the new approach clearance)	ATC_App_Diff_NoORD	APP Controller wants to update the arrival sequence (e.g. for performance purposes) and gives an updated approach clearance (e.g. ILS instead of the expected IGS-to-SRAP) and omits to update the system.	Proposed mitigation: ***SR2.008*** about the APP ATCO being able to associate and record the cleared approach procedure. Mitigated also by: ***SR2.016*** *For IGS-to-SRAP operations, Approach Executive Control should be supported by arrival sequencing optimisation or role in assigning aircraft to an active approach procedure. In case this support is not available and when the traffic pressure is sufficiently high such that the runway throughput is penalised due to the increased separation minima introduced by IGS-to-SRAP procedures, Approach Executive Control shall apply the following general rule for arrival sequence: Heavy and Super Heavy aircraft types shall always fly on the lower glide path.*
			Regarding the flight crew: It is expected that the FC will challenge the difference between the expected and the instructed approach clearances from the APP controller/s

FC executes the first expected approach without ATC awareness (e.g. ILS instructed instead of expected IGS-to-SRAP & FC selects IGS-to-SRAP and that goes undetected via read back)	FC_not_Quest_app_No ORD	FC decides to fly the expected approach that was provided in the first place and this goes undetected via read-back. Only without ORD tool support: since the controller did not update the system with the new clearance and the FC is flying the first expected clearance (i.e. the one that is actually in the system). The path deviation alert will not be efficient in this case and the fact that the controller will apply the separation rules for the instructed approach could go undetected.	This can cause an Imminent Wake Encounter under unmanaged under-separation.

5.5.2.1.4 Hz#05 (SO 205) Lateral or vertical deviation from the IGS-to-SRAP approach leading to a flight towards terrain

Basic causes for such failure have been captured in the Hz#05 Fault Tree (See Figure 4).

Furthermore, a table is attached to the Fault Tree describing in more detail these basic causes and identifying the existing mitigations for preventing the occurrence of this hazard as well as deriving new required mitigations as safety requirements to satisfy the Safety Objective SO 205 associated to this operational hazard. Requirements in italics are requirements already derived during the analysis in normal or abnormal conditions.



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195 **Figure 4 Hz#05 Fault Tree**

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
SRAP/IGS-to-SRAP only: Aircraft flying an approach different from the instructed one (flies IGS-to-SRAP instead of standard threshold) and standard threshold is closed			
The standard threshold is closed	Closed_THR		It is assumed that the Aerodrome Operator will verify that in case of a closed approach associated to a

		The flight crew selects the non-displaced runway aiming point despite a NOTAM indicating that such a procedure is closed (e.g. Work area at the standard threshold level)	specific runway aiming point, the associated navigation aid: * does not transmit the FAS Data Block, for approaches using GBAS * is not active, for approaches using ILS
			SR2.312: When supported by ground surveillance displays, Tower Executive Control shall be able to easily and unambiguously identify the assigned landing aiming point for each landing aircraft
			Also mitigated by: ***SR2.023*** *In case of IGS-to-SRAP, Flight Deck shall be able to clearly distinguish between each threshold and aiming point and be supported by appropriate landing visual aid references (e.g. location and identification of the second runway threshold and aiming point, a second PAPI)*
Aircraft flying an approach different from the instructed one – Detectable via the Path Deviation Alert	See Hz#02 Fault Tree		
Failure of ATC initiated Go around (or alternative instructions to prevent separation infringement)	See Hz#06b Fault Tree		

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Approach path corruption (FAS DB for GLS, FMS procedure for RNAV)			
Procedure design error	Proc_Design_Er	The GLS/RNAV approach supporting the IGS-to-SRAP operations is not designed in accordance with the rules; or The GLS/RNAV design error is not detected during the procedure validation process (ground and flight)	**SR2.310:** The design of the GLS or RNAV (LPV, LNAV-VNAV) procedures supporting IGS-to-SRAP shall be compliant with ICAO Doc 8168 and shall be validated in accordance with the Instrument Flight Procedure process specified in ICAO Doc 9906
			SR2.311: For the design of GLS or RNAV (LPV, LNAV-VNAV) procedures with a glide path angle greater than 3.5°, the rule for the Height Loss increase shall be standardised at ICAO level (IFPP)
		There is an error in the survey for the GLS/RNAV procedure design	Mitigated by existing means: The terrain, obstacle and aerodrome data used in the design of the GLS/RNAV approach will 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.
Approach path corruption (FAS DB for GLS, FMS procedure for RNAV)	Path_Corrupt	The GBAS Ground Station transmits a corrupted Final Approach Segment (FAS) or The RNAV procedure uploaded in FMS is corrupted	Mitigated by existing means: For GBAS the quality assurance process for GBAS data coding (e.g. channel). Also, the installation of the GBAS Ground Station will be approved by the competent authority For RNAV the quality assurance process for FMS procedure coding and loading. Additionally, the crew crosschecks the flight plan information (including final approach slope) that has been loaded into the FMS.
Deviating Laterally or vertically from a correct IGS-to-SRAP approach path			
GLS equipped A/C: GBAS Ground Station error (integrity)	GBAS_GS_Er	The aircraft GLS system provides a wrong lateral and/or vertical deviation due to an integrity failure of the ground station during the final approach	GLS is considered an existing enabler for which integrity requirements should have already been developed.

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RNAV equipped A/C: GNSS Signal in Space Error (integrity)	GNSS_Er	The aircraft FMS system provides a wrong lateral and/or vertical deviation due to a failure of the GNSS system.	GNSS is considered an existing enabler for which integrity requirements should have already been developed.
Inadequate ATCO vectoring instruction during break-off or Go-around	Wrg_ATCO_Instr	Inadequate ATCO vectoring instruction during break-off or Go-around	
Deviation following integrity failure at A/C level			
GLS equipped A/C: GLS system integrity failure	A/C_GLS_Fail	The Aircraft GLS system provides incorrect lateral and/or vertical deviation despite a correct FAS Data Block	Mitigated by existing means: For GBAS the installation of the GBAS Ground Station and the on-board GLS capability will be approved by the competent authority and be at least GAST-C compliant
RNAV equipped A/C: RNAV or VNAV function Integrity failure	A/C_RNAV_Fail	The RNAV lateral or vertical guidance is incorrect despite correct FMS RNAV procedure	Mitigated by existing means: The quality assurance process for FMS procedure coding and loading
A/C Flight Control and guidance system failure	A/C_Guidance_Fail	The Aircraft Control and Guidance system provides incorrect lateral and or vertical guidance during the approach despite correct lateral and vertical information from the aircraft GLS system The RNAV lateral or vertical guidance is incorrect despite correct FMS RNAV procedure	GLS and FMS are considered existent enablers for which integrity requirements should have already been developed.
Flight Crew does not detect the wrong guidance despite a correct raw data	FC_Int_Det	Flight Crew is not able to see that the guidance is wrong (despite the correct raw data)	Please see requirement **SR2.306** about the Path Deviation Alert
Deviation following continuity failure			
GLS equipped A/C: A/C GLS system continuity failure	A/C_GLS_Loss	The Aircraft GLS system does not continuously provide vertical guidance during the final approach, despite correct vertical information from the ground GLS system	The a/c GLS system is considered an existent enabler for which continuity requirements should have already been developed.

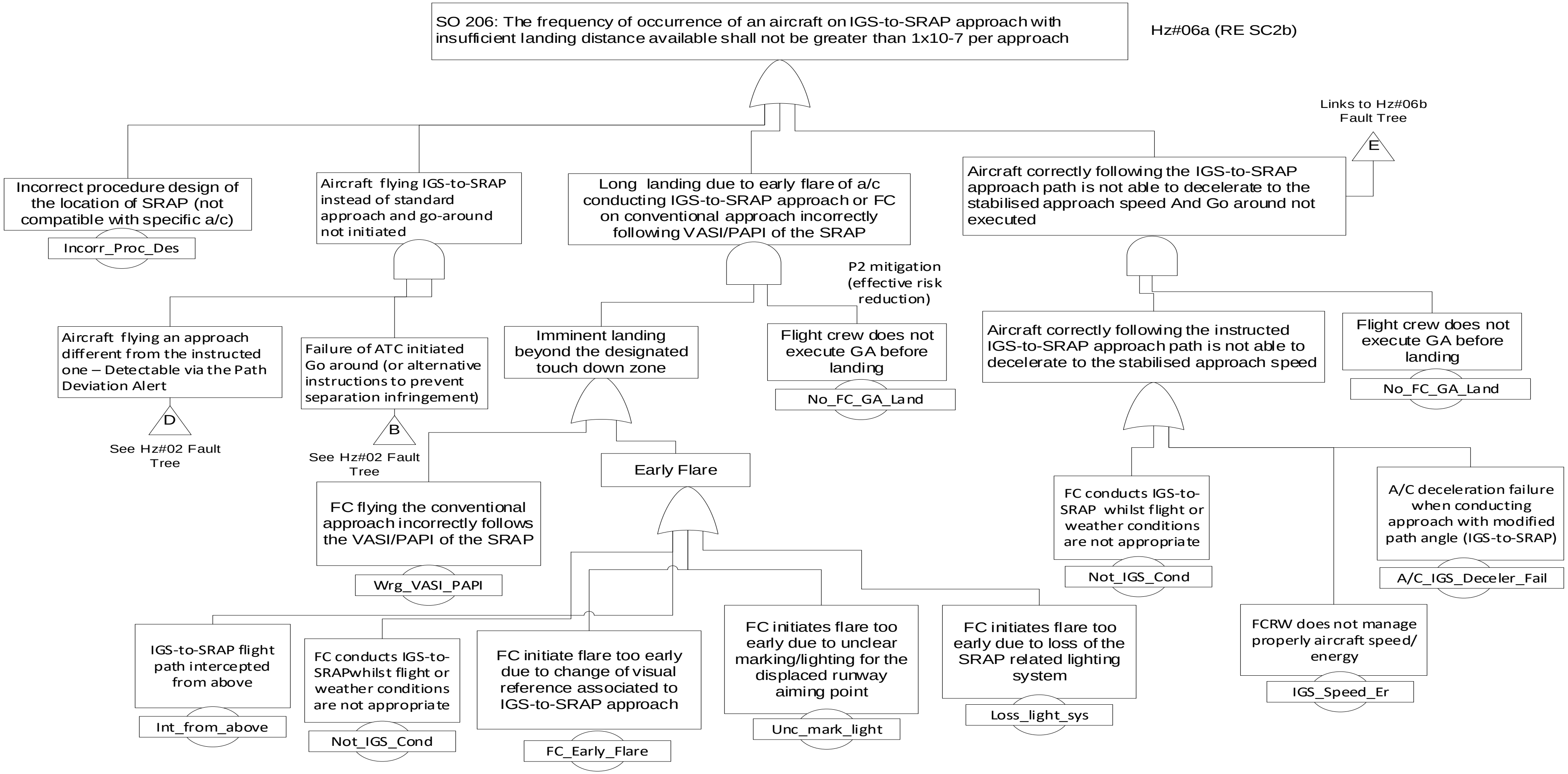
GLS equipped A/C: GBAS Ground Station continuity failure	GBAS_GS_Loss	The Aircraft GLS system does not provide vertical guidance during the final approach, due to vertical information not being continuously provided by the ground GLS system	The ground GLS system is considered an existent enabler for which continuity requirements should have already been developed.
RNAV equipped A/C: RNAV or VNAV function continuity failure	A/C_RNAV_Loss	The RNAV lateral or vertical guidance is not continuously provided despite correct FMS RNAV procedure	The FMS is considered an existent enabler for which continuity requirements should have already been developed.
RNAV equipped A/C: GNSS Signal in Space continuity failure	GNSS_Loss	The aircraft FMS system does not provide lateral and/or vertical guidance due to a failure of the GNSS system.	The GNSS system is considered an existent enabler for which continuity requirements should have already been developed.
Flight Crew does not react following continuity failure	FC_Loss_Det	FC does not react to the continuity failure (due to e.g. channelized attention on some other task)	Please see requirement **SR2.306** about the Path Deviation Alert

5.5.2.1.5 Hz#06a (SO 206) An aircraft on IGS-to-SRAP approach with insufficient landing distance available

Basic causes for such failure have been captured in the Hz#06a Fault Tree (See Figure 5).

Furthermore, a table is attached to the Fault Tree describing in more detail these basic causes and identifying the existing mitigations for preventing the occurrence of this hazard as well as deriving new required mitigations as safety requirements to satisfy the Safety Objective SO 206 associated to this operational hazard.

Requirements in italics are requirements already derived during the analysis in normal or abnormal conditions.



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205 **Figure 5 Hz#06a Fault Tree**

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement

Incorrect procedure design of the location of IGS-to-SRAP (not compatible with specific a/c)	Incorr_Proc_Des	The IGS-to-SRAP procedure design does not give sufficient landing distance for all the a/c that it should.	**SR2.317** When designing the IGS-to-SRAP local procedure, the location of the second runway aiming point shall provide sufficient landing distance available for all eligible aircraft at that specific airport
Aircraft flying SRAP/IGS-to-SRAP instead of standard approach and go-around not initiated			
Aircraft flying an approach different from the instructed one – Detectable via the Path Deviation Alert	See Hz#02 Fault Tree		
Failure of ATC initiated Go around (or alternative instructions to prevent separation infringement)			
Imminent landing beyond the designated touch down zone			
FC flying the conventional approach incorrectly follows the VASI/PAPI of the IGS-to-SRAP	Wrg_VASI_PAPI	Flight crew is misled by the VAS/IPAPI information which led to confusion on when to initiate the flare	Mitigated by ***SR2.042*** and ***SR2.041*** about discrepancies in visual references; but also by ***SR2.023*** about the flight deck being able to distinguish between each threshold and aiming point.
Early Flare			
IGS-to-SRAP flight path intercepted from above	Int_from_above	FC intercepts the glide path from above which leads to an un-stabilised approach which could eventually lead to runway excursion	**SR2.318** Approach Executive Control shall vector the aircraft onto IGS-to-SRAP approach such as to avoid final approach interception from above
FC conducts IGS-to-SRAP whilst flight or weather conditions are not appropriate	Not_IGS_Cond	The operating conditions required for IGS-to-SRAP operations are not met (e.g. Weather conditions like tailwind, temperature, etc.)	Mitigated by ***SR2.004:*** *Approach Supervision shall decide when a published IGS-to-SRAP becomes active/inactive for operations, considering the conditions for application are and remain met:* *1. No operational ATC & weather limitations* *2. necessary navigation guidance means are serviceable*

FC initiate flare too early due to change of visual reference associated to IGS-to-SRAP approach	FC_Early_Flare	Flight crew initiate the flare too early due to the change of visual references associated to the increased glide slope angle	***SR2.022****: Flight Deck shall be able to execute flare during IGS-to-SRAP operations without increasing the risk of hard landing or long landing* ***SR2.060*** *Flare assistant shall help flight crew to correctly perform flare*
IGS-to-SRAP only: FC initiates flare too early due to unclear marking/lighting for the displaced runway aiming point	Unc_mark_light	FC initiates flare too early due to unclear marking/lighting for the displaced runway aiming point	Mitigated by ***SR2.051*** about the flight deck clearly seeing the approach lighting and aiming points and **SR2.303** about the flight deck being supported by appropriate landing visual aid references for their flown approaches.
IGS-to-SRAP only: FC initiates flare too early due to loss of the SRAP related lighting system	Loss_light_sys	Mitigated through the definition of integrity requirements for the SRAP related lighting system. Note that quantitative Safety Requirements will not be derived in this safety assessment. This will however need to be done by the industry in the validation stages prior to implementation (i.e. V4 onwards).	
Aircraft correctly following the instructed IGS-to-SRAP approach path is not able to decelerate to the stabilised approach speed and go-around not executed			
FC conducts IGS-to-SRAP whilst flight or weather conditions are not appropriate	Not_IGS_Cond	The operating conditions required for IGS-to-SRAP operations are not met (e.g. Weather conditions like tailwind, temperature, etc.)	Mitigated by ***SR2.004:*** *Approach Supervision shall decide when a published IGS-to-SRAP becomes active/inactive for operations, considering the conditions for application are and remain met:* *1. No operational ATC & weather limitations* *2. necessary navigation guidance means are serviceable*
IGS-to-SRAP only: FCRW does not manage properly aircraft speed/energy	IGS_Speed_Er	Flight Crew does not manage the aircraft speed/energy properly during the IGS-to-SRAP approach with modified path angle	Proposed mitigation for increasing crew awareness of IGS-to-SRAP operations (i.e. aircraft speed/energy management for approaches with increased glide slope angle): ***SR2.200***

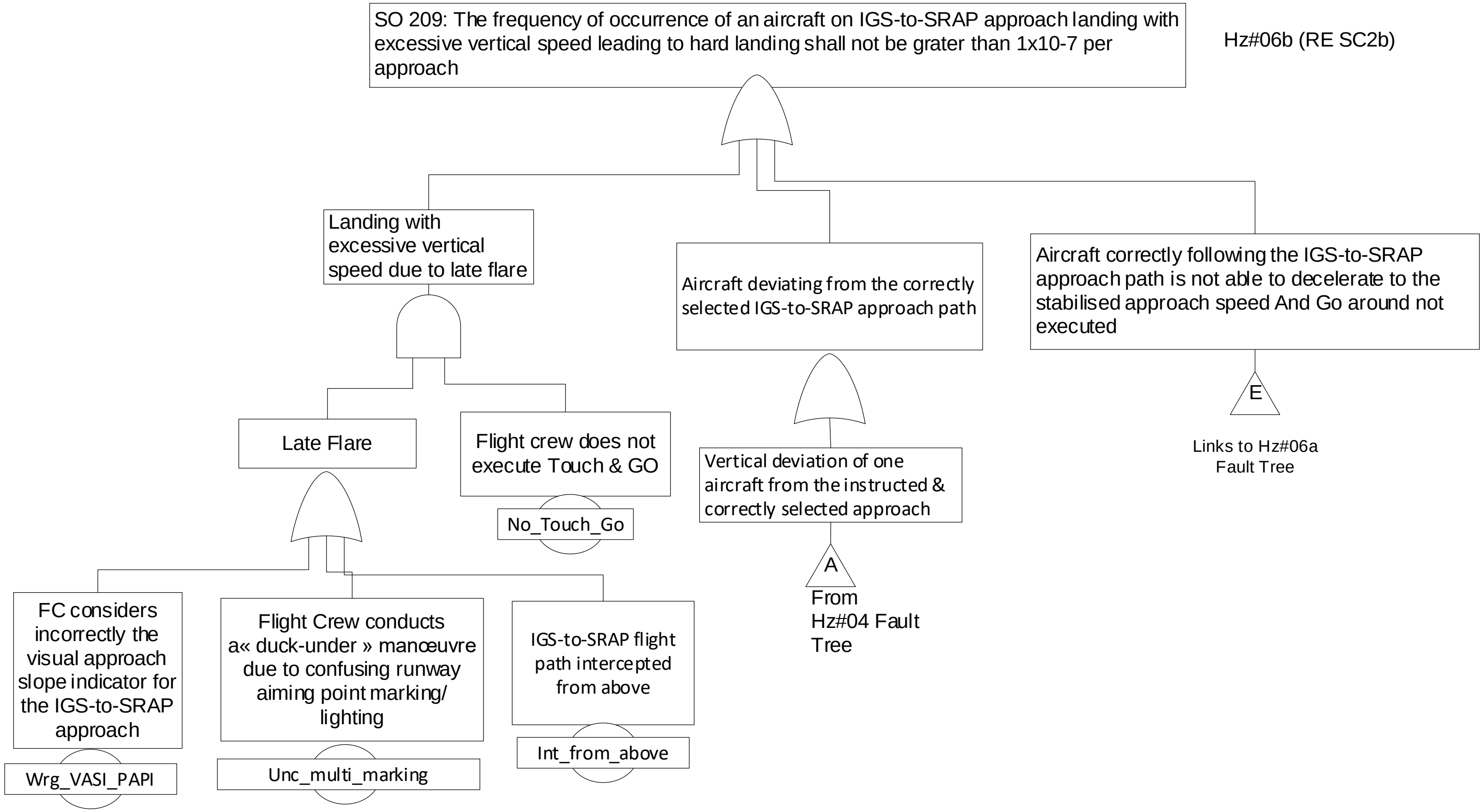
A/C deceleration failure when conducting approach with modified path angle (IGS-to-SRAP)	A/C_A/IGS_Deceler_Fail	Aircraft systems essential to decelerate properly when conducting an approach with modified path angle fail or are inoperative	**SR2.308:** The Aircraft Manufacturer shall provide in the master minimum equipment list (MMEL) the operational impact in case a specific functionality is required by IGS-to-SRAP operations (e.g. the energy management function and/or the flare assistance supporting function)

5.5.2.1.6 Hz#06b (SO 209) An aircraft on IGS-to-SRAP approach landing with excessive vertical speed leading to hard landing

Basic causes for such failure have been captured in the Hz#06b Fault Tree (See Figure 6).

Furthermore, a table is attached to the Fault Tree describing in more detail these basic causes and identifying the existing mitigations for preventing the occurrence of this hazard as well as deriving new required mitigations as safety requirements to satisfy the Safety Objective SO 209 associated to this operational hazard.

Requirements in italics are requirements already derived during the analysis in normal or abnormal conditions.



