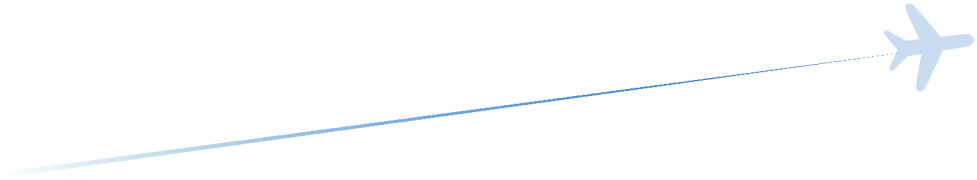

SESAR Solution PJ.06-01 SPR-INTEROP/OSED for V3 - Part II - Safety Assessment Report

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PJ06

PJ.06-01 — OPTIMIZED TRAFFIC MANAGEMENT TO ENABLE FREE ROUTING IN HIGH AND VERY HIGH COMPLEXITY ENVIRONMENTS

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Abstract

This document contains the Specimen Safety Assessment for a typical application of Free Route Operations within the scope of SESAR PJ.06-01 solution (in cross-borders high and very high complexity environment). 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 SESAR PJ.06-01 Solution OSED/SPR/INTEROP.

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1 Executive Summary

This document contains the Specimen Safety Assessment for a typical application of Free Route Operations within the scope of SESAR PJ.06-01 solution (in cross-borders high and very high complexity environment). 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 SESAR PJ.06-01 Solution OSED/SPR/INTEROP.

This document addresses the Safety Assessment of the concept of Free Routing for Flights both in cruise and vertically evolving within cross-borders high and very high complexity environments.

In accordance with the Free Route Safety Plan ([3]), this safety assessment is performed up to SPR level for the definition of safety requirements.

The PJ.06-01 Solution Safety Assessment starts with the definition of Safety Criteria for implementation of Free Routing in cross-borders high and very high complexity environments and supports the definition of Safety objectives (i.e. safety requirements at OSED level) so that the concept is capable of meeting the Safety Criteria. Finally, the SAR addresses the Safe Design at SPR Level, defining Safety Requirements to meet the Safety Objectives.

This Safety Assessment Report has been developed in parallel with the development of the Free Route Safety and Performance Report. It has been built through a series of workshops conducted with various operational and validation experts.

2 Introduction

2.1 Background

The Free Route operational concept has been under development for many years now (before, aside and in the context of the SESAR Programme). The current activities under PJ.06-01 scope are based upon previous initiatives / projects / studies related to Free Route, among which:

- The EUROCONTROL European Route Network implementation plan (ERNIP), and more specifically ERNIP Part 1,
- The outcomes of the SJU Free Route Task Force 2013-2014,
- The work conducted within SESAR 1, building on the outcomes of the SJU Free Route Task,
- The validation activities conducted within SESAR 1 to achieve a V3 maturity level of the SESAR Solutions #32 and #33.

For more details, please refer to SPR-Interop/OSED PJ.06-01 documentation [7]

The SESAR Solution PJ.06-01 is about optimized traffic management to facilitate Free Routing in upper En-Route airspace. It is focused on the improvement of Aircraft-to-Aircraft Separation Provision to enable Free Routing operations in high and very high complexity cross-border environments.

The aim of the PJ06-01 safety assessment is:

- To ensure that the functionality & performance (Success Approach) is adequately specified from a safety perspective.
- To ensure that the integrity & reliability (Failure Approach) is adequately specified from a safety perspective.

2.2 General Approach to Safety Assessment

This safety assessment is conducted as per the Safety Reference Material [1] which itself is based on a twofold approach:

- a success approach which is concerned with the safety of the solution operations in the absence of failure within the end-to-end solution system
- a conventional failure approach which is concerned with the safety of the solution operations in the event of failures within the end-to-end solution system.

Together, the two approaches lead to Safety Objectives at OSED level and to Safety Requirements at SPR level, which set the minimum positive and maximum negative, safety contributions of the solution system.

2.3 Scope of the Safety Assessment

This Free Route Safety Assessment includes:

- the setting of the Safety Criteria (SAC),
- the description of the key properties of the environment,
- the definition of the safety objectives (i.e. safety requirements at OSED level) from success and failure approach
- the definition of safety requirements at SPR level from success and failure approach.

Since the properties of the operational environment are crucial to the safety assessment, this assessment cannot be generic – it has to be specific to the Operational Environment defined in section 3.2 and consequently, the term 'specimen' safety assessment should be used.

2.4 Layout of the Document

Section 3 describes the Free Route concept, defines the high level Safety Criteria and defines the safety objectives at the OSED level, i.e. operational safety requirements for the free routing concept

Section 4 defines safety requirements at SPR level

Section "References" contains the References

Appendix A contains a consolidated list of safety objectives for the Free Route solution

Appendix B contains a consolidated list of safety requirements at SPR level

Appendix C states the assumptions, safety issues and limitations

Appendix D presents the operational processes, extracted from EATMA model, used as input for the identification of the safety objectives in normal operations

3 Safety specifications at the OSED Level

3.1 Scope

This section addresses the following activities:

- Description of the key properties of the Operational Environment that are relevant to the safety assessment – section 3.2
- Identification of the pre-existing hazards that affect Free Routing operations in relevant operational environment (airspace) and the risks of which operational services provided by ATS System may reasonably be expected to mitigate to some degree and extent – section 3.4.
- Setting of the Safety Criteria – section 3.5
- Comprehensive determination of the operational services that are provided by the solution to address the relevant pre-existing hazards and derivation of Safety Objectives (success approach) in order to mitigate the pre-existing risks under normal operational conditions – section 3.6.
- Assessment of the adequacy of the operational services provided by the Solution under abnormal conditions of the Operational Environment – section 3.7
- Assessment of the adequacy of the operational services provided by the solution in the case of internal failures and mitigation of the system-generated hazards (derivation of Safety Objectives (failure approach)) – section.3.8
- Achievability of the SAfety Criteria – section 3.9.
- Validation & verification of the safety specification – section 3.10

3.2 Solution Operational Environment and Key Properties

3.2.1 Solution Objectives

The **SESAR Solution PJ.06-01** is about optimized traffic management to enable Free Routing in high and very high complexity environments. It contributes to the **OI Step AOM-0505**: “Free Routing for Flights both in cruise and vertically evolving within high and very high complexity environments in Upper En Route airspace”

The Free Routing concept seeks Airspace Users being able to plan flight trajectories without reference to a fixed route network or published directs, so they can optimise their associated flights in line with their individual operator business needs or military requirements. It is a transversal operational concept that affects many ATM activities at regional, sub-regional and local level.