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214 Figure 6 Hz#06b Fault Tree

215

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Late Flare			

FC considers incorrectly the visual approach slope indicator for the IGS-to-SRAP approach	Wrg_VASI_PAPI	Flight crew is misled by the VASI/IPAPI information which led to confusion on when to initiate the flare	***SR2.023****: In case of IGS-to-SRAP, Flight Deck shall be able to clearly distinguish between each threshold and aiming point and be supported by appropriate landing visual aid references (e.g. location and identification of the second runway threshold and aiming point, a second PAPI)*
			SR2.042: *Flight Crew shall be informed about discrepancies from visual aid references when not specifically adapted to increased glideslope procedures.*
			SR2.041: *Flight Crew shall recall during approach briefing the possible differences in visual references (VASI/PAPI, runway aspect, etc) that are expected in IGS-to-SRAP operations*
IGS-to-SRAP only: Flight Crew conducts a « duck-under » manœuvre due to confusing runway aiming point marking/lighting	Unc_multi_marking	Flight crew initiate a "duck under" manoeuvre at low altitude due to confusing runway aiming point runway marking/lighting	Mitigated by **SR2.023** regarding flight crew being able to distinguish between each threshold and aiming point.
			SR2.050: *When supported by ground surveillance (with aerodrome maps), the runway markings for all active approaches shall be displayed to Tower Runway Control*
IGS-to-SRAP flight path intercepted from above	Int_from_above	FC intercepts the glide path from above which leads to an un-stabilised approach which could eventually lead to runway excursion	**SR2.318** Approach Executive Control shall vector the aircraft onto IGS-to-SRAP approach such as to avoid final approach interception from above
Flight crew does not execute Touch & GO	No_GA_In_Flare	FC fail to execute a timely Go-around, while aircraft having excessive vertical speed during touch down due to late flare	Late or not executing a go-around at this stage could lead to a hard landing. Proposed mitigation for increasing crew awareness of aircraft speed/energy management for approaches with increased glide slope angle: ***SR2.200*** **and** ***SR2.022***
Aircraft deviating from the correctly selected IGS-to-SRAP approach path			

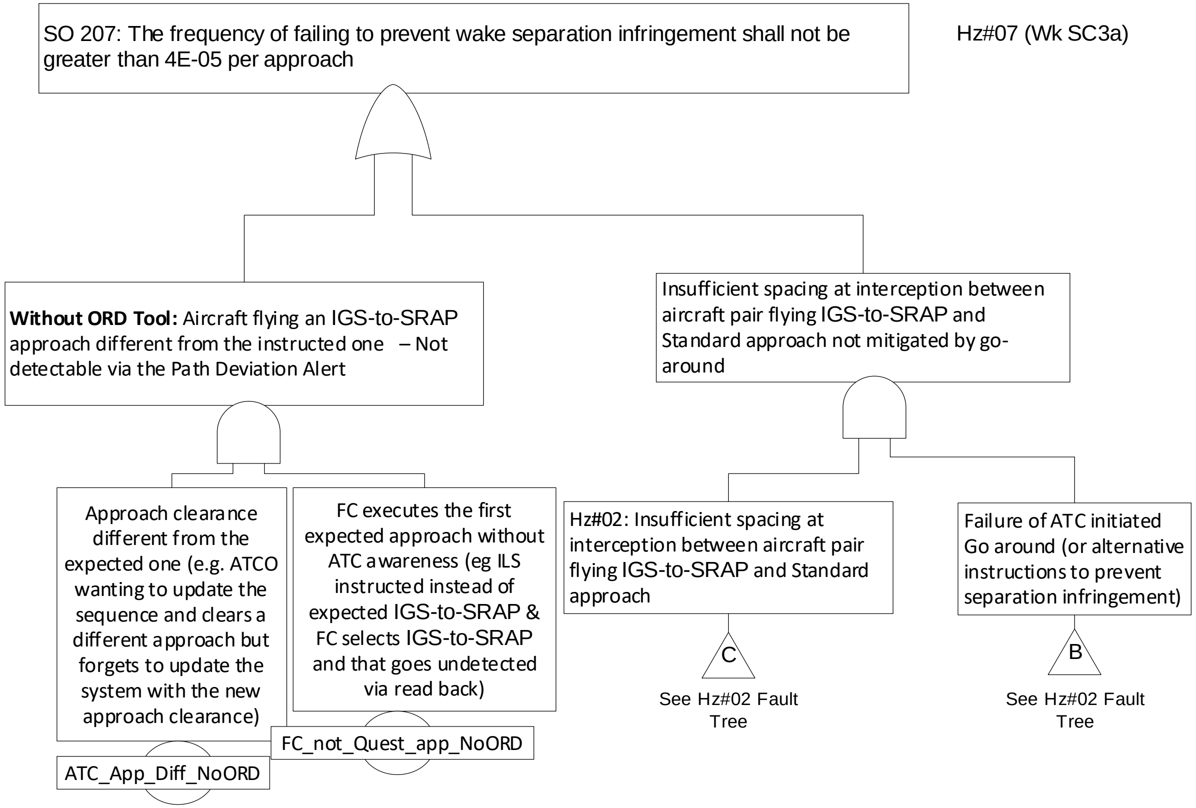
Vertical deviation of one aircraft from the instructed & correctly selected approach	See Hz#04 Fault Tree
Aircraft correctly following the IGS-to-SRAP approach path is not able to decelerate to the stabilised approach speed And Go around not executed	
See Hz#06a Fault Tree	

5.5.2.1.7 Hz#07 (SO 207) Fail to prevent wake separation infringement

Basic causes for such failure have been captured in the Hz#07 Fault Tree (See Figure 7).

Furthermore, a table is attached to the Fault Tree describing in more detail these basic causes and identifying the existing mitigations for preventing the occurrence of this hazard as well as deriving new required mitigations as safety requirements to satisfy the Safety Objective SO 207 associated to this operational hazard.

Requirements in italics are requirements already derived during the analysis in normal or abnormal conditions.



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224 **Figure 7 Hz#07 Fault Tree**

225

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Without ORD Tool: Aircraft flying an IGS-to-SRAP approach different from the instructed one – Not detectable via the Path Deviation Alert			
Approach clearance different from the expected one (e.g. controller wanting to update the sequence and clear a different	ATC_App_Diff_NoORD	APP Controller wants to update the arrival sequence (e.g. for performance purposes) and gives an updated approach	Proposed mitigation: ***SR2.008*** about the APP ATCO being able to record the cleared approach procedure.

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approach but forgets to update the system with the new approach clearance)		clearance (e.g. ILS instead of the expected IGS-to-SRAP) and omits to update the system.	Mitigated also by ***SR2.016*** regarding sequence optimisation.
			Regarding the flight crew: It is expected that the FC will challenge the difference between the expected and the instructed approach clearances from the APP controller/s
FC executes the first expected approach without ATC awareness (e.g. ILS instructed instead of expected IGS-to-SRAP & FC selects IGS-to-SRAP and that goes undetected via read back)	FC_not_Quest_app_No ORD	FC decides to fly the expected approach that was provided in the first place and this goes undetected via read-back. Only without ORD tool support: since the controller did not update the system with the new clearance and the FC is flying the first expected clearance (i.e. the one that is actually in the system). The Path Deviation Alert will not be efficient in this case and the fact that the controller will apply the separation rules for the instructed approach could go undetected.	This can cause an Imminent Wake Encounter under unmanaged under-separation.
Insufficient spacing at interception between aircraft pair flying IGS-to-SRAP and Standard approach not mitigated by go-around			
Hz#02: Insufficient spacing at interception between aircraft pair flying IGS-to-SRAP and Standard approach	Please see Hz#02		
Failure of ATC initiated Go around (or alternative instructions to prevent separation infringement)			

5.5.2.1.8 Hz#08 (SO 208) Interception and landing to the incorrect aiming point going undetected with risk of runway excursion during IGS-to-SRAP approach

Basic causes for such failure have been captured in the Hz#08 Fault Tree (See Figure 8).

Furthermore, a table is attached to the Fault Tree describing in more detail these basic causes and identifying the existing mitigations for preventing the occurrence of this hazard as well as deriving new required mitigations as safety requirements to satisfy the Safety Objective SO 208 associated to this operational hazard.

Requirements in italics are requirements already derived during the analysis in normal or abnormal conditions.

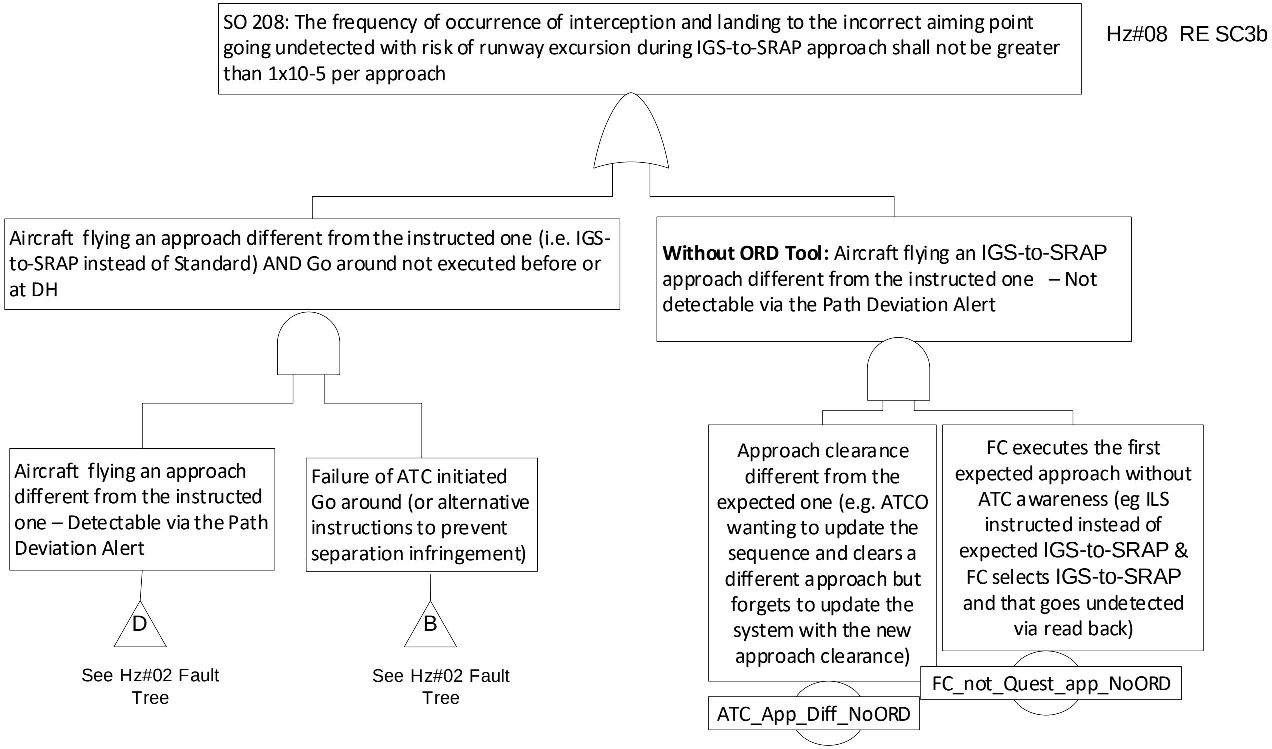

Figure 8 Hz#08 Fault Tree

Type of failure	Cause Id	Cause description	Mitigation/Safety Requirement
Without ORD Tool: Aircraft flying an IGS-to-SRAP approach different from the instructed one – Not detectable via the Path Deviation Alert			
Approach clearance different from the expected one (e.g. ATCO wanting to update the sequence and clears a different approach but forgets to update the system with the new approach clearance)	ATC_App_Diff_NoORD	Please see Hz#07	
FC executes the first expected approach without ATC awareness (eg ILS instructed instead of expected IGS-to-SRAP & FC selects IGS-to-SRAP and that goes undetected via read back)	FC_not_Quest_app_NoORD		
Aircraft flying a different approach from the instructed one (i.e. IGS-to-SRAP instead of Standard) or flying an incorrect IGS-to-SRAP approach path And Go around not executed before or at DH			
Aircraft flying a different approach from the instructed one or flying an incorrect IGS-to-SRAP approach path – Detectable via the Path Deviation Alert	Please see Hz#02 Additional mitigation proposed: **SR2.313:** The IGS-to-SRAP approach chart shall include altitude/distance information for the applicable runway aiming point to facilitate Flight Crew procedure check during the approach		
Failure of ATC initiated Go around (or alternative instructions to prevent separation infringement)			

5.5.3 Common Cause Analysis

The main common causes that have been identified are related to the use of the separation indicators (ITDs and/or FTDs). More specifically, they are related to the lack of information needed to display the separation indicators or to incorrect information leading to the corruption of the separation indicators. These common causes affect Hz#02, Hz#03 and Hz#04 - all three leading to imminent wake separation infringement.

The common causes identified in this solution are identical with the ones in PJ02.01, therefore the same two operational hazards previously identified in PJ02.01 are used to deal with them:

- ***PJ02.01 Hz#05***: One or multiple imminent infringements not detected and not recovered due to undetected corruption of separation indicator
- ***PJ02.01 Hz#06***: One or multiple imminent infringements due to lack of separation indicator for multiple or all aircraft.

To avoid duplication, please refer to PJ02.01 SAR [14] for the analysis of the two hazards above.

5.5.4 Formalization of Mitigations

Considering the outcome of the causal analysis and more particularly the Mitigations identified in each table accompanying the hazards fault trees, the table below formalizes the system generated hazard mitigation which have not been already captured during the design analysis in normal conditions.

SO Description	SR ID	SR Description
SO 202 The frequency of occurrence of insufficient spacing at interception between aircraft pair flying IGS-to-SRAP and Standard approach or between aircraft conducting the same IGS-to-SRAP approach shall not be greater than 2E-03 per approach	SR2.301	At each aircraft transfer on frequency when contacting the next ATC unit, the Flight Deck shall indicate the expected or cleared approach procedure
	SR2.316 REQ-14.5-SPRINTEROP-CTL.1013	At each aircraft transfer on frequency, Approach Executive Control or Tower Runway Control shall confirm the expected or cleared IGS-to-SRAP Approach.
	SR2.302 REQ-14.5-SPRINTEROP-CTL.1014	Approach Executive Control shall consider, when establishing and maintaining separation, that aircraft ability to respect ATC speed instructions may be limited during -IGS-to-SRAP operations, especially for slope angles above 3.5 degrees, and aircraft's speed might need to be reduced earlier compared to standard approach. Note: the higher the slope angle, the longer it takes for the aircraft to decelerate. However, this should not

		be a problem with slopes under 3.5 degrees.
	SR2.305 REQ-12.02.02-TS-OPS1.1040	The Separation Delivery Tool shall send to CWP HMI a speed conformance alert when an aircraft's ground speed exceeds its offline defined air speed - corrected by the wind value - by a predefined offline tolerance value
	SR2.306 REQ-14.5-SPRINTEROP-CTL.1108	Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.
SO 203 The frequency of occurrence of wrong spacing management on Final Approach between two aircraft of which at least one flies an increased glide slope angle (IGS-to-SRAP, involving a/c reduced reactivity to decelerate) shall not be greater than 2E-03 per approach	SR2.302 REQ-14.5-SPRINTEROP-CTL.1014	Approach Executive Control shall consider, when establishing and maintaining separation, that aircraft ability to respect ATC speed instructions may be limited during - IGS-to-SRAP operations, especially for slope angles above 3.5 degrees, and aircraft's speed might need to be reduced earlier compared to standard approach. Note: the higher the slope angle, the longer it takes for the aircraft to decelerate. However, this should not be a problem with slopes under 3.5 degrees.
	SR2.304 REQ-14.5-SPRINTEROP-CTL.1107	For IGS-to-SRAP operations with complex separation minima scheme in high traffic environment, Approach Executive Control shall be warned when an aircraft is significantly catching-up the preceding traffic with an anticipated risk of loss of separation minima.
	The following mitigation from PJ02.14.5 also applies: *SR1.117 (REQ-02.01-SPRINTEROP-ARR0.1250)*	

SO 204 The frequency of occurrence of vertical deviation of either a/c in a pair where the leader is on the lower glide slope and the follower is on the higher IGS-to-SRAP glide slope leading to imminent WT separation infringement shall not be greater than 2E-03 per approach	SR2.301	At each aircraft transfer on frequency when contacting the next ATC unit, the Flight Deck shall indicate the expected or cleared approach procedure
	SR2.316 REQ-14.5-SPRINTEROP-CTL.1013	At each aircraft transfer on frequency, Approach Executive Control or Tower Runway Control shall confirm the expected or cleared IGS-to-SRAP Approach.
	SR2.303 REQ-14.5-SPRINTEROP-APT.1301	Flight Deck shall be supported by appropriate landing visual aid references for their flown approach procedure (e.g. PAPIs associated to the additional threshold), down to the approach minima.
	SR2.306 REQ-14.5-SPRINTEROP-CTL.1108	Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.
	The following requirements apply from the normal operational conditions (Table 8): SR2.001 REQ-14.5-SPRINTEROP-CTL.1005 SR2.008 REQ-14.5-SPRINTEROP-CTL.1006 SR2.010 REQ-14.5-SPRINTEROP-CTL.1201 SR2.013 REQ-14.5-SPRINTEROP-CTL.1104 SR2.014 REQ-14.5-SPRINTEROP-CTL.1105 SR2.015 REQ-14.5-SPRINTEROP-CTL.1106 SR2.016 REQ-14.5-SPRINTEROP-CTL.1112 The following apply from the abnormal operational conditions (Table 10):	

	SR2.200 REQ-14.5-SPRINTEROP-ACFT.2102 SR2.204 REQ-14.5-SPRINTEROP-CTL.1012	
SO 205 The frequency of occurrence of lateral or vertical deviation from the IGS-to-SRAP approach leading to a flight towards terrain shall not be greater than 2x10-7 per approach	SR2.301	At each aircraft transfer on frequency when contacting the next ATC unit, the Flight Deck shall indicate the expected or cleared approach procedure
	SR2.316 REQ-14.5-SPRINTEROP-CTL.1010	At each aircraft transfer on frequency, Approach Executive Control or Tower Runway Control shall confirm the expected or cleared IGS-to-SRAP Approach.
	SR2.306 REQ-14.5-SPRINTEROP-CTL.1108	Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.
	SR2.310 REQ-02-02-SPRINTEROP-ITSR.1209	The design of the GLS or RNAV (LPV, LNAV-VNAV) procedures supporting IGS-to-SRAP shall be compliant with ICAO Doc 8168 and shall be validated in accordance with the Instrument Flight Procedure process specified in ICAO Doc 9906
	SR2.311 REQ-02-02-SPRINTEROP-ITSR.1210	For the design of GLS or RNAV (LPV, LNAV-VNAV) procedures with a glide path angle greater than 3.5°, the rule for the Height Loss increase shall be standardised at ICAO level (IFPP)
	SR2.312 REQ-14.5-SPRINTEROP-CTL.1110	When supported by ground surveillance displays, Tower Executive Control shall be able to easily and unambiguously identify the assigned landing aiming point for each landing aircraft

	The following requirements apply from the normal operational conditions (Table 8): SR2.001 REQ-14.5-SPRINTEROP-CTL.1005 SR2.008 REQ-14.5-SPRINTEROP-CTL.1006 SR2.013 REQ-14.5-SPRINTEROP-CTL.1104 SR2.014 REQ-14.5-SPRINTEROP-CTL.1105 SR2.015 REQ-14.5-SPRINTEROP-CTL.1106 SR2.023 REQ-14.5-SPRINTEROP-APT.1302 SR2.051 REQ-14.5-SPRINTEROP-APT.1303	
	The following apply from the abnormal operational conditions (Table 10): SR2.200 REQ-14.5-SPRINTEROP-ACFT.2102 SR2.204 REQ-14.5-SPRINTEROP-CTL.1012	
SO 206 The frequency of occurrence of an aircraft on IGS-to-SRAP approach with insufficient landing distance available shall not be greater than 1x10-7 per approach	SR2.301	At each aircraft transfer on frequency when contacting the next ATC unit, the Flight Deck shall indicate the expected or cleared approach procedure
	SR2.316 REQ-14.5-SPRINTEROP-CTL.1013	At each aircraft transfer on frequency, Approach Executive Control or Tower Runway Control shall confirm the expected or cleared IGS-to-SRAP Approach.
	SR2.317 REQ-14.5-SPRINTEROP-CTL.1213	When designing the IGS-to-SRAP local procedure, the location of the second runway aiming point shall provide sufficient landing distance available for all eligible aircraft at that specific airport
	SR2.303 REQ-14.5-SPRINTEROP-APT.1301	Flight Deck shall be supported by appropriate landing visual aid references for their flown approach procedure (e.g. PAPIs associated to

		the additional threshold), down to the approach minima.
	SR2.306 REQ-14.5-SPRINTEROP-CTL.1108	Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.
	SR2.318 REQ-14.5-SPRINTEROP-CTL.1009	Approach Executive Control shall vector the aircraft onto IGS-to-SRAP approach such as to avoid final approach interception from above
SO 207 The frequency of failing to prevent wake separation infringement shall not be greater than 4E-05 per approach	SR2.306 REQ-14.5-SPRINTEROP-CTL.1108	Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.
SO 208 The frequency of occurrence of interception and landing to the incorrect aiming point going undetected with risk of runway excursion during IGS-to-SRAP approach shall not be greater than 1x10-5 per approach		
	SR2.316 REQ-14.5-SPRINTEROP-CTL.1013	At each aircraft transfer on frequency, Approach Executive Control or Tower Runway Control shall confirm the expected or cleared IGS-to-SRAP Approach.
	SR2.306 REQ-14.5-SPRINTEROP-CTL.1108	Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.

	SR2.313 REQ-14.5-SPRINTEROP-CTL.1211	The IGS-to-SRAP approach chart shall include altitude/distance information for the applicable runway aiming point to facilitate Flight Crew procedure check during the approach
SO 209 The frequency of occurrence of an aircraft on IGS-to-SRAP approach landing with excessive vertical speed leading to hard landing shall not be greater than 1x10-7 per approach	SR2.303 REQ-14.5-SPRINTEROP-APT.1301	Flight Deck shall be supported by appropriate landing visual aid references for their flown approach procedure (e.g. PAPIs associated to the additional threshold), down to the approach minima.
	SR2.306 REQ-14.5-SPRINTEROP-CTL.1108	Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.
	SR2.318 REQ-14.5-SPRINTEROP-CTL.1009	Approach Executive Control shall vector the aircraft onto IGS-to-SRAP approach such as to avoid final approach interception from above
	SR2.319 REQ-14.5-SPRINTEROP-APT.1304	When the second runway threshold is not active (i.e. operating only the conventional threshold), the lightings of the secondary runway threshold and aiming point shall be switched off such as to avoid confusing Flight Deck

Table 11 Additional success-case safety requirements to mitigate System generated Hazards for the IGS-to-SRAP concepts

5.5.5 Safety Requirements (integrity/reliability)

As mentioned previously, quantitative Safety Requirements will not be derived in this safety assessment. This will however need to be done by the industry in the validation stages prior to implementation (i.e. V4 onwards).

5.6 Realism of the safe design

The development and safety analysis of the design would be seriously undermined if it were found in the subsequent Implementation phase that the Safety Requirements were either not ‘testable’ or impossible to satisfy (i.e. not achievable), and / or that some of the assumptions were in fact incorrect.

5.6.1 Achievability of Safety Requirements / Assumptions

All the requirements in this SAR have been developed in different workshops at project level, involving the different partners in this solution. The requirements have also been coordinated at project level such that to avoid duplications and/or contradictions with the OSED, HP and TS requirements.

The vast majority of the Safety Requirements have been demonstrated as capable of being satisfied in a typical implementation because they have been tested during validation exercises or because their achievability has been confirmed with Controllers, pilots and ground manufacturers during meetings, SAF/HP workshop or debriefing sessions. The information regarding the coverage and /or validation of the requirements in validation exercises is not provided in the current SAR. However, this is taken care of in the VALP [17] (which shows the link between the requirements and the validation objectives for each validation exercise), VALR [18] (which shows the detailed results of the exercises) and the OSED [16] (which shows for each requirement if it has been validated or not).

5.6.2 “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 cases 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.

5.7 Process assurance for a Safe Design

A safety team encompassing controllers, pilots, engineers, safety and human performance specialists have supported 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 section 4).

In the frame of SESAR 1, a PSSA workshop was organised in September 2015 with the support of operational people including controllers and pilots. Further, a Safety/HP workshop to clarify the remaining open points and to discuss the V3 Validation results was organised in July 2016 with technical and operational people.

In the frame of SESAR 2020, a Safety-Human Performance workshop took place in March 2018. This workshop helped clarifying outstanding concept elements and any other possible safety and human performance issues.

In the frame of SESAR 2020 Wave 2, two workshops were held on 19th November 2020 and 7th May 2021 with Paris CDG controllers to begin the development of the non-nominal procedures. They were further validated during the real-time simulation and developed/enhanced where required.

Appendix C provides the consolidated list of Safety Objectives.

Appendix D provides the consolidated list of Safety Requirements.

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

6 SAfety Criteria achievability

This section outlines the results of the safety assurance activities in response to the safety validation objectives. These results encompass outcomes of the modelling, data collection and analysis dedicated to the risk of Wake Vortex Encounter (to meet any mode-SAC#1), results of the validation exercises (mainly Real Time Simulations) or outcomes of the safety-dedicated workshops (making use of operational experts' judgment). Such results may confirm that the validation objectives are satisfied (thus proving that the correspondent SAC is met by the design of the new WT separation modes) or may enable to validate Safety Requirements or to derive new ones.

It is recalled that at SPR-design level, Safety Objectives have been mapped to Safety Requirements for normal conditions, for abnormal conditions and for failure aspects. It was shown in these sections (using a combination of safety engineering techniques, safety assessment and results from validation exercises) that these Safety Requirements satisfy the Safety Objectives which in turn have been already shown to satisfy Safety Criteria.

The next table summarizes the results for the Safety KPA dedicated to each of the safety-related validation objectives identified in the VAL PLN [17] for the IGS-to-SRAP concepts. For detailed results please see the corresponding VALR **Error! Reference source not found.**

Note with regard to all the success criteria about the quantification of the under-separations and go-arounds:

- Based on the data collected in the RTS and due to the limited number of scenarios and conditions that can be tested in a RTS, only a limited statistical analysis could be performed for these success criteria, as the data is insufficient to derive a significant statistical conclusion. However, these results do give an indication of trends. Thus, this quantitative data in combination with the qualitative safety data/results obtained from the RTS and other safety related activities (e.g. workshops, HAZIDs) enables us to conclude that safety is not negatively impacted.

Exercise ID, Name, Objective	Exercise Validation objective	Success criterion	Safety Criteria coverage	Validation results & Level of safety evidence
PJ02-W1 RTS02: RTS conducted by EUROCONTROL in the CDG airport environment to assess the application of Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP) concepts, in comparison to the conventional approach procedure (ILS featuring a 3° glideslope).	**OBJ-02.02-V3-VALP-ITSR.0103** To confirm that Secondary Runway Aiming Point IGS-to-SRAP approach procedures do not negatively affect safety from ATC perspective	**CRT-02.02-V3-VALP-ITSR.0103-001** There is evidence that the level of operational safety is maintained and not negatively impacted under IGS-to-SRAP procedures compared to the reference scenario from ATC perspective	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4, IGS-to-SRAP-SAC#R-1	No safety related concerns were found in relation to the use of the ORD tool and the IGS-to-SRAP procedures. Safe standard controller practices are used when performing IGS-to-SRAP with ORD tool. Controllers' feedback and observations indicated that there is no increase in potential human errors with safety implications due to the introduction of IGS-to-SRAP with ORD tool (e.g. either in terms of the severity of current potential human errors or the introduction of new potential causes for human errors).
		CRT-02.02-V3-VALP-ITSR.0103-002 The probability of aircraft being under-separated and therefore experiencing a wake encounter is not increased under IGS-to-SRAP procedures compared to the reference scenario	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4	The results show that the use of IGS-to-SRAP arrival procedures with ORD tool decrease the percentage of under-spaced aircraft, as compared to the baseline scenario. The probability of go-arounds induced by under-spacing was also less than the reference scenario.
		CRT-02.02-V3-VALP-ITSR.0103-003 The probability of a go-around due to inadequate consideration of ROT	IGS-to-SRAP-SAC#R-1	

		constraint is not increased under IGS-to-SRAP procedures compared to the reference scenario		
PJ02-W1 RTS03: RTS conducted by EUROCONTROL in the CDG airport environment to assess the application of the Increased Glide Slope to Second Runway Aiming Point (IGS-to-SRAP) concept in comparison to the conventional approach procedure (typically a 3° glide slope with an ILS procedure).	**OBJ-02.02-V3-VALP-ITSR.0103** To confirm that Increase Glide Slope to Secondary Aiming Point (IGS-to-SRAP) approach procedures do not negatively affect safety from ATC perspective	**CRT-02.02-V3-VALP-ITSR.0103-001** There is evidence that the level of operational safety is maintained and not negatively impacted under IGS-to-SRAP procedures compared to the reference scenario from ATC perspective	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4, IGS-to-SRAP--SAC#R-1	Based on observations and data from the simulation, it has been concluded that the operational safety was not affected when applying IGS-to-SRAP. The controllers did not experience safety issues during the simulations.
		CRT-02.02-V3-VALP-ITSR.0103-002 The probability of aircraft being under-separated and therefore experiencing a wake encounter is not increased under IGS-to-SRAP procedures compared to the reference scenario	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4	The results showed that the use of the IGS-to-SRAP arrival procedures with the ORD tool decreased the percentage of under-spaced aircraft conditions compared to the baseline scenario.
		CRT-02.02-V3-VALP-ITSR.0103-003 The probability of a go-around due to inadequate consideration of ROT constraint is not increased	IGS-to-SRAP-SAC#R-1	An increase in the number of go-arounds was observed in the reference scenario compared to the solution scenario. It can be concluded therefore that the probability of a go-around is not increased in the solution scenario compared to the reference scenario.

		under IGS-to-SRAP procedures compared to the reference scenario		
PJ02-W1 RTS05 led by EUROCONTROL to assess IGS-to-SRAP runway aids from pilots' point of view, via flight cockpit simulations using a high level professional Level D/Type 7 flight crew training simulator.	**OBJ-02.02-V3-VALP-ITSR.0203** To confirm that IGS-to-SRAP does not negatively affect safety from the crew's perspective	**CRT-02.02-V3-VALP-ITSR.0203-001** There is evidence that the level of operational safety is maintained and not negatively impacted under IGS-to-SRAP procedures compared to the reference scenario, from the crew's perspective	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4, IGS-to-SRAP-SAC#R-1	A reduction in the perceived level of safety for IGS-to-SRAP was observed in lower visibility conditions. Pilots explained that this perceived reduction in safety was brought by the uncertainty caused by seeing only the first aiming point while having to land on the second. Additionally, regarding IGS-to-SRAP only, pilots stated that flying to the second runway aiming point with a steeper glide enhances the feeling of being too high when passing the first threshold despite the fact that the second PAPI gives the right indications. On the positive side the steeper glide slope supports the pilot in identifying the second threshold and focusing on the aiming point.
PJ02-W1 R01 led by EUROCONTROL in order to evaluate the impact of IGS-to-SRAP on ATCOs during non-nominal situations and to develop procedures to help the controllers to deal with such situations.	**OBJ-14.2-V3-VALP-0103:** To confirm that IGS-to-SRAP approach procedures do not negatively affect safety from ATC perspective, in non-nominal situations	**CRT-14.2-V3-VALP-0103-001:** There is evidence that the level of operational safety is maintained and not negatively impacted when IGS-to-SRAP procedures are active, in non-nominal situations	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4, IGS-to-SRAP-SAC#R-1	Results from the simulation show that participants found the procedures helpful in enabling them to resolve the situation safely and in a timely manner.

PJ02-W1 R10 led by EUROCONTROL aimed at assessing IGS-to-SRAP runway lighting solutions from pilots' perspective via flight cockpit simulations using a high level professional Level D/Type 7 flight crew training simulator. The simulator of the type Airbus A319 has full motion, control loading and a configurable visual system.	**OBJ-14.2-V3-VALP-SRAP.0203** To confirm that IGS-to-SRAP does not negatively affect safety from the crew's perspective	**CRT-14.2-V3-VALP-SRAP.0203-001** There is evidence that the level of operational safety is maintained and not negatively impacted under IGS-to-SRAP procedures compared to the reference scenario, from the crew's perspective	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4, IGS-to-SRAP-SAC#R-1	Overall, it can be summarized that safety was not negatively impacted by neither the static nor the switching lighting systems. A very small decrease in safety was recorded overall compared to the reference scenario, but this was not statistically relevant. Additionally, no statistically relevant difference was observed with respect to safety between the static and the switching lighting systems.
PJ02-W1 R15 led by EUROCONTROL aimed at assessing IGS-to-SRAP runway markings solutions from pilots' perspective via flight cockpit simulations using a high level professional Level D/Type 7 flight crew training simulator. The simulator of the type Airbus A319 has full motion, control loading and a configurable visual system.	**OBJ-14.2-V3-VALP-SRAP.0203** To confirm that IGS-to-SRAP does not negatively affect safety from the crew's perspective	**CRT-14.2-V3-VALP-SRAP.0203-001** There is evidence that the level of operational safety is maintained and not negatively impacted under IGS-to-SRAP procedures compared to the reference scenario, from the crew's perspective	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4, IGS-to-SRAP-SAC#R-1	Option 1 (ICAO duplication) and 2 (chequered aiming point) were seen as acceptable from a safety perspective. Options 3 and 4 (yellow markings) and 5 (blue markings) were seen to reduce the perceived level of safety.

PJ02-W1 R25 led by EUROCONTROL aimed at assessing IGS-to-SRAP static runway lighting solution, under various weather circumstances, from pilots' perspective via flight cockpit simulations using a high level professional Level D/Type 7 flight crew training simulator. The simulator of the type Airbus A319 has full motion, control loading and a configurable visual system.	**OBJ-14.2-V3-VALP-SRAP.0203** To confirm that IGS-to-SRAP does not negatively affect safety from the crew's perspective	**CRT-14.2-V3-VALP-SRAP.0203-001** There is evidence that the level of operational safety is maintained and not negatively impacted under IGS-to-SRAP procedures compared to the reference scenario, from the crew's perspective	IGS-to-SRAP-SAC#WT-F2, IGS-to-SRAP-SAC#WT-F4, IGS-to-SRAP-SAC#R-1	Overall, it can be summarized that from pilot's perspective the level of safety is not influenced by using the static approach lighting configuration under various weather circumstances (e.g. reduced visibility, crosswind).

333 **Table 12 Safety Validation Results**

334 # 7 Acronyms and Terminology

Term	Definition
A/C	Aircraft
ACAS	Airborne Collision Avoidance System
AFS CP	Automatic Flight System Control Panel
A-IGS	Adaptive Increased Glide Slope
AIC	Aeronautical Information Circular
AIM	Accident Incident Model
AIP	Aeronautical Information Publication
AMAN	Arrival Manager
ANS	Air Navigation Service(s)
ANSP	Air Navigation Service Provider
AP/FD	Autopilot/flight director
APM	Approach Path Monitoring
APP	Approach
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATIS	Automatic Terminal Information Service
ATM	Air Traffic Management
ATS	Ait Traffic Services
A-SMGCS	Advanced Surface Movement Guidance and Control System
CAT I	Category I
CWP	Controller Working Position
CFIT	Controlled Flight Into Terrain
CFTT	Controlled Flight Towards Terrain
CNS	Communication, Navigation & Surveillance
CSPR	Closely Spaced Parallel Runways

DB	Database
DF	
DH	Decision Height
DME	Distance Measuring Equipment
DS	Double Slope
DSNA	Direction des Services de la Navigation Aérienne
CSPR ST	Closely Spaced Parallel Runways Staggered Threshold
DCB	Demand Capacity Balancing
Doc	Document
DA/H	Decision Altitude / Height
DMAN	Departure Manager
IGS-to-SRAP	Enhanced Arrival Procedures
EASA	European Aviation Safety Agency
EATMA	European Air Traffic Management Architecture
EUROCONTROL	European Organisation for the Safety of Air Navigation
FAP	Final Approach Point
FAS	Final Approach Segment
FC	Flight Crew
FCF	Facilitate Capture of the Final approach
FCOM	Flight Crew Operating Manual
FHA	Functional Hazard Assessment
FLD	Facilitate Landing & Deceleration
FMS	Flight Management System
FPL	Flight Plan
FTD	
G/S	Glide Slope
GAST-C	GBAS Approach Service Type C
GBAS	Ground Based Augmentation System

GLS	GNSS Landing System
GPS	Global Positioning System
HAZID	Hazard Identification
HMI	Human Machine Interface
HP	Human Performance
ICAO	International Civil Aviation Organization
IFPP	Initial Flight Plan Processing
IGS	Increased Glide Slope
IGS-to-SRAP	Increased Glide Slope to a Second Runway Aiming Point
ILS	Instrument Landing System
INTEROP	Interoperability
IRS	Interface Requirement Specification
ITD	
KPA	Key Performance Area
LNAV	Lateral Navigation
LOC	Localiser
LPV	Lateral Precision with Vertical Guidance Approach??
MAC	Mid-Air Collision
MLS	Microwave Landing System
MRAP	
MRS	Minimum Radar Separation
MSS	Minimum Surveillance Separation
NAVDB	Navigation Data Base
NM	Nautical Miles
NOTAM	Notice to Airmen
NAVDB	Navigation Data Base
OFZ	Obstacle Free Zone???
OHA	Operational Hazard

OI	Operational Improvement Step
ORD	Optimised Runway Delivery
OSED	Operational Service and Environment Definition
PANS OPS	Procedures for Air Navigation Services Operations
PAPI	Precision Approach Path Indicator
PJ02-02	Project 02 Solution 02
P06.08.08	Project 06.08.08 SESAR I
QFU	Magnetic Orientation of Runway
RC	Runway Collision
RCS	Risk Classification Schemes
RE	Runway Excursion
RECAT-EU	European separation standard for aircraft wake turbulence
RIMCAS	Runway Incursion Monitoring and Conflict Alert System
RIMS	Runway Incursion Monitoring System
RNAV	Area Navigation
RNP	Required Navigation Performance
ROT	Runway Occupancy Time
RPA	Runway Protected Area
RTS	Real-Time Simulation
RVR	
RWY	Runway
SA	Situational Awareness
SAC	SAfety Criteria
SAR	Safety Assessment Report
SBAS	Satellite-Based Augmentation System
SC	Severity Class
SESAR	Single European Sky ATM Research
SMI	Separation Minima Infringement???

SO	Safety Objectives
SP	SeParate aircraft with other aircraft
SPR	Safety and Performance Requirements
SPT	SeParate aircraft with Terrain
SRAP	Second Runway Aiming Point
SRD	Safety Requirements (functionality & performance) at Design level
SRM	Safety Reference Material
SRS	
TS	Technical Specifications
TDI	Target Distance Indicator
TDZ	Touchdown Zone
TMA	Terminal Manoeuvring Area
TS	Technical Specifications
TWR	Tower
VALP	Validation Plan
VASI	Visual Approach Slope Indicator
VHF	Very High Frequency
VNAV	Vertical Navigation
V1, V3, etc.	Validation Maturity Leve 1, Level 3, etc.
WT	Wake Turbulence
WTA	Wake Turbulence-induced Accident
WTC	Wake Turbulence Category
WTE	Wake Turbulence Encounter
xLS	Instrument Approach using either ILS, MLS, SBAS or GBAS

335 **Table 13: Acronyms and terminology**

336

8 References

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[13] GBAS enhanced arrival procedures – Safety Assessment Report (SAR), Edition 00.00.04, October 2016

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[15] SESAR Solution PJ02-02 SRP-INTEROP/OSED – Part II – Safety Assessment Report, Edition 00.00.07, March 2020.

[16] PJ.02-W2-14.2 SPR-INTEROP/OSED Part I, Edition 00.01.00 May 2022

[17] PJ.02-W2-14.2 VALP Part I, Edition 00.01.00, 28 May 2021

[18] PJ.02-W2-14.2 VALR, Edition 00.01.00, April 2022

[19] PJ.02-W2-14.05 VALP Part II SAP, Edition 00.01.00, 30 April 2021

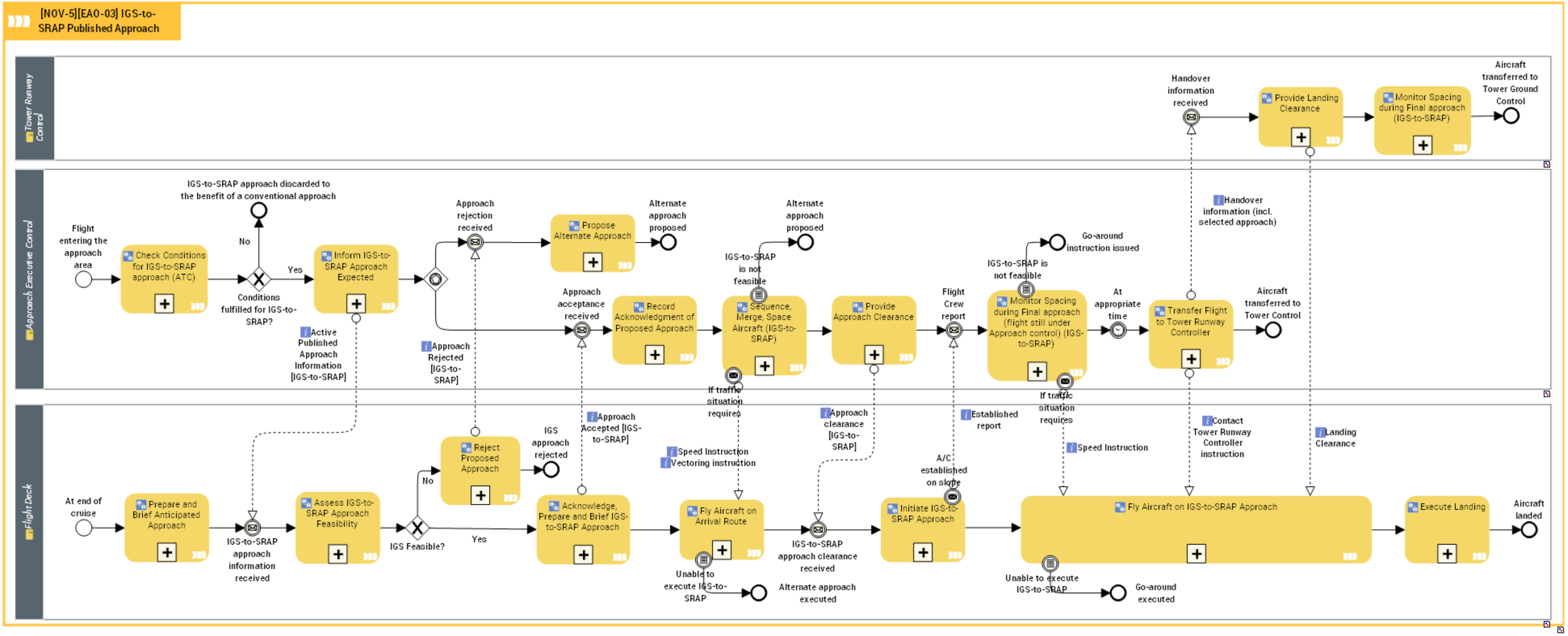
Appendix A Derivation of Safety Objectives (Functionality & Performance – success approach) for Normal Operations

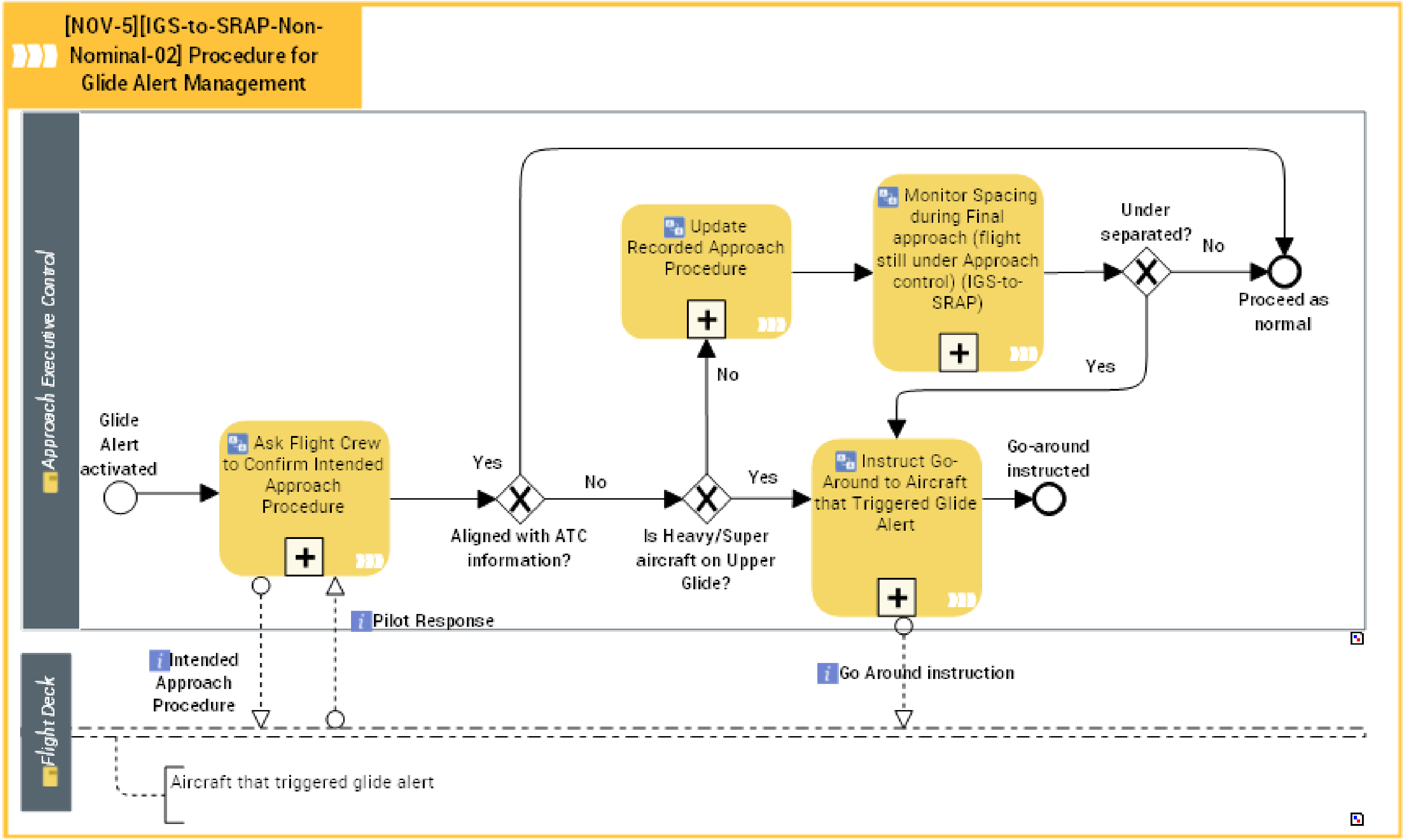
A.1 EATMA Process Models

The following Use Cases (extracted from PJ02-W2.14.5 OSED [16]) and their related EATMA Process Models have been taken into consideration for the elaboration of the Safety Assessment:

- UC-EA0- 01 IGS-to-SRAP Published Approach
- UC-EAO-01, 02, 03 IGS-to-SRAP Non nominal

Note that for the non-nominal process models, it has been decided that deriving Safety Requirements at Design Level (i.e. from the corresponding lower level NSV-4 diagrams) would suffice. Therefore, no Safety Objectives were derived for the NOV-5 non-nominal process models.