The Solution PJ.06-01 is contributing to the improvement of air traffic management at local level. More precisely, it focuses on the improvement of Aircraft-to-Aircraft Separation Provision to enable Free Routing operations in upper En-route airspace in high and very high complexity cross-border environments (with minimum structural limits to manage airspace and demand complexity).

3.2.2 Projects Deliverables

PJ06-01 will produce the following set of deliverables:

- **SPR-INTEROP/OSED**, encompassing the specification of the operational concept and hosting the operational, safety and performance requirements.
- **Safety Plan** presenting the safety considerations associated to the Free Route PJ06-01 solution, the scope of the safety assessment, the methodology that will be applied for the safety assessment and the schedule of the safety assessment
- **Safety Assessment Report** (present document) presenting the results of the PJ06-01 Free Route safety activities, performed in accordance with the present plan.
- **Validation Plans and Validation reports** presenting the plan/results of each exercise.

3.2.3 Justification for the Projects

SESAR 2020 PJ19 [8] expected validation target for PJ06-01 solution is 4.86% benefit in Environment/Fuel Efficiency and 0,16% in predictability. Solution has no other targets allocated, however these environment and predictability targets could be reviewed before the final Data Pack according to BIM and VALP work.

However, solution expects also:

- Capacity not to be enhanced purely by the application of Free Routing operations, but at least to be maintained.
- Safety level to be at least maintained
- Environment: +4.86% saving.
- Predictability: +0.16% reduction in variance of block-to-block flight time

For more information refer to SESAR Solution PJ06.01: Validation Plan (VALP) V3 - Part I [4], section 3.4.

3.2.4 Solution Scope

See Section 3.1 of OSED [7] for information about the Solution scope.

3.2.5 Operational Concept – Overview

The Free routing activities developed in the frame of the solution PJ.06-01 aim at allowing Airspace users to perform Free Routing operations in a cross border environment along user defined segments in airspace of high and very high complexity.

The relevant Operational Improvements (OI) for solution PJ.06-01 is:

- AOM-0505 “Free Routing for Flights both in cruise and vertically evolving within high and very high complexity environments in Upper En Route airspace”

While the Free Routing concept is a transversal operational concept that affects many ATM activities at regional, sub-regional and local level, the solution PJ.06-01 seeks to contribute to Free Routing in high and very high complexity cross border environments at local level. Therefore, improvements of **some ATC aspects** are expected:

- Aircraft-to-Aircraft Separation Provision (airspace)

The expected benefits related to this operational improvement are:

- Capacity not to be enhanced purely by the application of Free Routing operations, but at least to be maintained.
- Safety level to be at least maintained
- Fuel Efficiency Focus Area - Actual average fuel burn per flight (FEFF1): fuel saving of 27.69 kg/flight (8.14% contribution to the SESAR2020 Validation Target starting point)
- Predictability Focus Area – Variance of differences between actual flight plan or RBT durations (PRD1): 0.93% reduction in variance of block-to-block flight time (1.5% contribution to the SESAR2020 Validation Target starting point)

3.2.6 Details of the change

Four types of changes at solution level are identified:

1. **The operational environment**

   The targeted environment is En-Route high and very high complexity Airspace (c.f. section 3.2 for more details) where the A.U have the ability to plan route according to user defined segment in defined Free Routing Airspace.

2. **The user requirements**

   In the frame of solution 06-01, the user requirements are focused on the ANSP perspective. In order to organize traffic flows that allow a reduction in the traffic complexity, user requirements are:

   - o <u>Enhanced ATC support tools</u>

     To perform their operational activities in a safe and efficient manner in Free Routing Airspace of high and very high complexity, ATCOs will need to be assisted by enhanced ATC support tools that allow

     - ✓ managing coordination of flights outside named Co-Ordination Points (COP),

- ✓ providing aircraft-to-aircraft separation and managing conflict with airspace reservations taking into account airspace status and flight information within the Area of Interest (AoI) of the sector

3. **The Air traffic system**

   In order to support the development of Free Routing operations in the scope of the solution PJ.06-01, En route capabilities shall (required) be improved thanks to the introduction of:

   - Enhanced Flight Data Provider (FPD) that will use 4D trajectories to support Free routing beyond the local Area Of Responsibility (AOR)
   - Advanced Conflict Detection/Resolution Tools to support the separation provision in Free Routing environments of high and very high complexity

3.2.7 Types of Airspace – ICAO Classification

Airspace characteristics

The general assumptions regarding airspace characteristics eligible for Free Routing operations are:

- **Classification**: The FRA is assumed to be classified as Class C Airspace
- **Flight Level Orientation**: The Flight Level Orientation Scheme (FLOS) applicable within Free Route operations airspace will be promulgated through the relevant national AIS publications.
- **Airspace organisation**: The common lower level of Free Routing Airspace will be the lowest possible taking into account airspace and demand complexity across Europe. Airspace reservations and constraints for AUs will remain (see OSED [7] for more information).
- **Publication and maintenance of Significant Points and ATS Route Network**: It will be up to each ANSP to decide if the fixed route network shall be maintained or not, as the ATS route network is no longer required. Moreover, the usage of user-defined Significant Points will be defined in the relevant national AIS publications (see section Airspace Characteristics of OSED [7] for more information.
- **Sectorisation**: Sector design should be revisited in order to accommodate traffic flow within FRA.
- **Letters of Agreement and Coordination Procedures** shall be adapted in order to reflect the specificities of Free Route operations in regard to transfer points and changes described above (see section Airspace Characteristics of OSED [7] for more information.
- **ATS delegation:** letter of agreement shall be amended to better reflect any changes to the procedures in the Airspace where ATS is delegated when FRA Airspace is implemented
- **Complexity:** Score higher than 6 for high and very high complexity (as referred in in OSED [7] section 3.2.1.1)

Cross border Free routing airspace

In a cross-border FRA, published points at State/FIR/ACC borders can remain and be eligible for flight planning purposes, but not mandatory as in a fixed ATS route network environment. Then this FRA concept in high and very high complexity environments introduces needs on ATS compared to ARN environment in terms of working methods for safe and efficient coordination and transfer of flights at the border of two different States

Structurally limited FRA

To maintain the airspace complexity to an acceptable level for ATCOs taking into account the geographical and temporal variability of the traffic demand in Free Routing environment, more or less "structurally" limited FRA might be defined in high and very high complexity environments (see OSED [7] for more information).