[NOV-5][EA0-03] IGS-to-SRAP Published Approach
Tower Runway Control
Approach Executive Control
Flight Deck
Handover information received
Provide Landing Clearance
Monitor Spacing during Final approach (IGS-to-SRAP)
Aircraft transferred to Tower Ground Control
IGS-to-SRAP approach discarded to the benefit of a conventional approach
Flight entering the approach area
Check Conditions for IGS-to-SRAP approach (ATC)
No
Yes
Conditions fulfilled for IGS-to-SRAP?
Inform IGS-to-SRAP Approach Expected
Active Published Approach Information [IGS-to-SRAP]
Approach rejection received
Propose Alternate Approach
Alternate approach proposed
Approach Rejected [IGS-to-SRAP]
Approach acceptance received
Record Acknowledgment of Proposed Approach
IGS-to-SRAP is not feasible
Sequence, Merge, Space Aircraft (IGS-to-SRAP)
If traffic situation requires
Provide Approach Clearance
Flight Crew report
IGS-to-SRAP is not feasible
Go-around instruction issued
Monitor Spacing during Final approach (flight still under Approach control) (IGS-to-SRAP)
At appropriate time
Handover information (incl. selected approach)
Transfer Flight to Tower Runway Controller
Aircraft transferred to Tower Control
At end of cruise
Prepare and Brief Anticipated Approach
IGS-to-SRAP approach information received
Assess IGS-to-SRAP Approach Feasibility
IGS Feasible?
Reject Proposed Approach
IGS approach rejected
Approach Accepted [IGS-to-SRAP]
Acknowledge, Prepare and Brief IGS-to-SRAP Approach
Speed Instruction
Vectoring instruction
Fly Aircraft on Arrival Route
Unable to execute IGS-to-SRAP
Approach clearance [IGS-to-SRAP]
IGS-to-SRAP approach clearance received
Alternate approach executed
Established report
A/C established on slope
Initiate IGS-to-SRAP Approach
Speed Instruction
Contact Tower Runway Controller instruction
Landing Clearance
Fly Aircraft on IGS-to-SRAP Approach
Unable to execute IGS-to-SRAP
Go-around executed
Execute Landing
Aircraft landed



[NOV-5][IGS-to-SRAP-Non-Nominal-02] Procedure for Glide Alert Management
Approach Executive Control
Flight Deck
Glide Alert activated
Ask Flight Crew to Confirm Intended Approach Procedure
Yes
No
Aligned with ATC information?
Is Heavy/Super aircraft on Upper Glide?
Yes
No
Update Recorded Approach Procedure
Monitor Spacing during Final approach (flight still under Approach control) (IGS-to-SRAP)
Under separated?
No
Yes
Proceed as normal
Instruct Go-Around to Aircraft that Triggered Glide Alert
Go-around instructed
Pilot Response
Intended Approach Procedure
Go Around instruction
Aircraft that triggered glide alert

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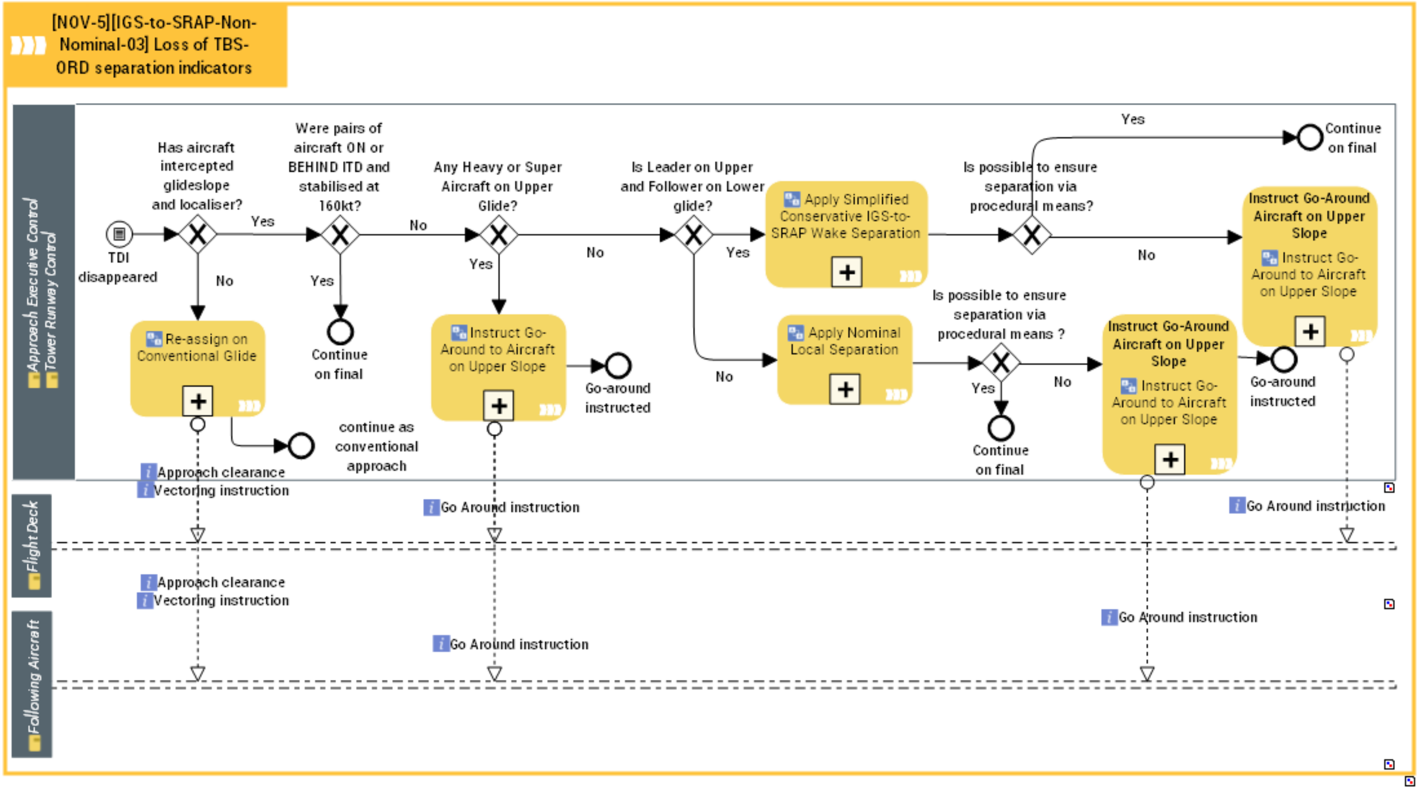

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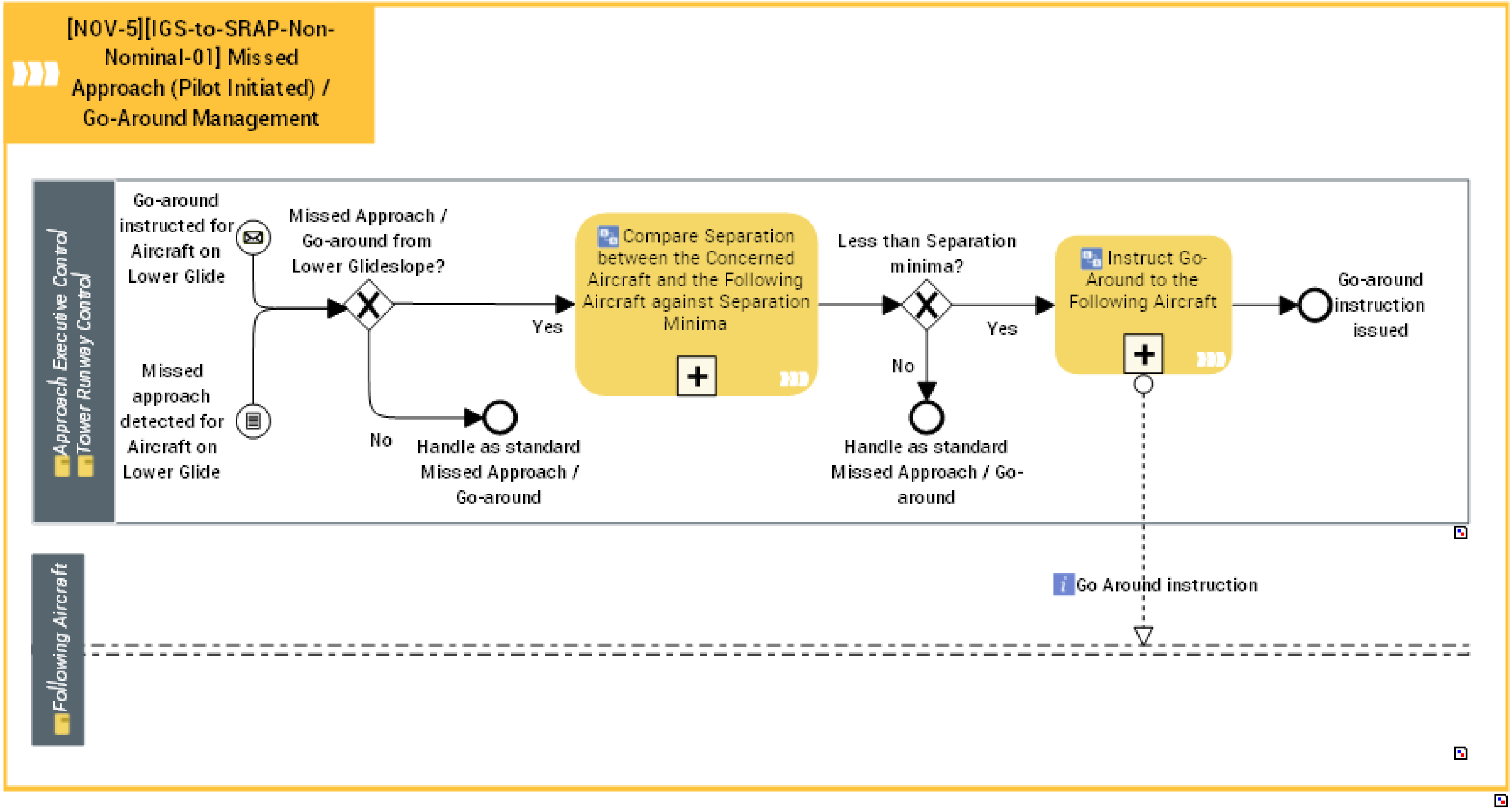
[NOV-5][IGS-to-SRAP-Non-Nominal-01] Missed Approach (Pilot Initiated) / Go-Around Management
Approach Executive Control
Tower Runway Control
Go-around instructed for Aircraft on Lower Glide
Missed approach detected for Aircraft on Lower Glide
Missed Approach / Go-around from Lower Glideslope?
Yes
No
Handle as standard Missed Approach / Go-around
Compare Separation between the Concerned Aircraft and the Following Aircraft against Separation Minima
Less than Separation minima?
Yes
No
Handle as standard Missed Approach / Go-around
Instruct Go-Around to the Following Aircraft
Go-around instruction issued
Following Aircraft
Go Around instruction

A.2 Derivation of Safety Objectives for Normal Operations driven by EATMA Process Models

Functionality & Performance Safety Objectives have been defined based on the Use Cases/ NOV5 EATMA models presented in the previous sub-section.

Note: Only the EATMA activities identified as impacted by the change (i.e. either new or modified) have been taken into account in the next table for the success case SO derivation.

Operational Service	EATMA Activity	Description of change	Derived SO	Related SAC (via AIM)
[NOV5-EAO 03] IGS-to-SRAP Published Approach				
FCF: Facilitate capture of the Final approach SP2 Maintain spacing/separation between aircraft on the same or on different final approach paths for the same runway end FLD Facilitate landing and deceleration on the runway	Approach Executive Control: Check Conditions for IGS-to-SRAP Approach (ATC)	New conditions have to be checked (e.g. if a/c is correctly equipped, navigation aids available, etc.) by Approach Executive Control depending on which ATC-initiated IGS-to-SRAP is being applied.	**SO 001:** Approach Executive Control shall be able to check the conditions for the new ATC-initiated IGS-to-SRAP approach, propose the expected approach to the flight crew and, in the event of a refusal from the flight crew, cancel the ATC-initiated IGS-to-SRAP approach and propose a standard approach instead	***IGS-to-SRAP* - SAC#F2** (AIM MAC FAP MF5.1 and MF5.2, in relation to aircraft unable to capture final approach path due to inadequate related capability) AIM RWE model: ***IGS-to-SRAP* SAC#RWE-1**, ***IGS-to-SRAP* - SAC#RWE-2**, ***IGS-to-SRAP* - SAC#RWE-3**, ***IGS-to-SRAP* - SAC#RWE-4**, ***IGS-to-SRAP* - SAC#RWE-5**, ***IGS-to-SRAP* - SAC#RWE-6**,
	Approach Executive Control: Inform IGS-to-SRAP Approach Expected	Approach Executive Control controller has to inform the flight crew (e.g. through "expect IGS-to-SRAP approach") about the expected approach procedure. Note this is not a clearance.		
	Approach Executive Control: Propose Alternate IGS-to-SRAP Approach	After the Flight Crew has rejected the proposed ATC-initiated IGS-to-SRAP, Approach Executive Control takes this refusal into account and clears the arrival flight for a standard approach.		

Operational Service	EATMA Activity	Description of change	Derived SO	Related SAC (via AIM)
As above	Flight Deck: Prepare & Brief Anticipated Approach	The Flight Crew has to perform new sub-tasks. E.g.: new approach type briefing, new approach charts to be checked, etc.	**SO 002:** The Flight Crew shall be able to assess the feasibility of the proposed ATC-initiated IGS-to-SRAP approach, prepare and brief it if feasible, or reject it if not feasible	As above
	Flight Deck: Assess IGS-to-SRAP Feasibility	The Flight Crew has to assess the feasibility of the ATC-initiated IGS-to-SRAP proposed by ATC by checking the new published procedure available on board.		
	Flight Deck: Reject IGS-to-SRAP Approach	Once the ATC-initiated IGS-to-SRAP approach has been assessed as "not feasible", the Flight Crew rejects it and requests Approach Executive Control to fly a standard approach instead.		
	Approach Executive Control: Record acknowledgement of Proposed IGS-to-SRAP acceptance	Once the Flight Crew has accepted the proposed ATC-initiated IGS-to-SRAP, Approach Executive Control records the corresponding approach for this particular flight.		
	Flight Deck: Acknowledge, Prepare & Brief IGS-to-SRAP Approach	The Flight Crew informs Approach Executive Control that the proposed ATC-initiated IGS-to-SRAP is accepted and immediately initiates the corresponding briefing to prepare the aircraft to fly the enhanced approach procedure, if not anticipated during the approach preparation and briefing at the end of cruise.		
SP1	Approach Executive Control: Sequence,	If an ATC-initiated IGS-to-SRAP is being flown, the Approach Executive Control has to sequence the	**SO 003:** Approach Executive Control shall be able to facilitate	**IGS-to-SRAP - SAC#WT-1** (AIM

Operational Service	EATMA Activity	Description of change	Derived SO	Related SAC (via AIM)
Maintain arrival flow separation	Merge, Space Aircraft	a/c according to the new ATC-initiated IGS-to-SRAP trying to account for the noise and capacity benefits.	the capture of the Final approach path whilst ensuring adequate spacing for the ATC-initiated IGS-to-SRAP approach clearance, such that the flight crew can start the approach	Wake FAP WE 6S); **IGS-to-SRAP - SAC#WT-F1** (AIM Wake FAP WE 6F); **IGS-to-SRAP - SAC#WT-F2** (AIM Wake FAP WE7F.1); **IGS-to-SRAP - SAC#WT-F4** (AIM Wake FAP WE8); **IGS-to-SRAP - SAC#WT-F5** (AIM Wake FAP WE10/11) **IGS-to-SRAP - SAC#F1** (AIM MAC FAP MF4); **IGS-to-SRAP - SAC#F2** (AIM MAC FAP MF5.1 and MF5.2)
[NOV5-EAO 03] IGS-to-SRAP Published Approach				
FCF:	Approach Executive Control: Provide Approach Clearance	Approach Executive Control issues, at the appropriate time, the approach clearance corresponding to the published IGS-to-SRAP chart. New inputs into the ATC system are also being done to account for the IGS-to-SRAP clearance.	Approach Executive Control shall be able to sequence, merge and space aircraft such that the different benefits of ATC-initiated	Non-optimal sequence would result in progressive TMA overload, with

Operational Service	EATMA Activity	Description of change	Derived SO	Related SAC (via AIM)
Facilitate capture of the Final approach			IGS-to-SRAP could be taken into account	need for putting arrivals on holding patterns
	Flight Deck: Initiate IGS-to-SRAP Approach	Once the IGS-to-SRAP approach clearance has been received, the Flight Crew arms the appropriate approach guidance modes (e.g. xLS) and monitors their engagement when capturing the lateral and vertical paths of the final approach.		**IGS-to-SRAP - SAC#F2** (to account for potential degradation of B4, B5, B5a, B7 and B8 when the ATCO is overloaded) (no WT risk identified here as the Approach Control is supposed to respect the WT separation minima when facilitating the capture of the final approach path)
[NOV5-EAO 03] IGS-to-SRAP Published Approach				

Operational Service	EATMA Activity	Description of change	Derived SO	Related SAC (via AIM)
SP2 Maintain spacing/separation between aircraft on the same or on different final approach paths for the same runway end	Approach Executive Control: Monitor Spacing Final Approach (flight still under approach control)	Approach Executive Control monitors the flights on the final approach path according to the new separating methods given by the ATC-initiated IGS-to-SRAP which is being flown.	**SO 005:** Approach Executive Control shall be able to monitor and manage spacing/separation on final approach, taking into account the cohabitation of aircraft on ATC-initiated IGS-to-SRAP with aircraft on standard approach	As for SO 003
	Approach Executive Control: Monitor Spacing Final Approach (flight still under approach control)	Approach Executive Control monitors the flights on the final approach path according to the new separating methods given by the ATC-initiated IGS-to-SRAP which is being flown.		
	Tower Runway Control: Monitor Spacing during Final Approach	Tower Control monitors the spacing/separation with the a/c ahead according to the new separating methods given by the ATC-initiated IGS-to-SRAP which is being flown.		
As above	Tower Runway Control: Monitor Spacing during Final Approach	Tower Control monitors the spacing during the final approach into account the new landing thresholds or new separating method given by the ATC-initiated IGS-to-SRAP which is being flown.	**SO 006:** Tower Runway Control shall be able to monitor spacing/separation on final approach, taking into account the new separating methods or the new landing threshold introduced by the ATC-initiated IGS-to-SRAP	**IGS-to-SRAP - SAC#WT-1** (AIM Wake FAP WE 6S); **IGS-to-SRAP - SAC#WT-F1** (AIM Wake FAP WE 6F); **IGS-to-SRAP -**

Operational Service	EATMA Activity	Description of change	Derived SO	Related SAC (via AIM)
				SAC#WT-F2 (AIM Wake FAP WE7F.1); **IGS-to-SRAP - SAC#WT-F4** (AIM Wake FAP WE8); IGS-to-SRAP - **SAC#WT-F5** (AIM Wake FAP WE10/11) **IGS-to-SRAP - SAC#R-1** (AIM RWY Col RP2.4); **IGS-to-SRAP - SAC#R-2** (AIM RWY Col RP2.1).
[NOV5-EAO 03] IGS-to-SRAP Published Approach				
SPT1: Separate aircraft from terrain/obstacles during the initial/intermediate approach	Flight Deck: Fly aircraft on IGS-to-SRAP	The flight crew will monitor and fly the aircraft throughout the approach (encompassing flight path conformance, speed stabilization, thrust level and landing in the prescribed touch down zone) taking into account the new IGS-to-SRAP procedure	**SO 007:** Flight Crew shall be able to safely fly the IGS-to-SRAP procedure (encompassing flight path conformance, speed stabilization, thrust level and landing in the prescribed touch down zone)	AIM CFIT model: **IGS-to-SRAP - SAC#CFIT-1; IGS-to-SRAP - SAC#CFIT-2; IGS-to-SRAP - SAC#CFIT-3; IGS-to-SRAP - SAC#CFIT-4;**

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Operational Service	EATMA Activity	Description of change	Derived SO	Related SAC (via AIM)
FLD Facilitate landing and deceleration on the runway				**IGS-to-SRAP - SAC#CFIT-5;** AIM RWE model: **IGS-to-SRAP - SAC#RWE-1; IGS-to-SRAP - SAC#RWE-2; IGS-to-SRAP - SAC#RWE-3; IGS-to-SRAP - SAC#RWE-4; IGS-to-SRAP - SAC#RWE-5; IGS-to-SRAP - SAC#RWE-6; IGS-to-SRAP - SAC#RWE-7**

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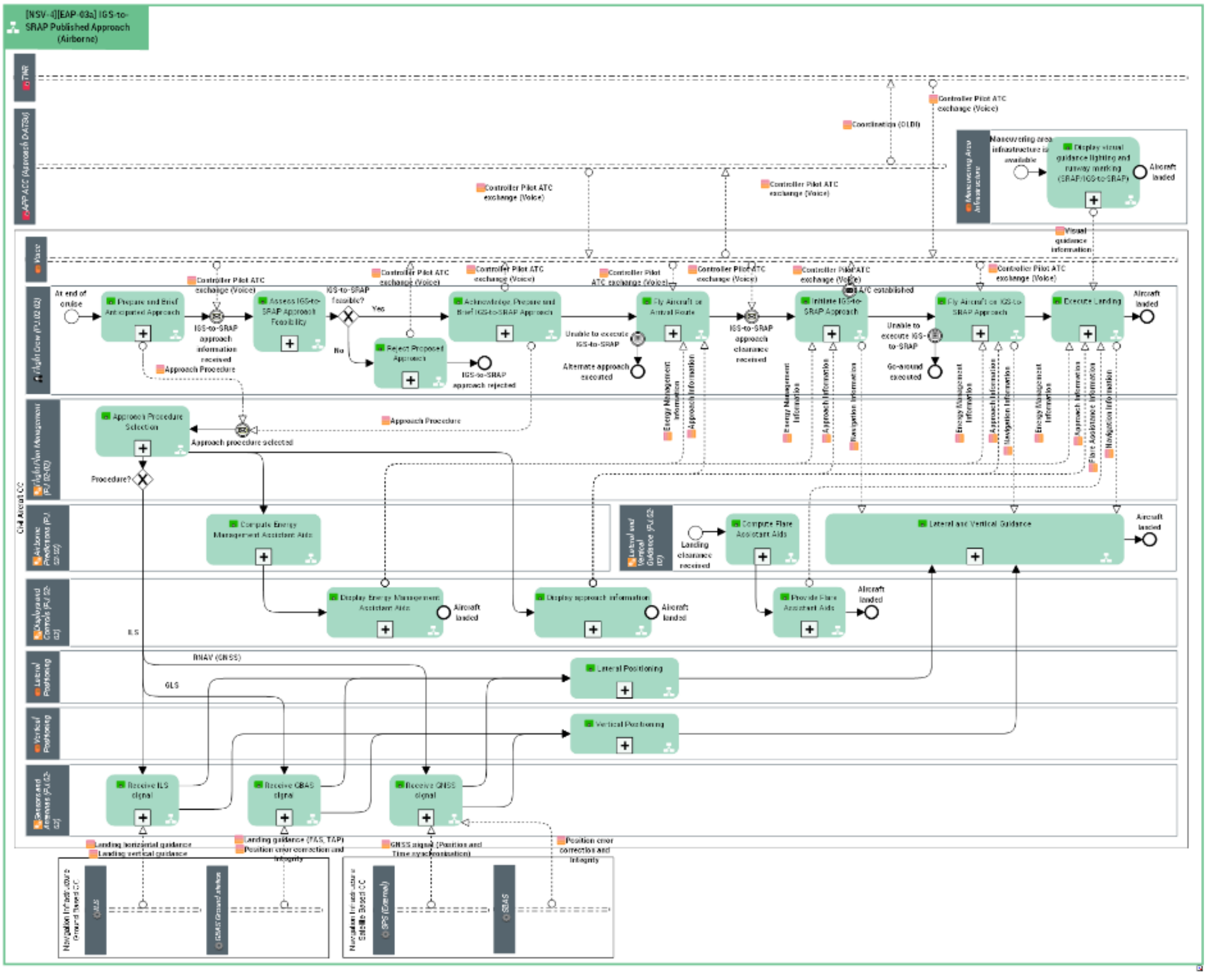
Appendix B NSV4 EATMA Models