3.2.8 Traffic characteristics and complexity

While in SESAR 1, the concept development was focused on the Low and Medium En-route Complexity, the solution PJ.06-01 is focused on En-Route High and Very High complexity sub operating environment. For more information on the definition of the complexity please refer to the OSED.

Traffics characteristics as defined in the OSED [7] are:

Traffic eligible for the FRA in PJ.06-01 gets the following characteristics:

- Presence of business and mission flights (essentially IFR flights)
- Accommodation of a variety of different aircraft capabilities
- Overflights, climbing and descending flights above a certain vertical limit, which limit might not necessarily be the same all over the ECAC airspace.
- Possible convergence phenomenon of traffic flows leading to a number of interactions, hotspots and conflicts at sector/ACC levels. These convergence phenomena can be reduced or avoided through structural limitation of the FRA.
- Higher variability in traffic demand and complexity in FRA (compared to a fixed ATS Route Network environment) due to more flight planning options offered to AUs

3.3 Airspace Users Requirements

The Free routing activities developed in the frame of the solution PJ.06-01 aim at allowing Airspace users to perform Free Routing operations in a cross border environment along user defined segments in airspace of high and very high complexity.

Airspace Users Benefit Mechanisms are detailed in the OSED [7], Appendix A.

The expected benefits for the Airspace Users, according to OSED [7] Section 3.1,will be:

- The ability to plan flight along user preferred routes including in upper En-Route airspace of high and very high complexity and across ACC/FIR/State borders will allow AUs to better optimise the flight plans in terms of time (more adequacy with schedule) and/or flight distance (shorter) and /or fuel and cost (more efficient) in regards with their business/mission needs.
- Ability to plan flight in upper En-Route airspace in optimised alignment with business needs will sometimes, but not necessarily always, result in shorter flight plan routes.
- Shorter flight plan routes in upper En-Route airspace means less planned flight emissions (CO2 / NOX) and lower fuel consumption. This links to Environment / Fuel Efficiency
- Ability to plan flight in FRA in optimised alignment with business needs will result in a better adherence of the planned 4D trajectory to the user-preferred / optimal trajectory.
- The resulting higher adherence to the user-preferred trajectory will give the opportunity to AUs to plan for routes with minimal fuel index, so fuel consumption, and consequently flight emissions (CO2 / NOX), will be reduced in En-Route, which links to Environment / Fuel Efficiency
- The ability to plan flight along user preferred routes including in FRA of high and very high complexity will allow AUs to fly flight much closer to planned trajectories as the flight plan will be in optimised alignment with business needs (with for instance less tactical directs requested by pilots or given by ATCO to expedite the traffic).
- As the planned trajectories in upper En-Route airspace will be much closer with business needs, the difference between planned and executed trajectories will be reduced.
- The resulting higher adherence to the planned, optimised and possibly shorter, trajectory in En-Route airspace will improve• fuel consumption and flight emissions (CO2 / NOX) (which links to Environment / Fuel Efficiency), as well as in-flight duration and its variability (there will be less trajectory revisions in En-Route, so RBT durations will be shorter and more stable, which links to Predictability)

Therefore, benefits for Airspace Users are expected on Environment KPA (**Fuel Efficiency**) and Predictability and Punctuality KPA (**Predictability**). There will be **no impact on Safety** KPA (positive or negative) from Airspace Users' perspective.

3.4 Relevant Pre-existing Hazards

The solution PJ.06-01 deals with Free Route Operations in high and very high complexity Airspace. Therefore, only the En Route hazards are relevant for this solution and the following pre-existing hazards are retained for the Free Route Concept at local level:

Hp#1	"Situation in which the intended trajectories of two or more aircraft are in conflict"
Hp#2	"Penetration of restricted airspace"
Hp#3	"Encounters with adverse weather"

Considering the pre-existing hazards that are impacted by the Free Route concept, the relevant accident type is the Mid-Air Collision.

3.5 SAfety Criteria

Safety Criteria are "high-level" criteria defined at the level of the Safety Barriers.

As stated in the D4.1 Performance Framework [11], for each Solution, Content Integration PJ19.4.1 will provide a Safety Validation Target defined at the level of the SAF KPI and at the level of the corresponding Influence Factors; from those Targets the corresponding Safety Criteria – SAC are defined at Solution level.

Currently, PJ19 has released validation targets [8] where no value has been allocated to PJ06-01 solution on safety. In this document it is included:

"The ATM Master Plan provides a Performance Ambition for Safety KPI as "Improvement by a factor 3-4", together with "No increase in accidents". These values are not measurable in order to assess a Validation Target for the SESAR Solutions."

Being so, the SAfety Criteria to be defined will be qualitative, in accordance to the top level safety claim: at least maintain safety level.