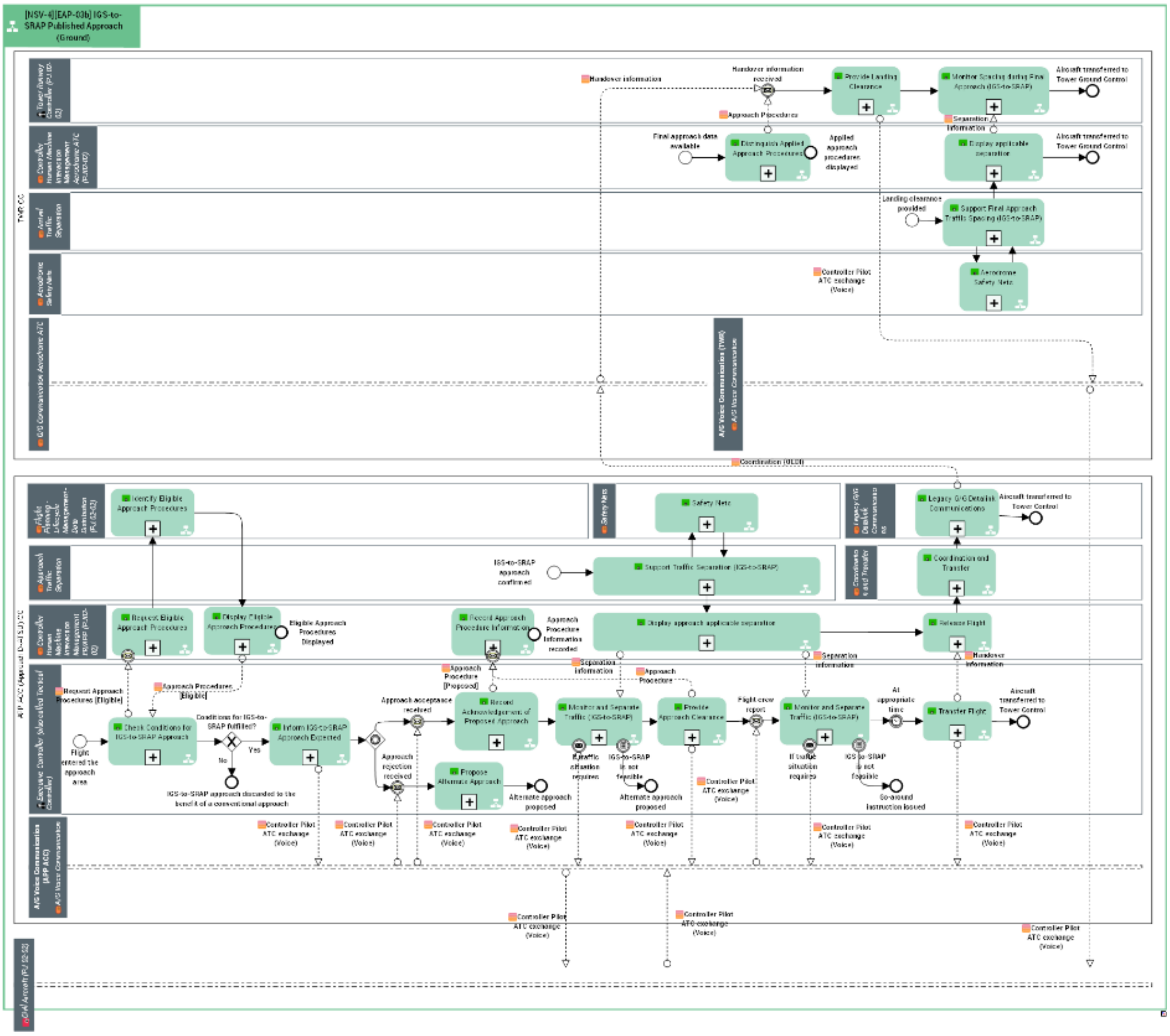
The following Use Cases (extracted from PJ02-W2.14.5 TS/IRS) and their related EATMA Technical Process Diagrams have been taken into consideration for the elaboration of the Safety Assessment:

- UC-EAP- 03a, b IGS-to-SRAP Published Approach
- UC-EAP-01, 02, 03 IGS-to-SRAP Non nominal

Note that the requirements for the non-nominal technical process diagrams, the design level requirements were derived in section 5.3.1.

B.1 IGS-to-SRAP Airborne / Ground





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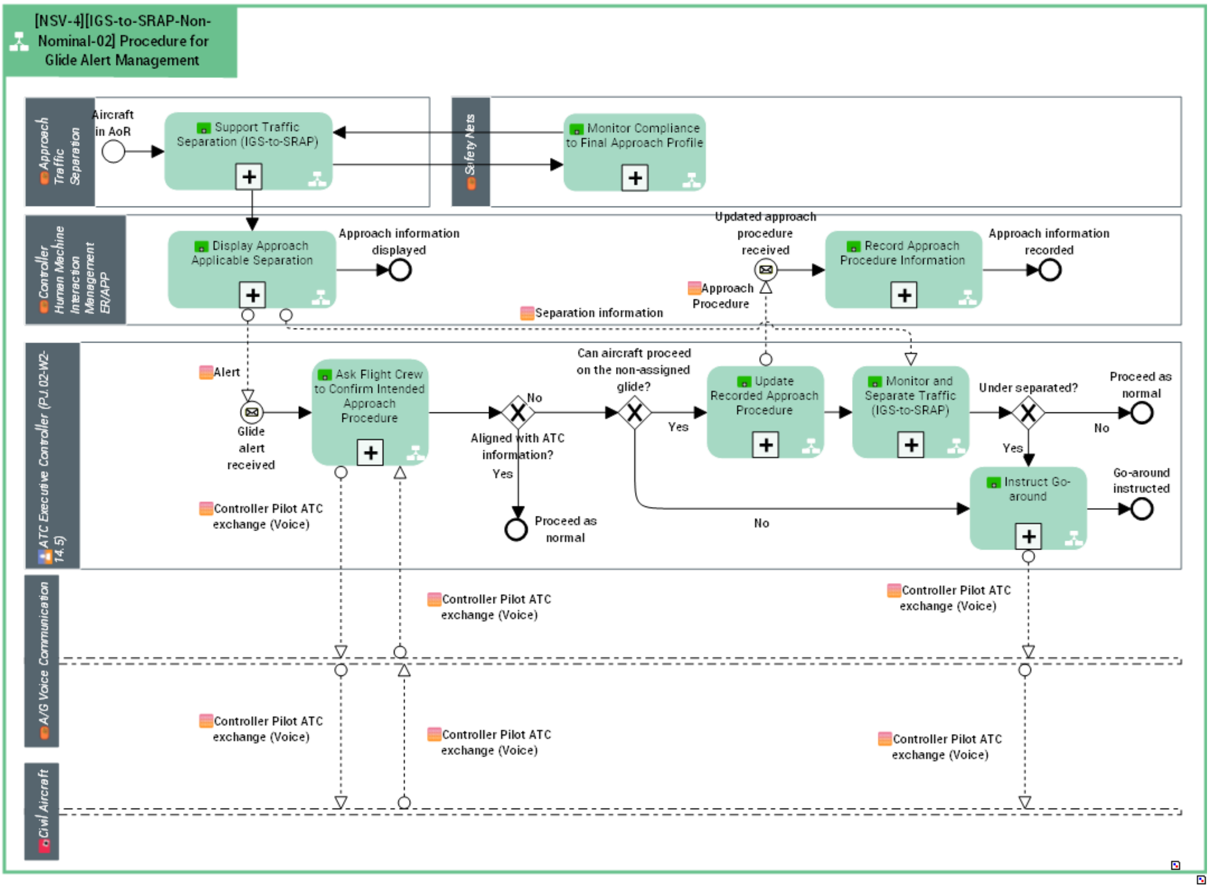
[NSV-4][IGS-to-SRAP-Non-Nominal-02] Procedure for Glide Alert Management
Approach Traffic Separation
Aircraft in AoR
Support Traffic Separation (IGS-to-SRAP)
Safety Nets
Monitor Compliance to Final Approach Profile
Controller Human Machine Interaction Management ER/APP
Display Approach Applicable Separation
Approach information displayed
Updated approach procedure received
Approach Procedure
Record Approach Procedure Information
Approach information recorded
Separation information
ATC Executive Controller (PJ.02-W2-14.5)
Alert
Glide alert received
Ask Flight Crew to Confirm Intended Approach Procedure
No
Aligned with ATC information?
Yes
Proceed as normal
Can aircraft proceed on the non-assigned glide?
Yes
Update Recorded Approach Procedure
Monitor and Separate Traffic (IGS-to-SRAP)
Under separated?
Proceed as normal
No
Yes
Instruct Go-around
Go-around instructed
No
Controller Pilot ATC exchange (Voice)
A/G Voice Communication
Civil Aircraft

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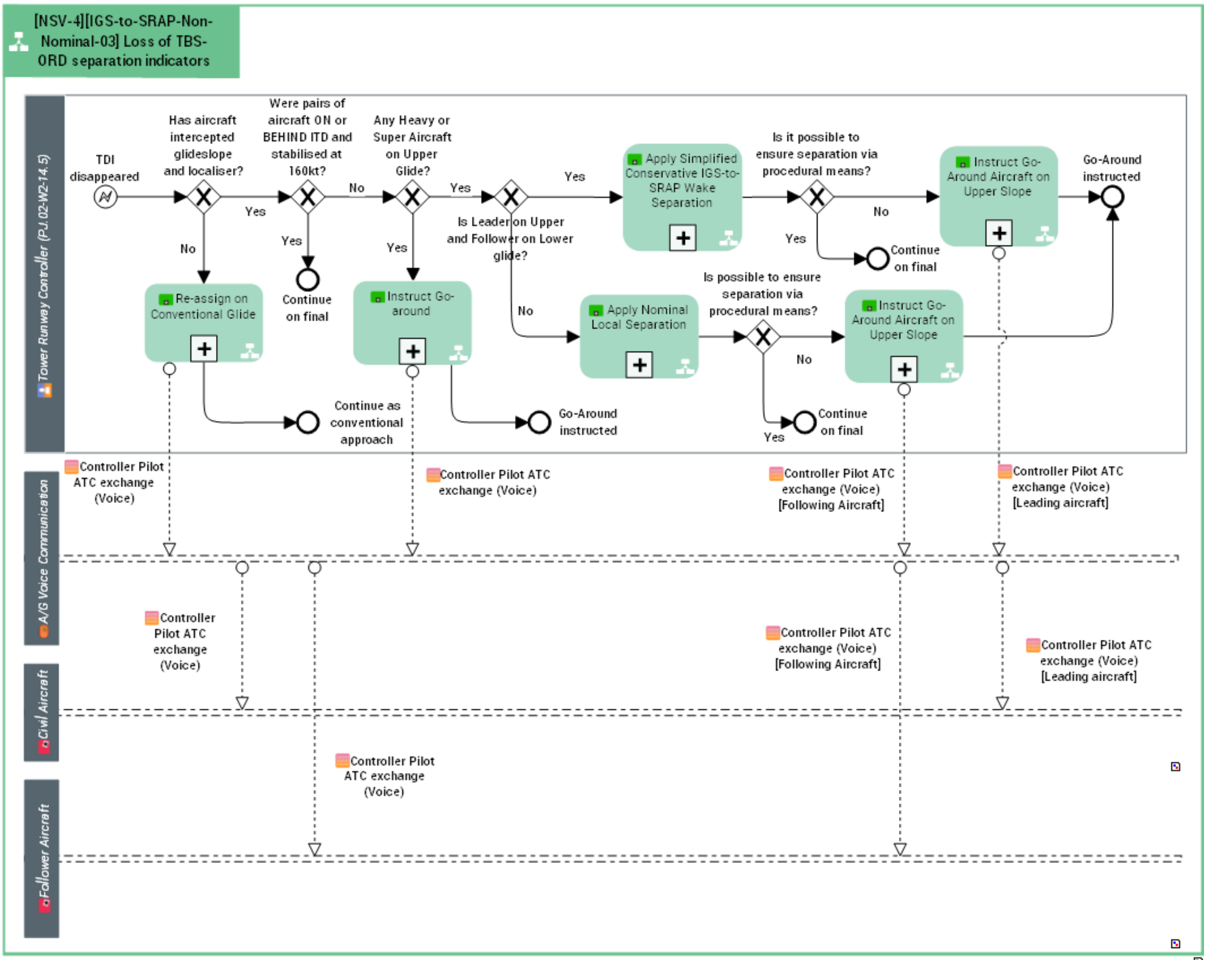
[NSV-4][IGS-to-SRAP-Non-Nominal-03] Loss of TBS-ORD separation indicators
Tower Runway Controller (PJ.02-W2-14.5)
A/G Voice Communication
Civil Aircraft
Follower Aircraft
TDI disappeared
Has aircraft intercepted glideslope and localiser?
Were pairs of aircraft ON or BEHIND ITD and stabilised at 160kt?
Any Heavy or Super Aircraft on Upper Glide?
Is Leader on Upper and Follower on Lower glide?
Yes
No
Re-assign on Conventional Glide
Continue on final
Instruct Go-around
Continue as conventional approach
Go-Around instructed
Apply Simplified Conservative IGS-to-SRAP Wake Separation
Is it possible to ensure separation via procedural means?
Instruct Go-Around Aircraft on Upper Slope
Apply Nominal Local Separation
Is possible to ensure separation via procedural means?
Controller Pilot ATC exchange (Voice)
Controller Pilot ATC exchange (Voice) [Following Aircraft]
Controller Pilot ATC exchange (Voice) [Leading aircraft]

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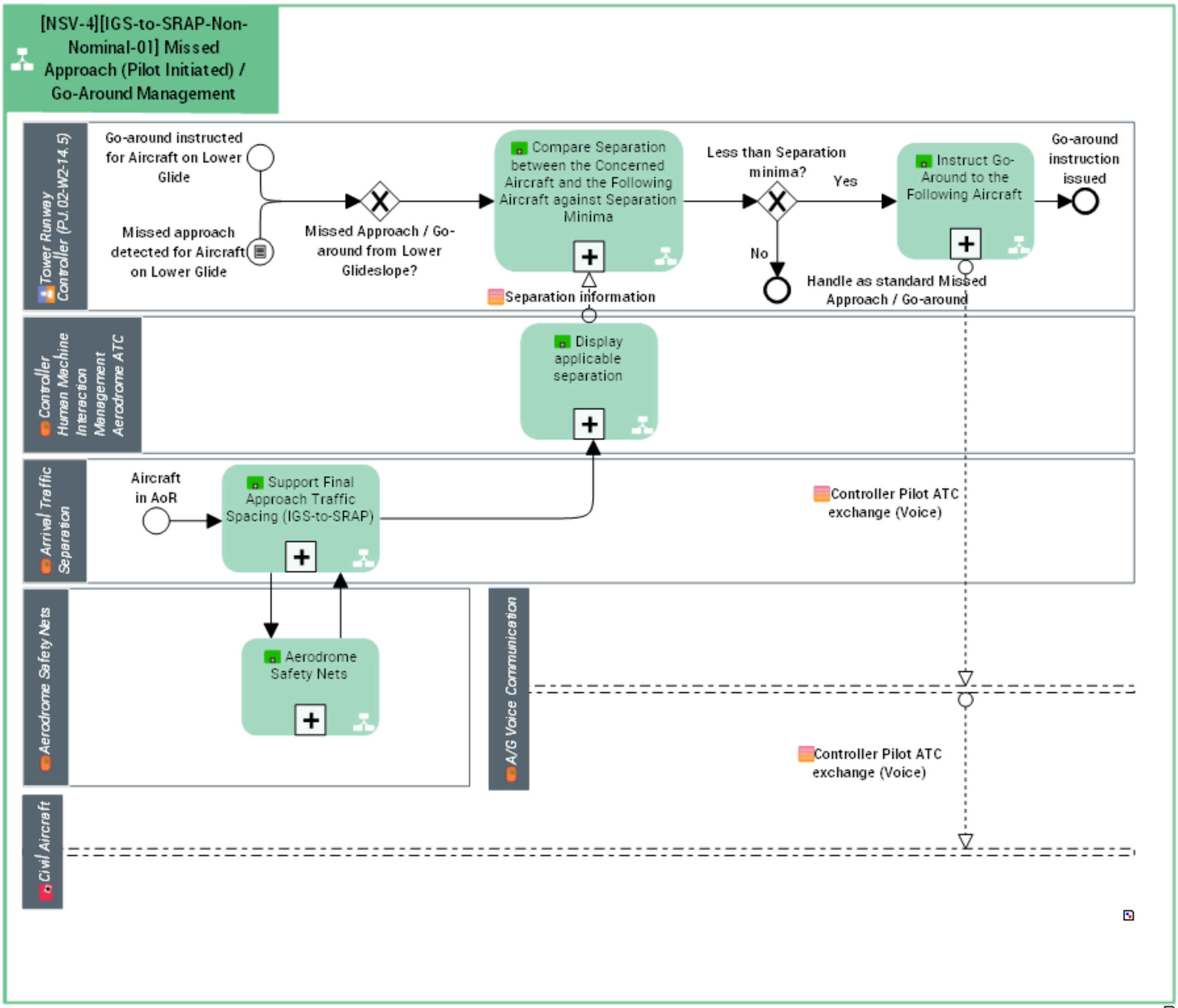
[NSV-4][IGS-to-SRAP-Non-Nominal-01] Missed Approach (Pilot Initiated) / Go-Around Management
Tower Runway Controller (PJ.02-W2-14.5)
Go-around instructed for Aircraft on Lower Glide
Missed approach detected for Aircraft on Lower Glide
Missed Approach / Go-around from Lower Glideslope?
Compare Separation between the Concerned Aircraft and the Following Aircraft against Separation Minima
Less than Separation minima?
Yes
No
Instruct Go-Around to the Following Aircraft
Go-around instruction issued
Handle as standard Missed Approach / Go-around
Separation information
Controller Human Machine Interaction Management Aerodrome ATC
Display applicable separation
Arrival Traffic Separation
Aircraft in AoR
Support Final Approach Traffic Spacing (IGS-to-SRAP)
Controller Pilot ATC exchange (Voice)
Aerodrome Safety Nets
Aerodrome Safety Nets
A/G Voice Communication
Controller Pilot ATC exchange (Voice)
Civil Aircraft

410 Appendix C Consolidated List of Safety Objectives

411 C.1 Safety Objectives (Functionality and Performance)

ID	Safety Objective (success approach)
SO 001	Approach Executive Control shall be able to check the conditions for the new ATC-initiated IGS-to-SRAP approach, propose the expected approach to the flight crew and, in the event of a refusal from the flight crew, cancel the ATC-initiated IGS-to-SRAP approach and propose a standard approach instead
SO 002	The Flight Crew shall be able to assess the feasibility of the proposed ATC-initiated IGS-to-SRAP approach, prepare and brief it if feasible, or reject it if not feasible
SO 003	Approach Executive Control shall be able to facilitate the capture of the Final approach path whilst ensuring an adequate spacing for the ATC-initiated IGS-to-SRAP approach clearance, such that the flight crew can start the approach
SO 004	Approach Executive Control shall be able to sequence, merge and space aircraft such that the different benefits of ATC-initiated IGS-to-SRAP could be taken into account
SO 005	Approach Executive Control shall be able to monitor and manage spacing/separation on final approach, taking into account the cohabitation of aircraft on ATC-initiated IGS-to-SRAP with aircraft on standard approach
SO 006	Tower Runway Control shall be able to monitor spacing/separation on final approach, taking into account the new separating methods or the new landing threshold introduced by the ATC-initiated IGS-to-SRAP
SO 007	Flight Crew shall be able to safely fly the IGS-to-SRAP procedure (encompassing flight path conformance, speed stabilization, thrust level and landing in the prescribed touch down zone)
SO 010	Spacing between aircraft pair conducting the standard approach and ATC-initiated IGS-to-SRAP shall consider the Runway Occupancy Time of the leader and any possible catch-up effect which might happen after DF (compression)

412 C.2 Safety Objectives (Abnormal)

ID	Description
SO 101	The aircraft shall no longer fly the expected or cleared IGS-to-SRAP approach if it is no longer compatible with the weather conditions, energy management and shall coordinate with ATC for another approach

SO 102	Aircraft shall keep on respecting the vertical profile of the IGS-to-SRAP approach in case of one engine failure or shall execute a missed approach
SO 103	During IGS-to-SRAP operations, ATC shall safely handle the situation where an aircraft on the lower glide executes a missed approach which will cross the trajectory of a follower aircraft on the upper glide, especially when the pair is separated close to the reduced separation minima
SO 104	Aircraft shall land in the touch down zone for the IGS-to-SRAP approach considering the combination of the significantly Increased Glide Slope angle, the runway aiming point and the possible slope of the runway surface (downslope and upslope runways) with or without approach slope indicator (VASI/PAPI)
SO 105	Aircraft shall respect the vertical profile of the IGS-to-SRAP approach in case of icing conditions impacting the engine thrust or shall execute a missed approach
SO 106	Aircraft shall decelerate as intended on the runway during an IGS-to-SRAP landing despite a contaminated runway by considering when needed additional landing distance margin
SO 107	During IGS-to-SRAP operations, the calculated required landing distance (accounting for updated weather and runway surface conditions) of the aircraft shall be compatible with the landing distance available for IGS-to-SRAP operations.

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414 C.3 Safety Objectives (Integrity)

ID	Safety Objective
SO 202	The frequency of occurrence of insufficient spacing at interception between aircraft pair flying IGS-to-SRAP and Standard approach or between aircraft conducting the same IGS-to-SRAP approach shall not be greater than 2E-03 per approach
SO 203	The frequency of occurrence of wrong spacing management on Final Approach between two aircraft of which at least one flies an increased glide slope angle IGS-to-SRAP, involving a/c reduced reactivity to decelerate) shall not be greater than 2E-03 per approach
SO 204	The frequency of occurrence of vertical deviation of either a/c in a pair where the leader is on the lower glide slope (standard or A-IGS) and the follower is on the higher IGS-to-SRAP glide slope leading to imminent WT separation infringement shall not be greater than 2E-03 per approach

SO 205	The frequency of occurrence of lateral or vertical deviation from the IGS-to-SRAP approach leading to a flight towards terrain shall not be greater than 2x10-7 per approach
SO 206	The frequency of occurrence of an aircraft on IGS-to-SRAP approach with insufficient landing distance available shall not be greater than 1x10-7 per approach
SO 209	The frequency of occurrence of an aircraft on IGS-to-SRAP approach landing with excessive vertical speed leading to hard landing shall not be greater than 1x10-7 per approach
SO 207	The frequency of failing to prevent wake separation infringement shall not be greater than 4E-05 per approach
SO 208	The frequency of occurrence of interception and landing to the incorrect aiming point going undetected with the risk of a runway excursion during IGS-to-SRAP approach shall not be greater than 1x10-5 per approach

Appendix D Consolidated List of Safety Requirements

The safety assessment allowed the identification of two types of functionality & performance safety requirements:

- Success approach – normal and abnormal cases (ensuring that the design enables safe operations in absence of failure within the Solution scope);
- Failure approach (mitigating safety risk related to failure within the Solution scope).