The steps to define the Safety Criteria are:

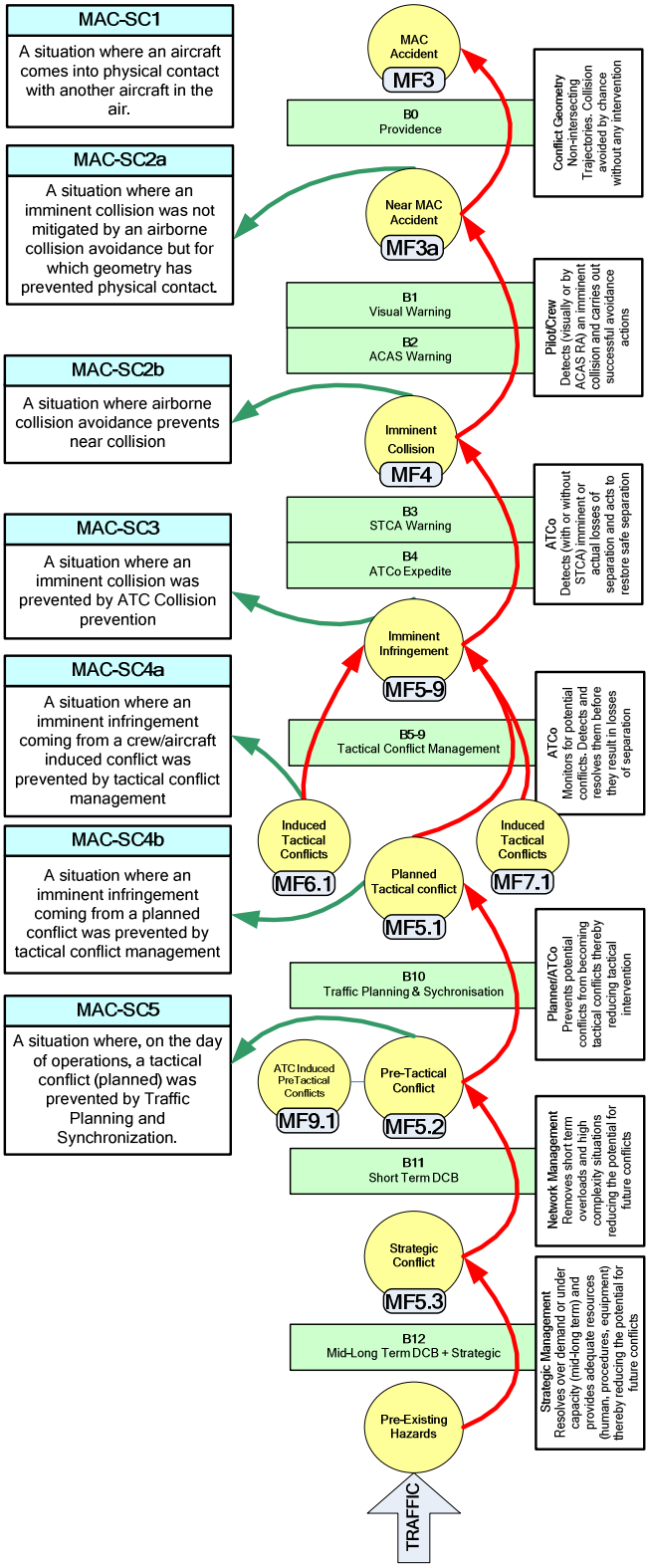
- Identification of the accident type impacted by the change (see section 3.5.1)
- Identification of the safety barriers and precursors of the relevant accident model impacted by the change and qualification of these impact (qualitative qualification or quantitative qualification) (see section 3.5.2)
- Definition of the Safety Criteria at the level of the safety barriers (see section 3.5.2)

3.5.1 Identification of the accident type impacted by the change

Different types of accidents can occur in ATM domain: Mid Air Collision, Runway Collision, Controlled Flight Into Terrain or Taxiway Accident. The whole ATM system acts as a set of barriers preventing these accidents from happening. Barriers models have been defined for each kind of accident representing all the ATM elements (equipment, procedures and people) that work together in order to stop the precursors before they become accidents.

Considering the pre-existing hazards that are impacted by the Free Route concept, the relevant accident type for this Solution is the **Mid-Air Collision**.

The barrier model of the Mid-Air Collision is the following:



Severity Class Scheme for Mid-air Collision
AIM MAC BARRIER MODEL (TMA&ER)

Figure 1: Mid Air Collision Barrier Model

The main barriers of this model are:

- "**Mid / Long Term Demand and Capacity Balancing + Strategic Planning**" This barrier consists in:
    - Performing the mid/long term demand and capacity balancing: forecast of long / medium term traffic demand and implementation of measure to balance capacity and demand
    - Performing the strategic planning in accordance with the demand forecast: airspace design, sector design, and definition of capacity threshold…
- "**Short Term Demand and Capacity Balancing**" This barrier consists in:
    - Identification of demand and capacity imbalance situation (i.e. cases where demand exceeds the capacity) based on occupancy count, entry count, complexity estimation…
    - Resolution of demand/capacity imbalance situation by implementation of DCB measures: sectorisation, STAM, regulation…
- "**Tactical planning barrier**: **traffic planning and synchronisation**" This barrier consists in:
    - Checking and coordinating entry conditions
    - Identifying the planned conflicts in the AOR and informing the TC
    - Checking and coordinating the exit conditions
    - Synchronizing the traffic

  This barrier is implemented by the planning controller.
- "**Tactical conflict resolution barrier**: **tactical conflict management**" This barrier consists in managing the tactical conflicts and consequently maintaining the separation between aircrafts or with restricted areas. This barrier includes:
    - Management of planned conflict (conflict detected by the PC),
    - Management of ATC induced conflict (conflict induced by the ATCO when solving another conflict or when dealing with a situation of bad weather / restricted area activation),
    - Management of crew/aircraft induced conflict (conflict induced by a failure of the pilot or the aircraft)

  This barrier is implemented by the tactical controller (for detection and resolution of the conflict) and the crew (for execution of the clearance)
- "**ATC collision prevention barrier.** This barrier includes the management of imminent collision situations detected by the ATCOs or by the short term conflict alert (STCA). This barrier is implemented by the tactical controller (for detection and resolution of the conflict) and the crew (for execution of the clearance).

- "**Airborne collision avoidance barrier: ACAS Warning / Visual Warning**" This barrier includes the management of imminent infringement situations detected by the pilot or by collision avoidance system (TCAS/ACAS). This barrier is implemented by the crew.

The main precursors (conditions, events, and sequences that precede and lead up to the mid-air collision) of this model are

- Strategic conflict
- Pre-tactical conflict
- ATC induced pre-tactical conflict: conflict induced by the planner controller within the frame of its activities.
- Planned Tactical conflict
- ATC induced tactical conflict: conflict induced by the tactical controller within the frame of its activities.
- Pilot induced tactical conflict: manoeuver performed by the aircraft or the pilot leading to a deviation and potentially to a conflict
- Imminent Infringement
- Imminent Collision

All these barriers and precursors contribute to "Mid Air Collision". These barriers and precursors are further developed in low-level barriers in a more detailed model.

The impact of the PJ.06-01 solution on these barriers and the definition of the associated Safety Criteria are presented in the following section.

3.5.2 Identification of barriers and precursors impacted and definition of Safety Criteria

Following sections present, for each barrier of the barrier/precursor of the model:

- The positive impact on the barrier
- The negative impact on the barrier
- The Safety Criteria associated to this barrier for the PJ06-01 Free Route solution, considering the overall balance between positive and negative impacts, as well as the expected mitigations.

The Safety Criteria have been defined during a safety workshop held on June 26th, 2017. During the workshop, the model barriers were analysed, also reviewing SAC and results from SESAR 1 Operational Focus Area (OFA) 03.01.03, "Free Routing", safety activities.

In a second step, these SAC have been updated to align with the scope of PJ.06-01 solution which does not embark any more dDCB/INAP aspects.

The result of the analysis for each barrier is shown next:

Barrier "Traffic Planning and Synchronisation" (B10 of Figure 1) **/ Precursor "Planned tactical conflict"** (MF 5.1 of Figure 1)	
Positive impact	**Negative impact**
Easier conflict detection due to better aircraft trajectory predictability (better anticipation of traffic situations, less unexpected trajectories, more straight trajectories, less turning points and less tactical directs given by upstream sectors)	On coordination with other sectors/ACCs: No more fixed coordination point between sectors, making it difficult to transfer and coordinate aircraft between sectors in free routing environment. This is not always an issue, at some environments coordination without fixed points is perfectly feasible. In high and very high complexity, appropriate tools and procedures will always be required.
	On coordination with others sectors/ACCs: Short crossing of sectors. When flight transit time in the sector is short, workload increases, inducing failures to identify conflicts and misjudgements in conflict resolution. These short crossings can be reduced or nearly removed through appropriate design of the Free Routing Airspace.
	On conflict detection/resolution: Some aircraft may fly trajectories along the sector border for which it is difficult to ensure separation. This also induces failures to identify conflicts and misjudgements in conflict resolution. It can happen, but not necessarily, depending on the environment and the supporting tools available. For instance, in a structurally limited environment, these kind of situations should be avoided by structuring flows.

Barrier "Traffic Planning and Synchronisation" (B10 of Figure 1) **/ Precursor "Planned tactical conflict"** (MF 5.1 of Figure 1)	
Positive impact	**Negative impact**
	Also addressed, but disregarded, two impacts on conflict detection: Difficulties to detect conflict on restricted areas, specially VPA (Variable Profile Area) are not considered because VPA it is out of Scope of solution (it is part of the environment, FUA) Difficulties to communicate conflict information from planner to executive caused by the absence of known point to relate the conflict to were also disregarded. No such negative impact will happen in high and very high complexity because there will always be a close known point. Waypoints can be picked and then specify the position with respect to them. Particularly, in an electronic environment, there is no issue as the conflict is graphically displayed on the screen.
	On planning tasks: Situational Awareness (SA). ATCO needs to use other references rather than fixed ATS routes, so maintaining SA in high and very high complexity environments can be more demanding. Aircraft are not on a fixed ATS network. At some environments, there is no impact on Situational Awareness: ATCO uses other references (different from fixed ATS routes) to keep Situational Awareness. Situational Awareness might be impacted due to random position of traffic. ATCo will consequently need appropriate tools to manage tactical conflicts
Safety Criteria: More negative impact than positive impact, but **mitigation** identified during the safety assessment should maintain barrier efficiency. **SAC#1:** The number of "Planned tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high / very high complexity Free Routing Environment	

Table 1: Barrier "Traffic Planning and Synchronisation" / Precursor "Planned tactical conflict"

Precursor "ATC induced tactical conflict" (MF 7.1 of Figure 1)	
Positive impact	**Negative impact**
on the precursor: Less ATCO intervention to provide more efficient trajectories to aircraft across their airspace (pilot requests), because aircraft are flying their preferred route in free routing environment, leading to less ATC induced conflicts. It is a positive impact, but very small in quantitative terms.	Increase in knock-on conflicts due to a possible impact on SA. Increase in conflicts by trajectory management instructions due to a possible impact on SA. ATCo will consequently need appropriate tools to manage tactical conflicts.
	Disregarded negative impact: Trajectory revision using LAT/LON is out of scope of this solution, so there is no negative impact on induced conflicts caused by more inadequate communications when using LAT/LON instead of fixed points.
Safety Criteria: Positive and negative impacts balanced: no increase in ATC induced conflicts. **SAC#2:** The number of "ATC induced tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high / very high complexity Free Routing Environment	

Table 2: Precursor "ATC induced tactical conflict"

Precursor "ATC induced pre-tactical conflict" (MF 9.1 of Figure 1)	
Positive impact	**Negative impact**
On the precursor: number of planning actions (pre-tactical instructions) in free routing. Less ATCO intervention from upstream sectors.	No negative impact
Safety Criteria: No negative impact. Conservative SAC: maintain ATC induced pre-tactical conflicts **SAC#3:** The number of "ATC induced pre-tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high / very high complexity Free Routing Environment	

Table 3: Precursor "ATC induced pre-tactical conflict"

Precursor "Crew/aircraft induced tactical conflict" (MF 6.1 of Figure 1)	
Positive impact	**Negative impact**
On the precursor: Aircraft are flying their preferred route in free routing environment, leading to less requests (both from pilots and ATCOs) for trajectory revision and then to fewer pilot induced deviations.	Disregarded negative impact: Trajectory revision using LAT/LON is out of scope of this solution, so there is no negative impact on crew induced conflicts caused by pilot misunderstanding when using LAT/LON instead of fixed points.
Safety Criteria: No negative impact. Conservative SAC: maintain crew induced tactical conflicts **SAC#4:** The number of "crew/aircraft induced tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high / very high complexity Free Routing Environment	

Table 4: Precursor "Crew/aircraft induced tactical conflict"

Barrier "Tactical Conflict Management" (B5 & B6 & B7 of Figure 1) / **Precursor "Imminent Infringement"** (M5-9 of Figure 1)	
Positive impact	**Negative impact**
On the barrier: Easier conflict detection due to better aircraft trajectory predictability (less unexpected trajectories)	On the barrier on conflict detection: Difficult to maintain and memorize the traffic model (routes of the aircrafts in the sector) due to irregularity of the traffic in free routing environment. This may not necessarily happen, depending on the environment and the variability of the traffic demand. Conflict will no longer occur at published points, but will be widely dispersed among numerous points: it can be more difficult to detect and locate conflicts in free routing environment. Difficult to monitor conformance to the route (since not all routes are known by the ATCO) in free routing environment and, consequently, difficult to detect aircraft deviations (potential pilot/aircraft induced conflict) Assumed to be mitigated by the MONA tool, maybe no requirements will be derived from this aspect.