The information regarding the coverage and/or validation of the requirements in validation exercises is not provided in the current SAR. However, this is taken care of in the VALP [8] (which shows the link between the requirements and the validation objectives for each validation exercise), VALR [18] (which shows the detailed results of the exercises) and the OSED [4] (which shows for each requirement if it has been validated or not).

D.1 Safety Requirements – Normal operating conditions (Functionality and Performance)

The following table includes the "success approach" requirements, i.e. those requirements defined during the SPR-INTEROP/OSED development that have been labelled with the SAFETY category. Column 3 shows the IGS-to-SRAP concept/s each requirement applies to, while column 4 indicates the operational hazard(s) (i.e. SO2YY) that might potentially occur in case the requirement were not satisfied, and it also provides traceability to the related success Safety Objective(s) (i.e. SO0YY).

SRs	General Description	Concepts	Derived from
SR2.001 REQ-14.5-SPRINTEROP-CTL.1005	After Flight Deck acknowledgment, Approach Executive Control shall record the expected IGS-to-SRAP approach associated to a given arrival aircraft	IGS-to-SRAP	SO 001 SO 009 SO 202 SO 204 SO 205 SO 206 SO 208
SR2.004 REQ-14.5-SPRINTEROP-CTL.1001	Approach Supervision shall decide when a published IGS-to-SRAP becomes active/inactive for operations, considering the conditions for application are and remain met: 1. No operational ATC & weather limitations 2. necessary navigation guidance means are serviceable	IGS-to-SRAP	SO 001 SO 206 SO 209

SR2.008 REQ-14.5-SPRINTEROP-CTL.1006	When Approach Executive Control clears an aircraft for an approach procedure, he/she shall be able to record the cleared approach procedure for this arrival aircraft.	IGS-to-SRAP	SO 003 SO 202 SO 204 SO 205 SO 206 SO 207 SO 208
SR2.054 REQ-14.5-SPRINTEROP-ACFT.2103	Upon cleared for IGS-to-SRAP Approach, Flight Deck shall confirm the feasibility of the instructed IGS operations under the actual flight and weather conditions	IGS-to-SRAP	SO 002
SR2.009 REQ-14.5-SPRINTEROP-ACFT.2108	Before contacting APP Control, Flight Deck shall assess the feasibility of the probable IGS-to-SRAP operations under the expected flight and weather conditions	IGS-to-SRAP	SO 002
SR2.010 REQ-14.5-SPRINTEROP-CTL.1201	The IGS-to-SRAP approach chart shall be specific to one final approach path (i.e. angle / touchdown aiming point) and supporting navigation guidance mean, and shall highlight the glide path angle in case it is significantly increased (e.g. more than 3.5°)	IGS-to-SRAP	SO 007 SO 204 SO 209
SR2.057 REQ-14.5-SPRINTEROP-CTL.1203	A single IGS-to-SRAP procedure type (i.e. one glideslope angle) may be supported by different navigation guidance systems and part of or all the procedures with same glideslope angle may be active at the same time	IGS-to-SRAP	SO 002
SR2.013 REQ-14.5-SPRINTEROP-CTL.1104	For IGS-to-SRAP operations with complex separation minima scheme, Approach Executive Control shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD), which necessitates to electronically record the expected and cleared approach procedures	IGS-to-SRAP	SO 003 SO 004 SO 005 SO 202 SO 204 SO 205 SO 206 SO 208

SR2.014 REQ-14.5-SPRINTEROP-CTL.1105	For IGS-to-SRAP operations with complex separation minima scheme in a high traffic environment, Approach Executive Control shall be supported by a Separation Delivery function providing indications about spacing required to account for compression (ITD) (due to difference in speed profiles of Leader and Follower after the Deceleration Fix) to be applied for achieving the separation minima at the separation delivery point	IGS-to-SRAP	SO 003 SO 004 SO 005 SO 202 SO 204 SO 205 SO 206 SO 208
SR2.015 REQ-14.5-SPRINTEROP-CTL.1106	For IGS-to-SRAP operations with complex separation minima scheme the Tower Controller shall be supported by a Separation Delivery function providing indications about applicable separation minima between arrival aircraft pairs onto final approach segment (FTD)	IGS-to-SRAP	SO 006 SO 202 SO 204 SO 205 SO 206 SO 208
SR2.016 REQ-14.5-SPRINTEROP-CTL.1112	For IGS-to-SRAP operations, Approach Executive Control should be supported by arrival sequencing optimisation or role in assigning aircraft to an active approach procedure. In case this support is not available and when the traffic pressure is sufficiently high such that the runway throughput is penalised due to the increased separation minima introduced by IGS-to-SRAP procedures, Approach Executive Control shall apply the following general rule for arrival sequence: Heavy and Super Heavy aircraft types shall always fly on the lower glide path.	IGS-to-SRAP	SO 004 SO 204 SO 207 SO 208
SR2.017 REQ-14.5-SPRINTEROP-CTL.1205	Approach Executive Control shall apply dedicated longitudinal wake turbulence distance-based separation minima for the following combinations: • Leader and follower on same glideslope • Leader upper glide - follower lower glide • Leader lower glide - follower upper glide when both aircraft are descending on their respective glide slope.	IGS-to-SRAP	SO 005 SO 006 SO 202

SR2.058 REQ-14.5-SPRINTEROP-CTL.1204	IGS-to-SRAP Approach separation minima shall be specified for each combination of published approach procedure with different glideslopes, taking into account the associated navigation means and the corresponding vertical accuracy around the published profile, for • Leader and follower on same glideslope • Leader upper glide - follower lower glide • Leader lower glide - follower upper glide	IGS-to-SRAP	SO 005 SO 006 SO 202
SR2.019 REQ-14.5-SPRINTEROP-CTL.1011	Applicable Contingency approach separation minima shall be available to Approach Executive Control and Tower Runway Control when controllers are supported by a separation tool.	IGS-to-SRAP	SO 005 SO 006 SO 202
SR2.022 REQ-14.5-SPRINTEROP-ACFT.2102	Flight Deck shall be able to execute flare during IGS-to-SRAP operations without increasing the risk of hard landing or long landing	IGS-to-SRAP	SO 007 SO 206 SO 209
SR2.060 **REQ-02.02-TS-IGS.2002**	Flare assistant shall help flight crew to correctly perform flare	IGS-to-SRAP	SO 007 SO 206
SR2.023 REQ-14.5-SPRINTEROP-APT.1302	In case of IGS-to-SRAP, Flight Deck shall be able to clearly distinguish between each threshold and aiming point and be supported by appropriate landing visual aid references (e.g. location and identification of the second runway threshold and aiming point, a second PAPI)	IGS-to-SRAP	SO 007 SO 205 SO 206 SO 209
SR2.062 REQ-14.5-SPRINTEROP-CTL.1212	Procedure design for IGS-to-SRAP operations shall use a glide path angle limited to 4.49°.	IGS-to-SRAP	SO 007
SR2.030 REQ-14.5-SPRINTEROP-ACFT.2104	Flight Deck shall recall during approach briefing the reduced landing distance available from the second aiming point to the expected runway exit in IGS-to-SRAP operations	IGS-to-SRAP	SO 007 SO 107
SR2.033 REQ-14.5-SPRINTEROP-CTL.1004	ANSPs shall reinforce through a request to Aircraft Operators the need for Flight Plans to be complete and correctly filled with aircraft navigation capabilities.	IGS-to-SRAP	SO 001

SR2.034 REQ-14.5-SPRINTEROP-CTL.1005	At first call from an incoming traffic with APPROACH, Approach Executive Control shall provide an information to the arrival aircraft about the expected approach procedure, taking in account the traffic eligibility to IGS-to-SRAP, local working methods for traffic assignment (e.g. Heavies left on conventional approach), and using related standard phraseology (e.g. BLUEBIRD 123, Expect GLS Z approach runway 28L) Then later on the approach clearance will be provided as usual	IGS-to-SRAP	SO 001
SR2.037 REQ-14.5-SPRINTEROP-CTL.1008	After Flight Deck has been informed of an expected approach procedure, if a change is needed from ATC, Approach Executive Control shall consider the time needed for the Flight Deck to re-configure the new approach procedure, shall inform Flight Deck at the earliest opportunity and with sufficient time before instructing final approach axis interception (special consideration should be given to the transition from ILS/GLS to RNP APCH which is demanding and time consuming for the pilot)	IGS-to-SRAP	SO 004
SR2.040 REQ-14.5-SPRINTEROP-CTL.1206	If the Runway Occupancy Time (ROT) is affected by landing on an active further runway aiming point, this ROT spacing shall be taken into account in the runway separation management (ROT might become the most constraining factor due to changes in separation minima)	IGS-to-SRAP	SO 010
SR2.041	Flight Crew shall recall during approach briefing the possible differences in visual references (VASI/PAPI, runway aspect, etc) that are expected in IGS-to-SRAP operations	IGS-to-SRAP	SO 002 SO 008 SO 204 SO 206 SO 209
SR2.042	Flight Crew shall be informed about discrepancies from visual aid references when not specifically adapted to increased glideslope procedures.	IGS-to-SRAP	SO 002 SO 008 SO 204 SO 206 SO 209

SR2.043 REQ-14.5-SPRINTEROP-CTL.1003	The ANSP shall inform Airspace Users (e.g. via AIC) about the availability of IGS procedure with their differences from the local conventional approaches (including applicable separation minima, location of the second aiming point, landing distance available etc.)	IGS-to-SRAP	SO 002 SO 008
SR2.045 REQ-14.5-SPRINTEROP-CTL.1002	Approach / Tower Supervisors shall inform the Approach / Tower Controllers about the list of active approach procedures	IGS-to-SRAP	SO 001
SR2.046 REQ-14.5-SPRINTEROP-CTL.1101	Information about a published IGS-to-SRAP being active to a given runway QFU shall be available to the Flight Crew in order to prepare expected approach briefing (e.g. via ATIS)	IGS-to-SRAP	SO 002
SR2.050 REQ-14.5-SPRINTEROP-CTL.1111	When supported by ground surveillance (with aerodrome maps), the runway markings for all active approaches shall be displayed to Tower Runway Control	IGS-to-SRAP	SO 006 SO 209
SR2.051 REQ-14.5-SPRINTEROP-APT.1303	For IGS-to-SRAP operations down to CAT I minima, Flight Deck shall be able to clearly see the approach lighting for the threshold and aiming point that they are flying to.	IGS-to-SRAP	SO 007 SO 205 SO 206 SO 209
SR2.064 REQ-14.5-SPRINTEROP-CTL.1109	The need for displaying to the Controllers the interception points respective for each procedure shall be evaluated as part of the local deployment, such that the visual references are operationally relevant and unambiguously presented without e.g. cluttering on the controller air surveillance display	IGS-to-SRAP	SO 003
SR2.065 REQ-14.5-SPRINTEROP-CTL.1207	For high density operations supported by Separation Delivery Function with TDIs, when IGS-to-SRAP are flown based on RNP APCH navigation, there is a need for flexibility in final approach axis interception (e.g. using vectoring). In such cases, the ANSP shall request on the charts Flight Crew to inform Approach Controller when aircraft is unable to use FMS guidance for final approach axis interception	IGS-to-SRAP	SO 003

435 ## D.2 Safety Requirements – Abnormal operating conditions
436 (Functionality and Performance)

SRs	General Description	Concepts	Derived from
SR2.200 REQ-14.5-SPRINTEROP-ACFT.2102	The Flight Crew shall be trained for managing and flying IGS-to-SRAP operations	IGS-to-SRAP	SO 007 SO 104 SO 202 SO 205 SO 206 SO 209 SO 204 SO 207 SO 208
SE2.202 REQ-14.5-SPRINTEROP-ACFT.2101	Flight Deck shall be able to decelerate the aircraft during final approach, even under flight conditions that reduce deceleration capability (e.g. anti-ice system ON)	IGS-to-SRAP	SO 105 SO 206 SO 209
SR2.204 REQ-14.5-SPRINTEROP-CTL.1012	When the lead aircraft flying on final conventional approach is executing a missed approach and a following traffic is flying on final IGS-to-SRAP spaced at or close to the separation minimum, Approach Executive Control or Tower Runway Control shall also instruct the following aircraft flying an IGS-to-SRAP to execute a missed approach, either with a "Turn left/right immediately" instruction or ensure that the follower is maintained above the lead traffic (taking into account a sufficient climb performance)	IGS-to-SRAP	SO 103 SO 202 SO 204 SO 205 SO 206 SO 207 SO 208
SR2.206 REQ-14.5-SPRINTEROP-CTL.1007	After an aircraft has been cleared to intercept the final approach, if Flight Deck informs ATC that they are no longer able to fly the expected IGS-to-SRAP approach, Approach Executive Control shall instruct a go-around	IGS-to-SRAP	SO 101

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SR2.207 REQ-14.5-SPRINTEROP-CTL.1103	In case Approach Executive Control changes the expected approach procedure, he/she shall be update the expected approach procedure recorded for this arrival aircraft	IGS-to-SRAP	SO 101

D.3 Safety Requirements – Mitigations to System Generated Hazards

The next table includes the "failure approach" requirements, i.e. those safety requirements aiming at mitigating the occurrence of the operational hazards (either preventing the occurrence of the cause or preventing the occurred cause to generate the hazard). Column 3 shows the IGS-to-SRAP concept/s each requirement applies to, while column 4 shows the operational hazard it mitigates.

SRs	General Description	Derived from
SR2.316 REQ-14.5-SPRINTEROP-CTL.1013	At each aircraft transfer on frequency, Approach Executive Control or Tower Runway Control shall confirm the expected or cleared IGS-to-SRAP Approach.	SO 202 SO 204 SO 205 SO 206 SO 208
SR2.302 REQ-14.5-SPRINTEROP-CTL.1014	Approach Executive Controller shall consider, when establishing and maintaining separation, that aircraft ability to respect ATC speed instructions may be limited during IGS-to-SRAP operations, especially for slope angles above 3.5 degrees, and aircraft's speed might need to be reduced earlier compared to standard approach. Note: the higher the slope angle the longer it takes for the aircraft to decelerate. However, this should not be a problem with slopes under 3.5 degrees.	SO 202 SO 203
SR2.317 REQ-14.5-SPRINTEROP-CTL.1213	When designing the IGS-to-SRAP local procedure, the location of the second runway aiming point shall provide sufficient landing distance available for all eligible aircraft at that specific airport	SO 206
SR2.303 REQ-14.5-SPRINTEROP-APT.1301	Flight Deck shall be supported by appropriate landing visual aid references for their flown approach procedure (e.g. PAPIs	SO 007 SO 204 SO 206 SO 209

	associated to the additional threshold), down to the approach minima.	
SR2.304 REQ-14.5-SPRINTEROP-CTL.1107	For IGS-to-SRAP operations with a complex separation minima scheme in high traffic environment, Approach Executive Control shall be warned when an aircraft is significantly catching-up the preceding traffic with an anticipated risk of loss of separation minima.	SO 010 SO 203
SR2.305 REQ-12.02.02-TS-OPS1.0140	The Separation Delivery Tool shall send to CWP HMI a speed conformance alert when an aircraft's ground speed exceeds its offline defined air speed - corrected by the wind value - by a predefined offline tolerance value	SO 202
SR2.306 REQ-14.5-SPRINTEROP-CTL.1108	Approach Executive Control shall be alerted when an aircraft is not complying / deviating from the assigned published final approach profile.	SO 202 SO 204 SO 205 SO 206 SO 209 SO 208 SO 207
SR2.308 REQ-14.5-TS-GND-0013	The Aircraft Manufacturer shall provide in the master minimum equipment list (MMEL) the operational impact in case a specific functionality is required by IGS-to-SRAP operations (e.g. the energy management function and/or the flare assistance supporting function)	SO 206 SO 209
SR2.310 REQ-02-02-SPRINTEROP-ITSR.1209	The design of the GLS or RNAV (LPV, LNAV-VNAV) procedures supporting IGS-to-SRAP shall be compliant with ICAO Doc 8168 and shall be validated in accordance with the Instrument Flight Procedure process specified in ICAO Doc 9906	SO 205
SR2.311 **REQ-02-02-SPRINTEROP-ITSR.1210**	For the design of GLS or RNAV (LPV, LNAV-VNAV) procedures with a glide path angle greater than 3.5°, the rule for the Height Loss increase shall be standardised at ICAO level (IFPP)	SO 205

SR2.312 REQ-14.5-SPRINTEROP-CTL.1110	When supported by ground surveillance displays, Tower Executive Control shall be able to easily and unambiguously identify the assigned landing aiming point for each landing aircraft	SO 205
SR2.313 REQ-14.5-SPRINTEROP-CTL.1211	The IGS-to-SRAP approach chart shall include altitude/distance information for the applicable runway aiming point to facilitate Flight Crew procedure check during the approach	SO 007 SO 208
SR2.318 REQ-14.5-SPRINTEROP-CTL.1009	Approach Executive Control shall vector the aircraft onto IGS-to-SRAP approach such as to avoid a final approach interception from above	SO 003 SO 206 SO 209
SR2.319 REQ-14.5-SPRINTEROP-APT.1304	When the second runway threshold is not active (i.e. operating only the conventional threshold), the lightings of the secondary runway threshold and aiming point shall be switched off such as to avoid confusing Flight Deck	SO 209
SR2.052 REQ-14.5-SPRINTEROP-GOAR.0001	If the lead aircraft is performing a missed approach or a go-around from the lower glide slope and the follower is on the upper glide slope, Approach Executive Control or Tower Runway Control shall compare the distance between the aircraft going around and the following one, against the reference separation minima applied at the airport.	Dynamic Analysis of Non-nominal situations
SR2.053 REQ-14.5-SPRINTEROP-GOAR.0002	When the separation between the aircraft going around and the following one is less than the reference separation minima, Approach Executive Control or Tower Runway Control shall instruct a go-around to the following aircraft, whilst ensuring the two aircraft are on diverging flight paths.	Dynamic Analysis of Non-nominal situations

SR2.054 REQ-14.5-SPRINTEROP-GOAR.0003	Approach Executive Control and Tower Runway Control should be able to check the vertical position of an aircraft.	Dynamic Analysis of Non-nominal situations
SR2.055 REQ-14.5-SPRINTEROP-GOAR.0004	When IGS-to-SRAP procedure is active, Flight Deck, on standard approach or IGS-to-SRAP one, shall communicate to Approach Executive Control or Tower Runway Control about a missed approach as soon as practicable.	Dynamic Analysis of Non-nominal situations
SR2.056 REQ-14.5-SPRINTEROP-ACFT.2109	Flight Deck shall pay particular attention to the transition of frequencies from APP to TWR and shall not delay it	Dynamic Analysis of Non-nominal situations
SR2.057 REQ-14.5-TS-GND-0013	The IGS-to-SRAP related go-around procedure shall be regularly briefed and included in the refresher training of the controllers	Dynamic Analysis of Non-nominal situations
SR2.058 REQ-14.5-SPRINTEROP-GALT.0001	When a wrong glide alert is activated, Approach Executive Control shall ask Flight Crew to confirm the flown approach procedure.	Dynamic Analysis of Non-nominal situations

SR2.059 REQ-14.5-SPRINTEROP-GALT.0002	When a wrong glide alert is activated by a Heavy aircraft wrongly on the IGS-to-SRAP procedure, and Flight Crew confirms flying a different approach procedure than the instructed one, Approach Executive Control shall instruct a go around to that aircraft.	Dynamic Analysis of Non-nominal situations
SR2.060 REQ-14.5-SPRINTEROP-GALT.0004	When a wrong glide alert is activated by an aircraft other than Heavy and Flight Crew confirms flying a different approach procedure than the instructed one, the Approach Executive Control shall: - Update the CWP HMI with the actually flown approach procedure - Check the position of the concerned aircraft, leading aircraft and following aircraft against their indicators - If any under separated, instruct go-around to the flight which triggered the glide alert.	Dynamic Analysis of Non-nominal situations
SR2.061 REQ-14.5-TS-GND-0013	The Glide Alert procedure shall be regularly briefed and included in the refresher training of the controllers	Dynamic Analysis of Non-nominal situations
SR2.062 REQ-14.5-SPRINTEROP-GALT.0003	After following the glide alert procedure, Approach Executive Control shall coordinate with Tower Runway Control about the aircraft that triggered the glide alert when IGS-to-SRAP is active.	Dynamic Analysis of Non-nominal situations
SR2.073 REQ-14.5-SPRINTEROP-CTL.1108	The alert shall be sufficiently reliable, the level of reliability being defined locally at each airport.	Dynamic Analysis of Non-nominal situations

SR2.063 REQ-14.5-SPRINTEROP-ORDF.0006	In case of loss of separation tool, Approach Executive Control or Tower Runway Control should let all aircraft from pairs which are stabilised at 160kts and on (or behind) the ITD, continue on final.	Dynamic Analysis of Non-nominal situations
SR2.064 REQ-14.5-SPRINTEROP-ORDF.0007	In case of loss of separation tool, for all mixed slope pairs which are not stabilised at 160kts or not on (or behind) the ITD, and for which a heavy aircraft is on the upper glide, Approach Executive Control or Tower Runway Control shall instruct a go-around to the heavy aircraft.	Dynamic Analysis of Non-nominal situations
SR2.065 REQ-14.5-SPRINTEROP-ORDF.0001	In case of loss of separation tool, for all upper-lower slope pairs without Heavy which are not stabilised at 160kts or not on (or behind) the ITD, Approach Executive Control or Tower Runway Control shall apply the addtional simplified mixed slope pairs table. It that is not possible, Approach Executive Control or Tower Runway Control shall instruct a go around to the aircraft flying the IGS-to-SRAP procedure.	Dynamic Analysis of Non-nominal situations
SR2.066 REQ-14.5-SPRINTEROP-ORDF.0002	In case of loss of separation tool, for all lower-upper and same slope pairs which are not stabilised at 160kts or not on (or behind) the ITD, Approach Executive Control or Tower Runway Control shall apply reference separation minima. It that is not possible, Approach Executive Control or Tower Runway Control shall instruct a go around to the aircraft flying the IGS-to-SRAP procedure.	Dynamic Analysis of Non-nominal situations
SR2.067 REQ-14.5-SPRINTEROP-ORDF.0003	In case of loss of separation tool, Approach Executive Control shall re-assign all the aircraft that have not yet intercepted the glide slope and localiser, to conventional approach procedure.	Dynamic Analysis of Non-nominal situations

SR2.068 REQ-14.5-SPRINTEROP-ORDF.0004	In peak traffic, in case of loss of separation tool, the coordinator/assistant shall aid the Approach Executive Control for checking the separations between aircraft and suggesting which aircraft should be sent around.	Dynamic Analysis of Non-nominal situations
SR2.069 REQ-14.5-SPRINTEROP-ORDF.0005	In case of loss of separation tool, Approach Executive Control should inform Tower Runway Control about the last aircraft flying the IGS-to-SRAP procedure.	Dynamic Analysis of Non-nominal situations
SR2.070 REQ-14.5-SPRINTEROP-ORDF.0004	In peak traffic, in case of loss of separation tool, the coordinator/assistant shall aid the Approach Executive Control for checking the separations between aircraft and suggesting which aircraft should be sent around.	Dynamic Analysis of Non-nominal situations
SR2.071 REQ-14.5-SPRINTEROP-ORDF.0005	In case of loss of separation tool, Approach Executive Control should inform Tower Runway Control about the last aircraft flying the IGS-to-SRAP procedure.	Dynamic Analysis of Non-nominal situations
SR2.072 REQ-14.5-TS-GND-0013	The IGS-to-SRAP related ORD tool failure procedure shall be regularly briefed and included in the refresher training of the controllers	Dynamic Analysis of Non-nominal situations

SR2.073	Applicable Standard approach separation minima when SRAP is active and no separation tool in use shall be available to Approach Executive Control and Tower Runway Control	Dynamic Analysis of Non-nominal situations

Appendix E Detailed operational hazard identification and analysis

This annex presents the OHA/HAZID tables for the IGS-to-SRAP operational concepts which have been generated in two iterations:

- initially built and validated within SESAR 1 Project 06.08.08 with operational people (Pilots and Controllers). and
- further updated following the safety-dedicated workshop conducted by the current PJ02-02 involving relevant operational people and project experts.