Barrier "Tactical Conflict Management" (B5 & B6 & B7 of Figure 1) / **Precursor "Imminent Infringement"** (M5-9 of Figure 1)	
Positive impact	**Negative impact**
	On the barrier on conflict resolution: Some conflict situations can be more workload demanding for ATCOs (for instance two converging trajectories with a low converging angle between the trajectories, or conflicts close to sector boundaries). Detection not impacted, only resolution. It is difficult to assess the impact of a clearance on upcoming sectors in free routing environment. It will be difficult to put back an aircraft on its route after a tactical clearance in free routing environment. The next point where to put the aircraft back can be unknown. Particularly in case of long user-defined (direct) routes across ACCs (outside the own airspace) in cross border environment, without the appropriate support tools. Traffic dispersion can make conflict resolution more difficult by vectoring.
	Disregarded negative impacts: Lack of 'classical solutions' to solve conflicts (due to irregularity of traffic in free route) was disregarded as a negative impact, because ATCOs always choose from a large 'library' of solutions, whether in fixed or free route, so there would be no difference in this respect. LAT/LON making more difficult to communicate clearances for conflict solving was also disregarded because LAT/LON is out of scope.
	it was initially expected that Free Routing Operations could reduce the number of conflicts, however, the validation activities have demonstrated that in high and very high complexity airspace, the number of conflicts remain the same and they are more difficult to anticipate due to the more random distribution of crossing points

Barrier "Tactical Conflict Management" (B5 & B6 & B7 of Figure 1) / **Precursor "Imminent Infringement"** (M5-9 of Figure 1)	
Positive impact	**Negative impact**
Safety Criteria: More negative impact than positive impact, but **mitigation** identified during the safety assessment should maintain barrier efficiency. **SAC#5:** The number of "imminent infringements" shall not increase in En Route sectors in cross border, permanent or temporary high / very high complexity Free Routing Environment.	

Table 5: Precursor "Tactical Conflict Management" / Precursor "Imminent Infringement"

Barrier "ATC Collision Avoidance" (ATCO expedite and STCA warning)	
Positive impact	**Negative impact**
No positive impact	On the barrier: no negative impact of Free Routing, except for a possible need to locally customize the STCA settings to the free routing environment
Safety Criteria: More negative impact than positive impact, but **mitigation** identified during the safety assessment should maintain barrier efficiency. **SAC#6:** The number of "imminent collisions" shall not increase in En Route sectors in cross border, permanent or temporary high / very high complexity Free Routing Environment.	

Table 6: Barrier "ATC Collision Avoidance"

Barrier "Crew Collision Avoidance" ("ACAS Warning / Visual Warning")	
Positive impact	**Negative impact**
No positive impact	No negative impact
Safety Criteria: Barrier not affected. **NO SAC**	

Table 7: Barrier "Crew Collision Avoidance"

3.5.3 Summary of Safety Criteria

SAC#1 The number of "Planned tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high / very high complexity Free Routing Environment.

SAC#2 The number of "ATC induced tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high / very high complexity Free Routing Environment.

SAC#3 The number of "ATC induced pre-tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high /very high complexity Free Routing Environment.

SAC#4 The number of “crew/aircraft induced tactical conflicts" shall not increase in En Route sectors in cross border, permanent or temporary high /very high complexity Free Routing Environment.

SAC#5 The number of "imminent infringements" shall not increase in En Route sectors in cross border, permanent or temporary high /very high complexity Free Routing Environment.

SAC#6 The number of “imminent collisions” shall not increase in En Route sectors in cross border, permanent or temporary high /very high complexity Free Routing Environment.

3.6 Mitigation of the Pre-existing Risks – Normal Operations

3.6.1 Operational Services to Address the Pre-existing Hazards

Within the EATMA ATM capabilities deemed to be contributed by PJ06-01 Solution, the following operational services are initially identified.

ATM capability			Operational Service
Level 1	Level 2	Level 3	
Conflict Management	Separation Provision	Aircraft-To-Aircraft Separation Provision (Airspace)	None existing

Table 8: Operational Services to address the pre-existing hazards.

Free Route is more an operational environment than an operational concept. Consequently, there is no operational service specific to Free Route operations in high and very high complexity environments, but these operations impact several of the “classical” operational services from the planning phase to the execution phase.

In order to ensure the completeness of the present analysis, the operational processes of the EATMA (European ATM Architecture) models (from the eATM portal [12]) have been used as input when available to identify the potential operational services impacted by the Free Route operations. Following approach has been followed:

- Operational processes relating to En Route Operations activities have been extracted from EATMA.

- A high level assessment of the impact of the Free Route operations on these processes has been performed with Free Route & Operational experts to identify which ones could be impacted by Free Route Operations.
- The list of Operational Processes identified as potentially impacted has been used as input for the definition of the safety objectives in normal operations (see Table 9)

Some operational processes identified below are potentially impacted in Free Route environment of high and very high complexity but are not covered by EATMA model (e.g. Design airspace, Perform airspace infringement management, Perform aircraft collision avoidance).

ID	Operational Activity	Pre-existing Hazards [Hp xx]
SEP_PLAN	Provide Planning Separation Assurance (see model in Appendix 0)	Hp#1, Hp#2, Hp#3
SEP_TACT	Provide Tactical Separation Assurance (see model in Appendix 0)	Hp#1, Hp#2, Hp#3
COOR	Coordination and transfer (e.g. cross border) (see model in Appendix 0)	Hp#1, Hp#2
DES	Design Airspace (*no model in EATMA*)	Hp#1, Hp#2
MONA	Ensure Trajectory Adherence (see model in Appendix 0)	Hp#1, Hp#2
STCA	Perform Short-Term Conflict Management (see model in Appendix 0)	Hp#1
APW	Perform airspace infringement management (no model in EATMA)	Hp#2
ACAS	Perform aircraft collision avoidance (no model in EATMA)	Hp#1

Table 9: ATM and Pre-existing Hazards

It is important to notice that the following operational processes were identified within SESAR 1 SAR for Free Routing but are no longer part of the scope of the solution of Free Routing within SESAR 2020:

- AFUA: Perform Civil / Military coordination in Planning phase (long term / medium term / short term) & Execution phase
- DEM: Determine Network Demand
- CAP: Plan Network Resources and Capabilities
- DCB: Balance Demand with Resources and Capabilities
- dDCB: Dynamically Balance Network Capacity with Demand
- EAP: Perform Extended ATC Planning

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

The following approach has been applied to identify the safety objectives for normal operations:

- First, the potential impact of Free Route operations on each activity of the operational processes listed in Appendix 0 have been identified, from a safety viewpoint
- Then, in case of expected impacts on an activity, the operational requirement to be implemented to counterbalance this impact, and consequently satisfy the Safety Criteria (i.e. maintain safety level for Free Route solution), have been defined

These safety objectives have been defined through two safety workshops, held with free route and operational experts (see section 3.10 for additional details regarding the participants during the safety workshops)

The following tables present:

- The impact and safety objectives identified for free routing operations
- The synthesis of the safety objectives identified for normal operations

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
0 - General				
GEN	All Flight Planning activities	In order to enable efficient and safe flight planning activities, it would be necessary that all actors (ANSP, airspace users and Network Manager) have the same level of information. Such level of information concerns both the initial flight plan intentions and any subsequent revision.	No safety objective.	The SO identified I SESAR 1 SAR is now beyond the scope of the solution. An **assumption** is defined to track the fact that all the stakeholders have to be informed of the change : **A-01** "ANSP, Airspace Users and Network Manager need to have the same level of information in flight planning phase regarding flight profile and routing in Free Routing Airspace" (see Appendix C).
1 - SEP_PLAN: Provide Planning Separation Assurance				
SEP_PLAN_01	Assess offered entry coordination and desired profile & Determine planning problems at offered entry FL	Today, acceptable entry and exit conditions are described with reference to the route structure and coordination point. In free routing environment, these conditions cannot be based on the route / published coordination point anymore.	SO-FP-001: The ATCOs shall be able to perform coordination of flights across ACC/sector boundaries not necessarily supported by published coordination points SO-FP-002: The acceptable entry and exit conditions of a sector/ACC shall be described in LoA without reference to published route network or fixed coordination point	

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
		Free route aircraft trajectories not adapted to sector design (as in fixed route network) Some flights make quick entry/exit in sector, increasing ATCOs workload, so he should be able to transfer them directly to the next sector.	SO-FP-003: The ATCOs (ATC Sector Planning and Executive Roles) shall be able to remove a sector from the ordered list of the flight sequence (list of sectors that are expected to assume the flight)	/
		Hard to communicate conflict information from an executive to a planner (no known point to relate the conflict to) without appropriate tool. Need specific ATC support tool (including HMI) to support the exchanges between PC and TC.	SO-FP-004: In order to avoid more ATC induced conflicts, ATC Sector Planning Role should be informed of ATC Sector Executive Role actions	The planning activity performed by the controller should not impact the tactical controller => new safety objective.

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
		Problem detection at entry FL is harder for planner controller due to: • no more fixed/known coordination point • traffic flow more widely spread.	SO-FP-005: The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary SO-FP-006: The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector SO-FP-007: The ATCOs shall be able to detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest.	The conflict detection is not impossible without appropriate conflict detection tool, but it takes more time. Adapted set of ATC support tool (including conflict detection tool) is required to perform efficiently and safely planning separation assurance activity.
SEP_PLAN_02	Refer to tactical who assesses problems	Hard to communicate conflict information from a planner to an executive. Harder to specify location. Can refer to points somehow but not so accurately. Need specific tool to exchange information regarding the planned conflicts.	SO-FP-008: The ATC Sector Planning Role shall be provided with tools to support information sharing between ATC Sector Planning and Executive Roles.	

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
SEP_PLAN_03	Revise entry coordination with previous sector	Hard for controllers of two sectors/ATSU to understand each other without shared references (points, routes). Need for specific coordination tool	SO-FP-009: The ATC Sector Planning Role shall be provided with tools and procedures to support coordination of flights across ACC/sector boundaries with unnamed coordination points, with the identification of a flight to any adjacent sector and support the negotiation of coordinations	
SEP_PLAN_04	Reject flight	No safety impact expected on this activity.	/	No increase of rejected flights by the Planner Controller expected in FRA.
SEP_PLAN_05	Agree entry coordination	No safety impact expected on this activity.	/	Coordination occurs at ATC planning level.

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
SEP_PLAN_06	Determine safe potential exit coordination & Assess sector profile for tactical controller suitability	Hard for controller to know the aircraft planned trajectory in its sector	SO-FP-005: The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary SO-FP-006: The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector SO-FP-010 The ATCOs should be able to assess alternative trajectories in support of the negotiation of coordination conditions with adjacent ATC sectors (planning what-if)	

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
		Structural limitation of the Free Routing Airspace should avoid or limit the complexity (e.g. conflicts close to sector/ACC boundaries). ATCO will still need conflict detection tools with appropriate time horizon and possibly working within the area of interest.	SO-FP-006: The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector SO-FP-011: The ATCOs shall be able to detect tactical encounters between two or more flights not necessarily on a fixed ATS route segment	New **safety issue I-01** "Risk of an increased number of coordinations (due to more traffic close to boundaries) and those coordinations will be more difficult to manage, increasing workload" (see Appendix C). This safety issue has been identified during SESAR 1 validation campaigns.