The tables in the next sub-sections show the updated HAZID for each concept. Based on these tables, on the results of the SESAR 2020 SAF/HP workshop and on subsequent discussions within the project, the hazards and the fault-trees have been restructured as presented in section 5.5.2.

E.1 MRAP Hazid Table

The table below illustrates how the operational hazards have been identified before the FHA/OHA session from negating the success SO.

Success SO	Failure mode	Operational effect	Operational hazard
SO# MRAP005 SO# MRAP020 SO# MRAP021 SO# MRAP035 SO# MRAP040	A/C is not on the correct MRAP approach	The aircraft is flying the displaced aiming point approach whereas it should fly the standard aiming point approach and has not a sufficient Landing Distance Available to stop the aircraft on the runway which could lead to a runway overrun	Hz#MRAP001: Failure to land at the appropriate runway aiming point during MRAP operations leading to landing abortion
		Aircraft (e.g. Heavy) is flying the displaced aiming point approach whereas it should fly the standard aiming point approach which could lead to separation minima infringement or Wake vortex encounter due to a reduction of separation with follower aircraft within the same approach or on the lower glide	Hz#MRAP002: Failure to maintain the separation between aircraft flying displaced and non-displaced aiming point procedures or between aircraft flying the same runway aiming point procedure
		Aircraft (e.g. Medium, Light) is flying the standard aiming point approach whereas it should fly the displaced aiming point approach which could lead to Wake vortex encounter due to e.g. Heavy aircraft on the upper glide	
SO# MRAP030 SO# MRAP035 SO# MRAP040	A/C deviates from the planned trajectory during the displaced aiming point approach	The aircraft exits from the planned vertical trajectory and may deviate towards terrain/obstacles	Hz#MRAP003: Failure to respect MRAP approaches which lead to a reduction of separation with terrain and/or obstacle
		The aircraft exits from the planned lateral trajectory and may deviate towards terrain/obstacles	
		The aircraft conducting displaced aiming point approach exits from the planned vertical trajectory and deviates towards the aircraft on the lower glide	Hz#MRAP004: Failure to respect the displaced aiming point approach which lead to a reduction of separation with the aircraft on the lower glide

Success SO	Failure mode	Operational effect	Operational hazard
SO# MRAP025 SO# MRAP030 SO# MRAP045	Separation (MRS or Wake) between aircraft on different aiming point approaches smaller than required	Catch up between aircraft conducting displaced and standard aiming point approaches which could lead to a loss of separation and possibly a wake vortex encounter	Hz#MRAP002: Failure to maintain the separation between aircraft flying displaced and non-displaced aiming point procedures or between aircraft flying the same runway aiming point procedure
SO# MRAP040 SO# MRAP050 SO# MRAP055	Pilot is confused with the runway marking/lights during the visual segment of a displaced aiming point approach	The aircraft, due to the runway infrastructure/suitability issues, lands before the threshold or makes a long landing leading to a runway overrun	Hz#MRAP005: Failure to land in the prescribed touch-down zone during displaced aiming point approach
SO# MRAP011 SO# MRAP015 SO# MRAP060	Aircraft lands with an insufficient landing distance considering the anticipated runway exit but sufficient considering the landing distance available	The aircraft cannot vacate the runway at the anticipated exit which could lead to block the runway	Hz#MRAP006: Failure to vacate the runway at the foreseen exit during displaced aiming point approach operations
SO# MRAP011 SO# MRAP015 SO# MRAP060	Aircraft cannot decelerate sufficiently during the rollout considering the anticipated runway exit	The aircraft vacates the runway at the anticipated runway exit but at a high speed which could lead to a runway excursion during the runway vacation turn	Hz#MRAP005: Failure to land in the prescribed touch-down zone during displaced aiming point approach

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461 The next OHA tables are the result of the FHA/OHA session conducted for each Operational Hazard in order to check if those operational hazards are relevant
462 and if others are missing.

These tables list the operational effects, possible failure causes; preventive & protective mitigations and considering these mitigation means and identify the Severity Class associated to the Hazard based on the severity scheme of the relevant Accident-Incident Model (AIM). It should be noted also that mitigation means have been captured as Candidate Safety Requirements (CSR). Furthermore Validations Items (VAL#), Recommendations (REC#) and Issues (ISSUE#) have been also identified when necessary.

Hz#MRAP1: Failure to land at the appropriate runway aiming point

Operational effects	Possible failures/causes	Preventive mitigations	Mitigations when OH occurs	Severity Class
A/C is flying a displaced aiming point approach whereas it should fly the standard approach and has not sufficient landing distance to stop the A/C on the runway (runway overrun) Note: in this case the aircraft was cleared to fly the standard approach	*Wrong/erroneous publication *Pilot fails to select correct approach *Unclear clearance *Incorrect readback *GBAS GS failure	**a) Publication/phraseology:** * Clear charting elements and one plate per approach [CSR#MRAP001] [OSED ID 17] *Altitude/distance table for each RAP [CSR#MRAP005] * Same procedure name between AIP and avionics system [Issue#MRAP001]/ [CSR#MRAP010] *Limit the number of published MRAP per runway end (e.g. less than 3) [CSR#MRAP002] *MRAP procedures published in AIP with restriction per aircraft category [CSR#MRAP015] *Repetitive phraseology (e.g. during handover) with readback [CSR#MRAP020] [OSED ID 34]	*** Aircraft/Pilot** -Pilot detects that he is not flying the correct approach during the visual segment and initiate a missed approach -Pilot might detect it early (2Nm/3Nm before RAP) and if weather conditions permit they could revert to a visual approach *** ATC/Controller**	***RE-SC3** / Aborted landing due to runway environment/suitability issues → It corresponds to a situation where a landing at the wrong runway aiming point was prevented by flight crew detection and recovery during the final approach

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	* Confusion with DME distance	*Specific runway identifier to be used for SRAP operations [OSED ID 14] **b) Aircraft/Flight Crew:** * Flight Crew training (transition to new procedures [CSR#MRAP025] *A/C GBAS system certified [CSR#MRAP080] *Pilot verifies GBAS RPID and arms the approach [CSR#MRAP085] *display of RAP at cockpit level following onboard selection [CSR#MRAP030] *Use of GLS distance and not DME distance[CSR#MRAP029] *A.O procedures for filling flight plan considering A/C capability [CSR#MRAP070] * Nav Data Base filtering considering A/C landing performance (e.g. limitation for e.g. CAT D,E aircraft) [CSR#MRAP035] **c) ATC and systems:** * ATCo Training [CSR#MRAP040] *Clearance provided through data-link with a new tool to support automatic clearance check [Issue#MRAP001]/[CSR#MRAP045] *ATCo verifies MRAP capability using flight plan data [CSR#MRAP046]	-ATCO detects that A/C is not flying a standard approach and informs the flight crew -Approach funnel deviation alert to be provided at Approach and Tower position (requires an accurate vertical input) [REC#MRAP002]/[CSR#MRAP1005] -ATCO instructs a missed approach	

		* Concept introduction in a stepped way (higher DH/RVR than CAT I in a first step) [CSR#MRAP050] * GBAS GS approval [CSR#MRAP055] and broadcast of all FAS data Block associated to the different MRAP approaches [CSR#MRAP056] * Approach name included in the radar label [CSR#MRAP058] *Use of GBAS CAT III specificities (authentication, distance from threshold to end of runway,…) [CSR#MRAP060]		
A/C is flying standard aiming point approach whereas it should fly the displaced approach because standard procedure is closed (e.g for construction works) which might lead to CFIT Note: in this case the aircraft was cleared to fly the displaced RAP approach	*Pilot fails to select correct approach * Absence of NOTAM informing the closure of the standard RAP	*Airport Safety Management System (SMS) [not a new requirement] *GBAS GS does not transmit FAS data for the "closed RAP" [CSR#MRAP065]	* **Aircraft/Pilot** -Pilot detects that marking indicates that standard aiming point is closed and initiates a missed approach	

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471 **Hz#MRAP2: Failure to maintain separation between A/C during MRAP operations**

Operational effects	Possible failures/causes	Preventive mitigations	Mitigations when OH occurs	Severity Class
A/C (e.g. Heavy) as a leader is flying displaced aiming point approach whereas it should fly the standard approach which leads to SMI and possibly WVE with follower aircraft A/C (e.g. Medium, Light) as a follower is flying standard aiming point approach whereas it should fly the displaced approach which could lead to WVE (e.g. Heavy leader on the upper Glide)	*Wrong/erroneous publication *Unclear clearance *Incorrect readback *Pilot fails to select correct approach *A/C is not MRAP capable whereas flight plan indicates it is capable *GBAS GS failure	**a) Publication/phraseology:** * Clear charting elements and one plate per approach [CSR#MRAP001] [OSED ID 17] *Altitude/distance table for each RAP [CSR#MRAP005] * Same procedure name between AIP and avionics system [CSR#MRAP010] *Limit the number of published MRAP per runway end (e.g. less than 3) [CSR#MRAP002] *MRAP procedures published in AIP with restriction per aircraft category [CSR#MRAP015] *Repetitive phraseology (e.g. during handover) with readback [CSR#MRAP020] [OSED ID 34] *Specific runway identifier to be used for SRAP operations [OSED ID 14] **b) Aircraft/Flight Crew:** * Flight Crew training (transition to new procedures [CSR#MRAP025]	* **ATC Collision Prevention Barrier** ATCo detects the imminent collision using radar information and instructs one aircraft to deviate immediately from its current trajectory ***Wake encounter recovery** - Follower A/C initiates a missed approach in case of WV encountered	***MAC-SC3**/Imminent Infringement. → It corresponds to a situation where an imminent collision was prevented by the ATC Collision prevention ***Wake SC3b**/ Imminent Infringement. → It corresponds to a situation where an unmanaged under separation was prevented by ATC separation recovery

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		*A/C GBAS system certified [CSR#MRAP080] *Pilot verifies GBAS RPID and arms the approach [CSR#MRAP085] *display of RAP at cockpit level following onboard selection [CSR#MRAP030] * Nav Data Base filtering considering A/C landing performance (e.g. limitation for e.g. CAT D,E aircraft) [CSR#MRAP035] *A.O procedures for filling flight plan considering A/C capability [CSR#MRAP070] *Pilot might detect reduction of separation using the ACAS display and inform ATC **c) ATC and systems:** * ATCO Training [CSR#MRAP040] * Clearance provided through data-link with a new tool to support automatic clearance check [Issue#MRAP001]/[CSR#MRAP045] * ATCO verifies MRAP capability using flight plan data [CSR#MRAP046] * Concept introduction in a stepped way (higher DH/RVR than CAT I in a first step) [CSR#MRAP050] * GBAS GS approval [CSR#MRAP055] and broadcast of all FAS data Block associated to the different MRAP approaches [CSR#MRAP056]

		* Approach name included in the radar label [CSR#MRAP058] * Use of GBAS CAT III specificities (authentication, distance from threshold to end of runway,…) [CSR#MRAP060] * ATCO knows the aircraft distance to the displaced runway aiming point and could locate the runway aiming point on HMI [CSR#MRAP041] * ATCO detects catch up by monitoring separation and re-establishes separation [OSED ID 69] * ATCO instructs a missed approach for the Heavy A/C *Approach funnel deviation alert to be provided at Approach and Tower position (requires an accurate vertical input) [REC#MRAP002]/ [CSR#MRAP1005] *A separation tool is not considered as a mitigation factor for this operational hazard for the time being. So far it was checked that under-separation could be checked thanks to existing markers on the HMI CSR#MRAP1010]		
Catch-up between A/C conducting displaced and standard aiming point approaches which leads to SMI and possibly WVE	*Separation not properly defined when considering mixed approach environment * ATCO fails to manage separation in “mixed mode”	*ANSP analysis to support separation/spacing during MRAP operations considering the ROT which might be the constraining factor [CSR#MRAP075] *ATCO detects catch up by monitoring separation and re-establishes separation [OSED ID 69]		

473 **Hz#MRAP3: Failure to respect the published MRAP approach which leads to a reduction of separation with terrain/obstacle**

Operational effects	Possible failures/causes	Preventive mitigations	Mitigations when OH occurs	Severity Class
A/C exits from the planned vertical and/or lateral trajectory during the final approach and may deviate towards terrain/obstacles	* Pilot fails to engage approach mode * A/C GBAS system failure * Autopilot failure * Pilot fails to respect displayed guidance (manual mode) * GBAS GS failure * VASI-PAPI not properly set for the ongoing approach (if installed) * confusion with DME distance	* A/C GBAS system certified [CSR#MRAP080] and GBAS G/S approved [CSR#MRAP055] and broadcast of all FAS data Block associated to the different MRAP approaches [CSR#MRAP056] * Flight crew training [CSR#MRAP025] * Use of GLS distance and not DME distance[CSR#MRAP029] * Pilot verifies GBAS RPID and arms the approach [CSR#MRAP085] * VASI/PAPI not used for displaced runway aiming points [ISSUE#MRAP003] Note: It should be analysed if a virtual aid in the cockpit could help? E.g. virtual PAPI in cockpit [VAL#MRAP004]	*** Aircraft/Pilot** - Pilot monitors lat and vert deviation - Pilot reacts following TAWS alert - Pilot initiates a missed approach[7] *** ATC/Controller** - ATCO detects the deviation (possible when far from the threshold e.g. 4Nm) and informs pilots	* **CFIT-SC3b** / Flight Toward Terrain Commanded. → It corresponds to a situation where a controlled flight towards terrain was prevented by flight crew monitoring
A/C is landing too short and might collide with terrain/obstacle				

[7] If A/C initiates a missed approach at the minima, obstacle clearance should be provided all along the procedure. DH are defined considering the runway aiming point and therefore each RAP procedure could have a different DH.

			- Approach funnel deviation alert to be provided at Approach/Tower position [REC#MRAP002]/ [CSR#MRAP1005]	

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475 **Hz#MRAP4: Failure to respect the published MRAP approach which leads to a reduction of separation with A/C on lower Glide**

Operational effects	Possible failures/causes	Preventive mitigations	Mitigations when OH occurs	Severity Class
A/C conducting displaced aiming point approach exits from the planned vertical trajectory and deviates towards a follower A/C on the lower glide Note: The safety risk is collision more than wake	Same causes compared to the risk of CFIT (Hz-MRAP3):	* Same mitigations compared to the risk of CFIT (Hz-MRAP3) * Extra spacing (buffer) will be necessary to provide the required separation to clear the runway for the first aircraft [VAL#MRAP005] * ATCO detects the imminent infringement and instructs a missed approach for the A/C on the upper glide[8] * Approach funnel deviation alert to be provided at Approach/Tower position [REC#MRAP002]/ [CSR#MRAP1005] * Multiple go around to be handled at ATC level due to a possible knock on effect	* **ATC Collision Prevention Barrier** ATCo detects the imminent collision using radar information and instructs one aircraft to deviate immediately from its current trajectory ***Wake encounter recovery** -Pilot reacts and recovers from the wake encounter	* **MAC-SC3**/Imminent Infringement. → It corresponds to a situation where an imminent collision was prevented by the ATC Collision prevention • **Wake SC3b**/ Imminent Infringement. → It corresponds to a situation where an unmanaged under separation was prevented by ATC separation recovery

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477 **Hz#MRAP5: Failure to land in the TDZ during displaced aiming point approach**

[8] Discussion on the A/C to be instructed for the Go around was not fully conclusive but it seems that this is the first A/C (the one on the upper glide) that will be instructed to go around

Operational effects	Possible failures/causes	Preventive mitigations	Mitigations when OH occurs	Severity Class
A/C due to runway infrastructure / suitability issues lands before threshold or make a long landing Note: runway infrastructure / suitability includes aspects like runway marking, runway lighting, surface friction,….	* approach lights are confusing for the flight crew during MRAP operations * runway marking is confusing for the flight crew during MRAP operations * VASI/PAPI not properly set for the displaced approach * confusion with DME distance	* Specific airport design for runway light and marking (design to be proposed) [ISSUE#MRAP006] * Use of GLS distance and not DME distance[CSR#MRAP029] * VASI/PAPI not used for displaced runway aiming points [ISSUE#MRAP003] * Autoland mode with CAT III conditions in order to not require visual reference or other on-board solution (HUD, SVS,…) [REC#MRAP004] - The definition of the TDZ for MRAP operations should be clarified [ISSUE#MRAP009] * OFZ considers the displaced runway aiming points [CSR#MRAP016]	*** Aircraft/Pilot** - Pilot detects that A/C is not on the optimum landing path and does not over react for the flare - Pilot applies procedures relative to runway overrun - Pilot executes a touch and go if needed *** ATC** It should be checked if RIMCAS is compatible with MRAP operations and does not lead to nuisance alerts. RIMCAS triggering values need to be different for different aiming points [ISSUE#MRAP007] - There is an uncertainty on the MRAP variability aspect (e.g. landing point dispersion)	**RE- SC2** Early/Late Touch down due to runway infrastructure/suitability issues →It corresponds to a situation where a runway excursion was prevented by appropriate pilot runway deceleration and stopping

			which might impact the ATC procedures for the Runway controller [ISSUE#MRAP008]	
A/C vacates the runway at the anticipated runway exit but at a high speed which could lead to Runway excursion during the turn	* A/C makes a long landing * Runway conditions * Braking capability * Required landing distance not properly computed	* Flight crew training [CSR#MRAP025] * Airport layout (high speed exit)	*** Aircraft/Pilot** - Pilot detects that A/C is too fast for the anticipated runway exit - Pilot continues the deceleration on the runway -Pilot applies emergency braking procedure to prevent runway overrun -....	

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479 **Hz#MRAP6: Failure to vacate the runway at the foreseen exit**

480 Based on the workshop discussions, it should be decided if Hz#MRAP6 should remain an operational Hazard

Operational effects	Possible failures/causes	Preventive mitigations	Mitigations when OH occurs	Severity Class
A/C cannot vacate the runway at the anticipated exit which could lead to blocking the runway Note: this is not really a safety issue and happens on a daily basis	* A/C makes a long landing * Runway conditions * Braking capability * Required landing distance not properly computed *....	* Airport design * Flight crew training [CSR#MRAP025] * MRAP not implemented at certain airports due to the runway configuration (crossing runway; MRAP exit which is then crossing another runway,...) [ISSUE#MRAP010]	* **ATC/Controller** - ATCO monitors the runway and detects that the landing aircraft does not vacate at the foreseen exit - ATCO gives clearances to other A/C, vehicles considering that A/C does not vacate at the proper exit or is blocking the runway -....	**RInc-SC5**- Imminent Runway Incursion →It corresponds to a situation where runway monitoring prevents a runway incursion

Based on the workshop discussion, it should be decided if Hz#MRAP6 should remain an operational Hazard.

Following the workshop it was decided to replace this Hazard (Hz#MRAP006) by a new one as follows: **Hz#MRAP6: "Failure to maintain aircraft separation on the runway protected area during displaced aiming point approach operations**". The operational effect is now a runway conflict between the aircraft which is landing and a mobile (A/C or vehicle) on or near the runway protected area. The associated severity class is Rinc-SC3 (Runway conflict).

Appendix F PJ02.02 SAF/HP workshop

In the frame of SESAR 2020, a two day Safety-Human Performance workshop took place on the 28th and 29th of March 2018, at EUROCONTROL HQ premises. This workshop helped clarifying outstanding concept elements and any other possible safety and human performance issues.

PJ02-02 SAF-HP workshop March 20

Appendix G PJ02.02 / PJ02.01 / PJ02.03 Pilots and ATCOs Workshop

A workshop with pilots from Air France and CDG ATCOs took place on the 28th of January 2019 on the Air France premises at CDG airport. The workshop was facilitated by SAF and HP experts from EUROCONTROL and it included APP and TWR ATCOs from DSNA, pilots from Air France, together with safety, human performance and concept experts from EUROCONTROL. The workshop helped clarifying remaining SAF/HP and concept questions for projects PJ02.02, PJ02.01 and PJ02.03. Note only the results from PJ02.02 were kept in this appendix.

PJ	QUESTION	RATIONALE	COMMENTS:
PJ02-02 general	1. Do you need more info on the ATIS than today for IGS-to-SRAP approaches? At what point do you check the ATIS info? Does it change as compared to today`s ops (e.g. also before TOD)?		Check before ToD if ATIS can be obtained Sometimes need to perform a new briefing during descent, in case ATIS info is obsolete

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Appendix H Assumptions, Safety Issues & Limitations

H.1 Assumptions

Safety criteria, safety objectives (both functionality & performance and integrity) and safety requirements have only been derived in this safety assessment if a change was introduced by the enhanced arrival concepts and if there was a safety need. Where there was no change introduced by the concepts, it was assumed that the current operations apply.

H.2 Safety Issues log

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

Ref	Safety issue	Resolution
	The frequency of wake turbulence encounters at lower severity levels might increase due to the reduced wake turbulence separation minima. As the frequency of wake turbulence encounters at each level of severity depends on local traffic mix, local wind conditions and intensity of application of the concept (e.g. proportion of time, proportion of aircraft), there is a need to find a suitable way for controlling the associated potential for WT-related risk increase.	To further analyse at local level, prior to implementation, the frequency of wake encounters at lower severity levels depending on the local traffic mix, local wind conditions and intensity of application of the concept

Table 14: Safety Issues log

Appendix I Relevant Accident Incident Models (AIM) & Risk Classification Schemes (RCS)

I.1 Simplified AIM and RCS for CFIT

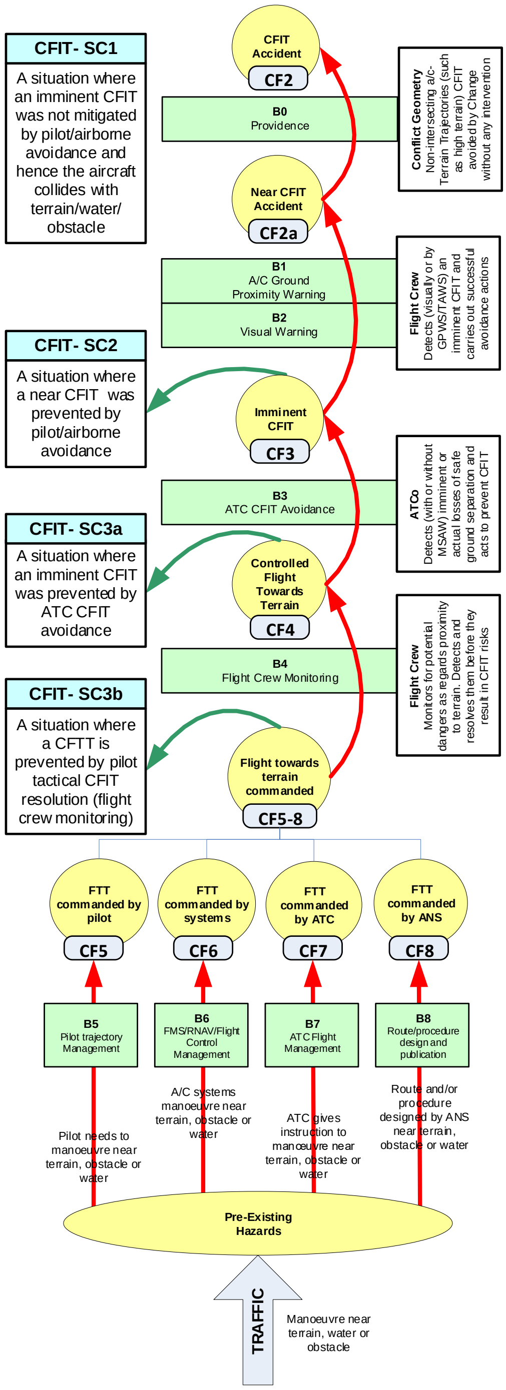

Figure 9. Simplified AIM for CFIT (Controlled Flight Into Terrain) accident

The following table shows the maximum tolerable frequency of occurrence for each Severity Class (SC) relative to CFIT (Controlled Flight Into Terrain) accident.

Severity Class	*Hazardous situation*	*Operational Effect*	*MTFoO [per flgt]*
CFIT-SC1	A situation where an imminent CFIT is not mitigated by pilot/airborne avoidance and hence the aircraft collides with terrain/water/ obstacle [note 1]	CFIT Accident (CF2) Near CFIT (CF2a)	1e-8
CFIT-SC2	A situation where a near CFIT is prevented by pilot/airborne avoidance	Imminent CFIT (CF3)	1e-6
CFIT-SC3a	A situation where an imminent CFIT is prevented by ATC CFIT avoidance	Controlled flight towards terrain (CF4)	1e-5
CFIT-SC3b	A situation where a controlled flight towards terrain is prevented by pilot tactical CFIT resolution (flight crew monitoring)	Flight towards terrain commanded (CF5-8)	1e-5

The apportionment for the Safety Objectives is given in the table below based on the estimation of the number of hazards (N) for each severity class:

Severity Class (SC)	MTFoO	Nb of hazards per SC	Quantitative Safety Objective (MTFoO / Number of Hazard) with modification factor (IM)=1
CFIT-SC1	1e-8	5	2e-9 per flight
CFIT-SC2	1e-6	10	1e-7 per flight
CFIT-SC3a	1e-5	50	2e-7 per flight
CFIT-SC3b	1e-5	50	2e-7 per flight

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I.2 Simplified AIM for MAC on Final Approach

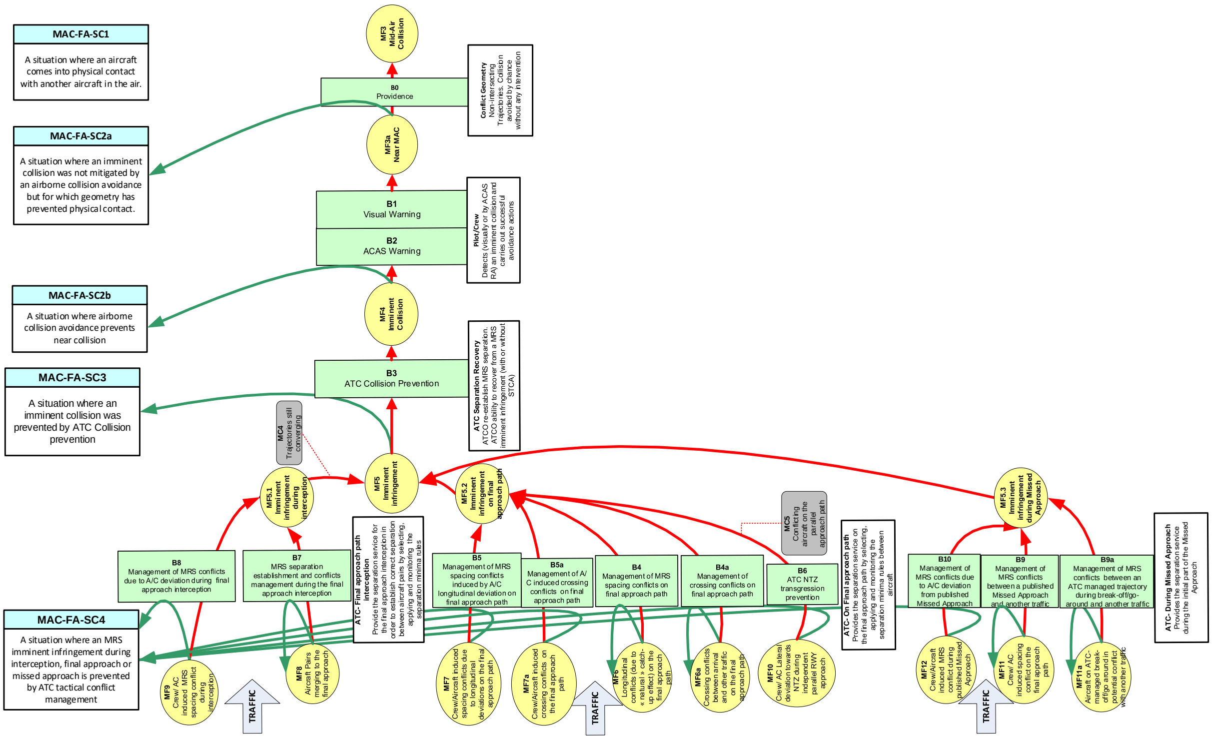

Figure 10. Simplified AIM for MAC (Mid Air Collision) accident on Final Approach

I.3 Simplified AIM and RCS for Wake Turbulence on Final Approach

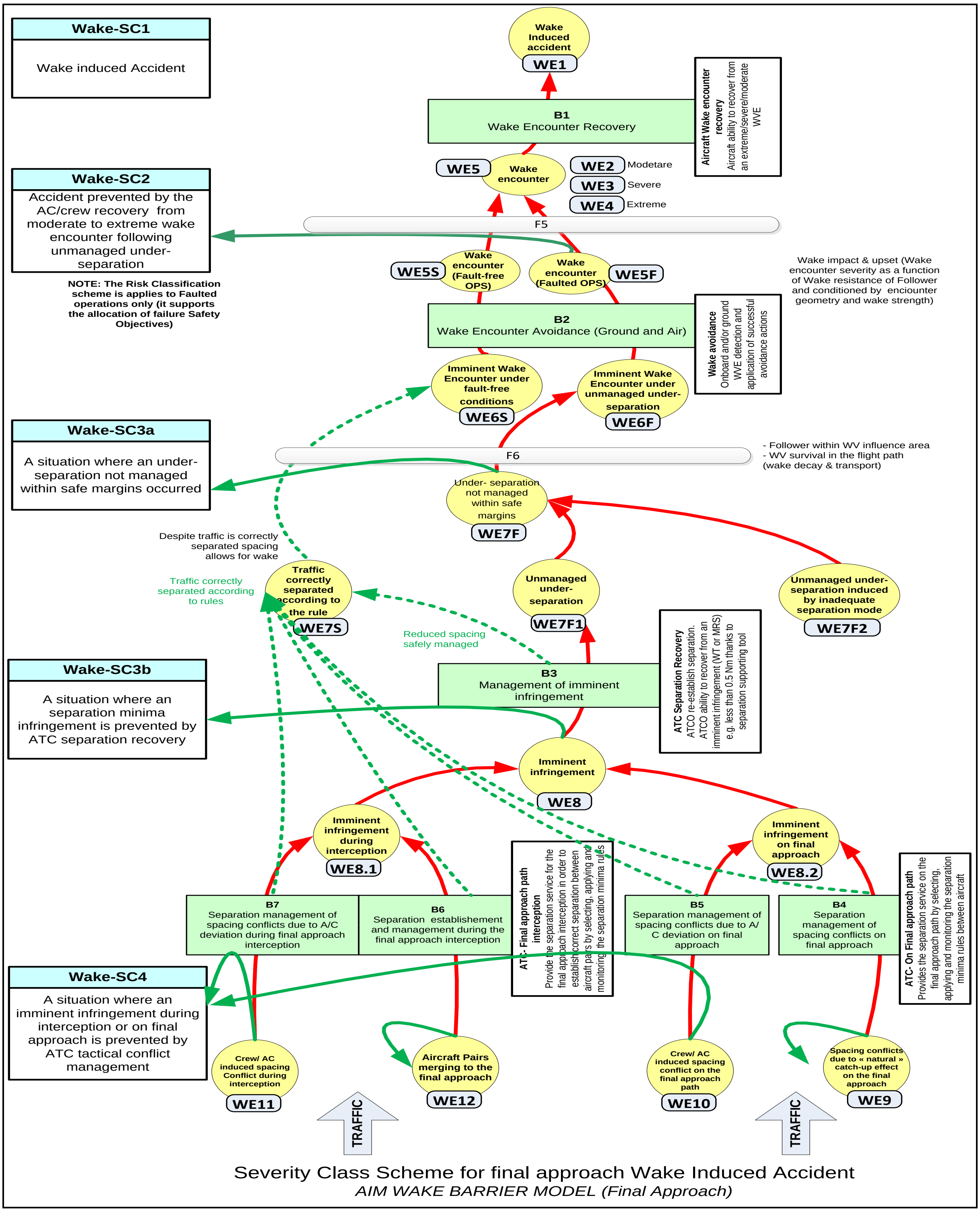

Figure 11. Simplified AIM for WTA (Wake Turbulence-induced) accident on Final Approach

The following table shows the maximum tolerable frequency of occurrence for each Severity Class (SC) relative to the WTA (Wake Turbulence-induced) accident on Final Approach.

Severity Class	*Hazardous situation*	*Operational Effect*	*MTFoO [per approach]*
Wake-SC1	Aircraft accident following an encountered wake turbulence which led to a fatal structural failure, a collision with the ground or a collision with other aircraft in the air	Wake Induced Accident (WE1)	2.00E-08
Wake-SC2a	A situation where a wake-induced accident was prevented by the aircraft wake encounter recovery (both correctly and under-separated aircraft)	Wake Encounter (WE5 i.e. WE2/3/4)	1E-05
Wake-SC2b	A situation where a wake encounter was prevented by the wake encounter avoidance (both correctly and under-separated aircraft)	Imminent wake encounter (WE6S, WE6F)	1E-05
Wake-SC3a	A situation where an under-separation not managed within safe margins occurred	Unmanaged under-separation (WE7F)	2.00E-04
Wake-SC3b	A situation where an unmanaged under separation is prevented by ATC separation recovery	Imminent Infringement (WE8)	1.00E-02
Wake-SC4	A situation where a Crew/aircraft induced an imminent infringement during the interception or on the Final Approach path which was prevented by ATC spacing conflict management	Crew/Aircraft Induced spacing Conflict during Interception (WE11) or on Final Approach (WE10)	1.00E-01

The apportionment for the Safety Objectives is given in the table below based on the estimation of the number of hazards (N) for each severity class relative to the WTA (Wake Turbulence-induced) accident on Final Approach:

Severity Class (SC)	MTFoO	Nb of hazards per SC	Quantitative Safety Objective (MTFoO / Number of Hazard) [per approach]	Nb of maximum occurrences per year (considering an airport with 135.000 landings per year)
SC1	2,00E-08	1	2,00E-08	Two every 1000 years
SC2a	1,00E-05	5	2,00E-06	2 every 10 years
SC2b	1,00E-05	5	2,00E-06	2 every 10 years
SC3a	2,00E-04	5	4,00E-05	5 per year
SC3b	1,00E-02	5	2,00E-03	2 every 3 days
SC4	1,00E-01	5	2,00E-02	7 per day

I.4 Simplified AIM and RCS for Runway Collision

Simplified Runway Collision model still under construction.

The following table shows the maximum tolerable frequency of occurrence for each Severity Class (SC) relative to the RC (Runway Collision) accident:

Severity Class	**Hazardous situation**	**Operational Effect**	**MTFoO [per movt.]**
RWY-SC1	A situation where an aircraft has come into physical contact with another object on the runway	Accident - Runway Collision (RF3)	1e-8
RWY-SC2a	A situation where an imminent runway collision was not mitigated by pilot/driver or aircraft system collision avoidance but for which the geometry has prevented a physical contact.	Near Runway Collision (RF3a)	1e-7
RWY-SC2b	A situation where pilot/driver runway collision avoidance prevents a near runway collision	Imminent runway collision (RP1)	1e-6
RWY-SC3	A situation where an encounter between a/c, vehicle or person on the runway and one a/c approaching occurs but ATC runway Collision avoidance prevents it to become an Imminent Runway Collision.	Runway Conflict (RP2)	1e-4
RWY-SC4	A situation where a runway incursion due to unauthorized entry/exit is concurrent with another aircraft awaiting clearance to use the runway but ATC runway conflict prevention prevents this situation to become a runway conflict	Runway incursion (RP3)	1e-3
RWY-SC5	A situation where runway monitoring prevents a runway incursion	Imminent Runway incursion (RP4)	1e-2

The apportionment for the Safety Objectives is given in the table below based on the estimation of the number of hazards (N) for each severity class relative to the RC (Runway Collision) accident:

Severity Class (SC)	MTFoO	Nb of hazards per SC	Quantitative Safety Objective
RWY-SC1	1e-8	1	1 e-8 per movement
RWY-SC2a	1e-7	5	2 e-8 per movement
RWY-SC2b	1e-6	10	1 e-7 per movement

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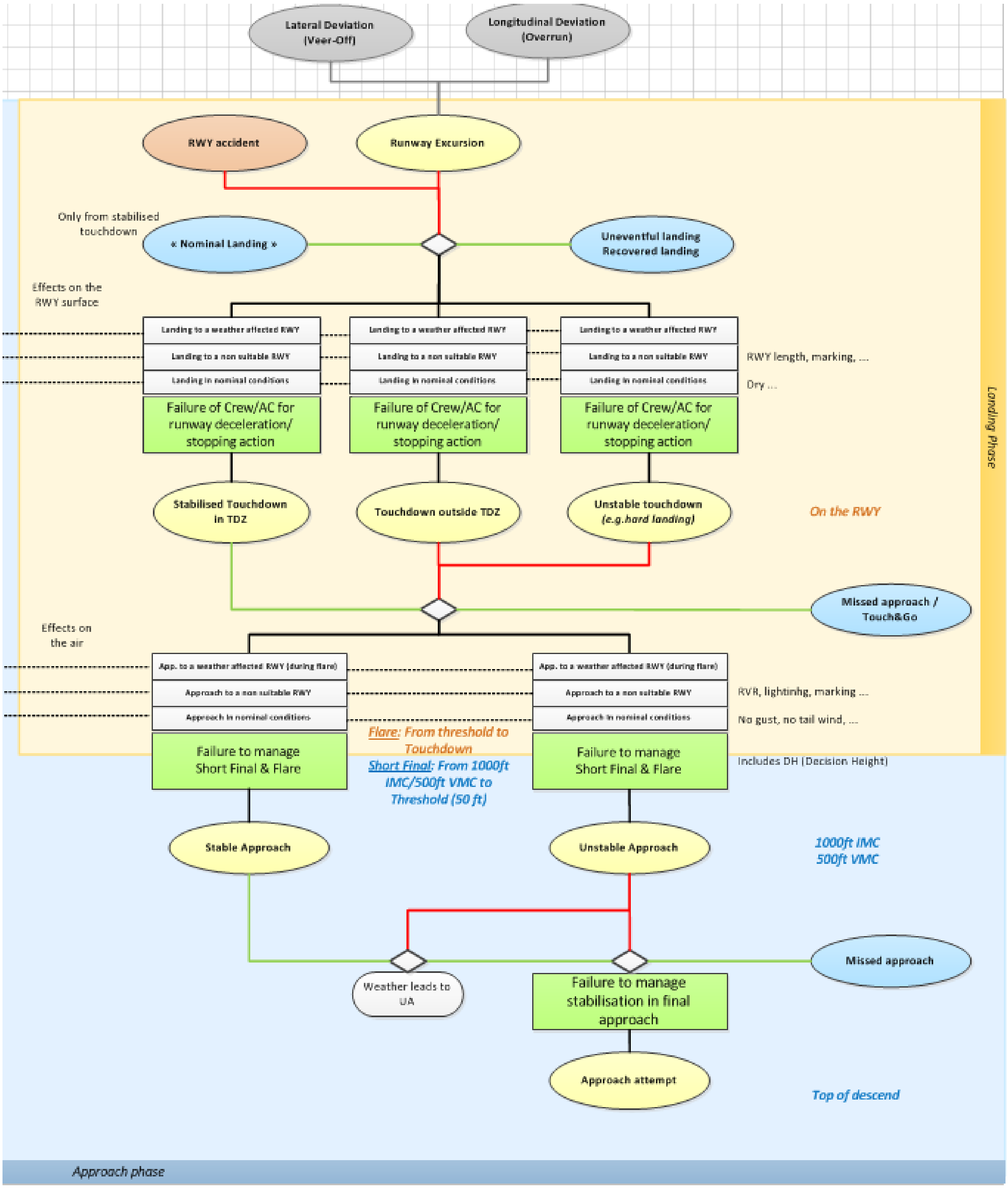
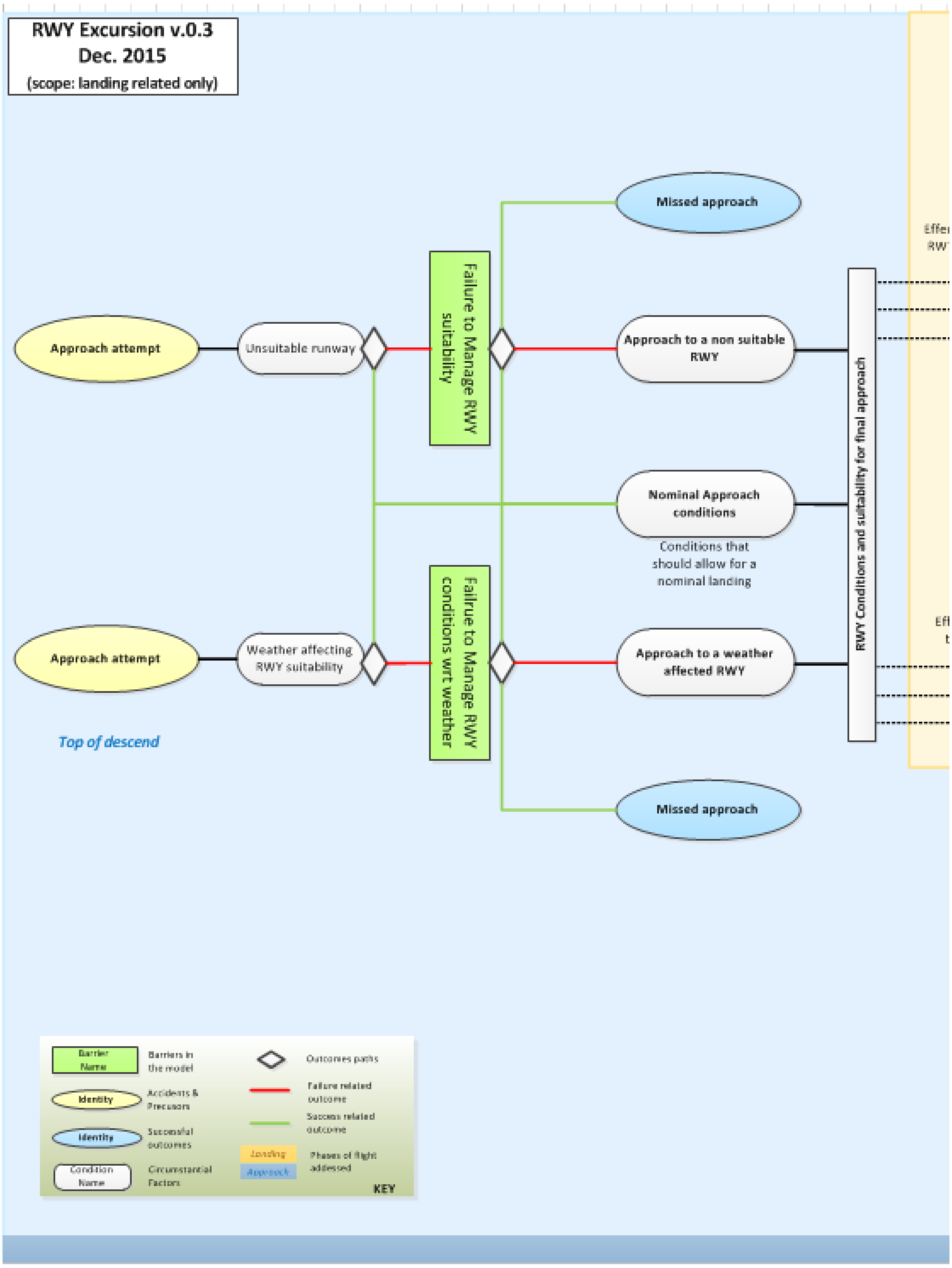
RWY-SC3	1e-4	10	1 e-5 per movement
RWY-SC4	1e-3	30	3.33 e-5 per movement
RWY-SC5	1e-2	50	2 e-4 per movement

I.5 Simplified AIM for Runway Excursion

Figure 12. Simplified AIM model for RWY excursion accident (A3 cut in 2 A4 parts)




RWY Excursion v.0.3
Dec. 2015
(scope: landing related only)
Approach attempt
Unsuitable runway
Failure to Manage RWY suitability
Missed approach
Approach to a non suitable RWY
Nominal Approach conditions
Conditions that should allow for a nominal landing
Approach attempt
Weather affecting RWY suitability
Failrue to Manage RWY conditions wrt weather
Approach to a weather affected RWY
Missed approach
RWY Conditions and suitability for final approach
Top of descend
Barrier Name
Barriers in the model
Identity
Identity
Condition Name
Circumstantial Factors
Outcomes paths
Failure related outcome
Success related outcome
Phases of flight addessed
KEY