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
SEP_PLAN_07	Make coordination offer to following sector	Hard for controllers of two sectors/ACC to understand each other without shared references (points, routes). Need for specific coordination tool	SO-FP-009: The ATC Sector Planning Role shall be provided with tools and procedures to support coordination of flights across ACC/sector boundaries with unnamed coordination points, with the identification of a flight to any adjacent sector and support the negotiation of coordinations SO-FP-005: The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary SO-FP-006: The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector SO-FP-010: The ATCOs should be able to assess alternative trajectories in support of the negotiation of coordination conditions with adjacent ATC sectors (planning what-if	

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
2 - SEP_TACT: Provide Tactical Separation Assurance				
New **safety issue I-02** "Will it be more difficult to keep a good situational awareness for both Executive and Planner ATCOs due to more atypical situations in FRA, combined with possible peak of high workload at sector level?" (see Appendix C).				
SEP_TACT_01	Assess planned / desired profile for problems	Traffic irregularity: harder to maintain and memorize the traffic model (aircraft routes in the sector) particularly in high and very high complexity environments Trajectory with turning point in the sector will become atypical, with the associated risk that the ATCO does not properly expect the aircraft behaviour.	SO-FP-005: The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary	Functionality to highlight critical flights (e.g. flight with turning point in the sector) is considered as baseline functionality. Note: Turning point issue detected at SESAR 1 Validations

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
		Conflicts widely dispersed instead of concentrated near published points: harder to detect and locate.	SO-FP-005: The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary SO-FP-006: The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector SO-FP-011: The ATCOs shall be able to detect tactical encounters between two or more flights not necessarily on a fixed ATS route segment	The conflict detection is not impossible without appropriate conflict detection tool, but it takes more time. Adapted set of ATC support tool (including conflict detection tool) is required to perform efficiently and safely tactical separation assurance activity.

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
		Structural limitation of Free Routing Airspace should reduce or limit the situations of aircraft flying along sector boundaries. Possible unusual conflicts (e.g. two converging trajectories with low converging angle) Need to detect this kind of situations inside the whole area of interest.	SO-FP-006: The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector	
		No strategic separation between trajectories of the aircraft and stack En Route: hard to detect conflicts with stack En Route. Need tool to detect this kind of conflicts	SO-FP-012: The ATCOs (ATC Sector Planning and Executive Roles) should be provided with a tool detecting the potential crossing between the planned trajectory of the aircraft and active stack En Route in the sector	This SO was not kept as safety requirement in SESAR 1 SAR because it was considered very unlikely to happen. This SO is now considered using “should”.

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
		Hard to detect conflicts with restricted areas. Tactical controller needs: • timely info of ARES status • tool to detect this kind of conflict	SO-FP-013: The ATCOs (ATC Sector Planning and Executive Roles) shall be informed in due time of ARES activation status (active/not active/released) within the area of interest of the sector SO-FP-014: The ATCOs shall be able to detect predicted infringement of active ARES by flights along their planned trajectories within the ATC sector area of interest	
SEP_TACT_02	• Assess planned profile constraints or agreed coordination • Establish necessary separation • Agree coordination actions	Conflict resolution is not so different from fixed route environment, where classical resolution solutions don't always work, requiring specific ones to be created ad-hoc.	No safety objective.	Harder conflict resolution with no airspace structure and where any kind of conflict may occur. Examples: • trajectories with a small angle: uneasy + unfamiliar resolution. • two close conflicts with different crossing points: difficult mutual resolution. It seems acceptable to use existing tools rather than a dedicated one

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
		The most critical part is the detection of the conflicts, not the resolution.	SO-FP-015: The ATCO of sector before FRA shall be aware of FRA lower limit and give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory	
SEP_TACT_03	• Establish necessary separation • Agree coordination actions	Support tool required to assess alternatives for trajectory revision unusual situations in high and very high complexity environment.	SO-FP-016: The ATCOs shall be able to assess tactical trajectory revision options including alternative trajectories across ACC/sector boundaries (tactical what-if)	
SEP_TACT_04	• Agree coordination actions	Tactical coordination not necessarily supported by coordination points. Less structured traffic. There will be more need for tactical coordination in FRA high and very high complexity, potentially increasing workload: potential need for support.	SO-FP-001: The ATCOs shall be able to perform coordination of flights across ACC/sector boundaries not necessarily supported by published coordination points	Tactical coordination shall be possible not necessarily supported by coordination points (most probably will be removed but we keep it for now). In case of no problem, just silent coordination.
SEP_TACT_05	Issue clearances to achieve conditions	No impact	No safety objective.	LAT/LON out of scope

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
SEP_TACT_06	Analyze and execute ATC clearance	No impact	No safety objective.	LAT/LON out of scope
SEP_TACT_07	Monitor clearance implementation	No expected impact: ATCO only monitors that the flight does not deviate from trajectory according to given clearance.	No safety objective.	Other deviations are then detected within the frame of the activity "ensure trajectory adherence" (see MONA operational activity)
SEP_TACT_08	Check conformance to planned constraints	No impact	No safety objective.	/
5 - COR: Coordination and Transfer				
No safety objective: The existing EATMA diagrams more apply for IOP and are not applicable for FRA. They have been developed specifically for IOP (Flight Object) which is considered as out of scope of the solution. At the moment, some high level operational requirements are defined (need for coordination support tools).				
6 - DES : Airspace design & management				

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
DES_01	Design of the airspace	The flight planning rules applicable in the free routing airspace need to be defined and published. They include entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility to plan or not user defined points.	SO-FP-032: Flight planning rules applicable inside the free routing airspace (entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility to plan user defined points...) shall be defined and published in national AIS publication.	/
7 - MONA: Ensure Trajectory Adherence				
MONA_01	Monitor trajectory adherence and detect deviations	Harder lateral monitoring due to absence of fixed routes. Trajectories can change from one day to another Trajectory display and deviation detection tools needed.	SO-FP-005: The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary SO-FP-029: The ATCOs shall be provided with support to monitor trajectory adherence	ATCO can hardly monitor by themselves the route adherence with unfamiliar routes. SO-FP-005 is part of the baseline (part of the environment).
MONA_02	Assess deviation cause	No safety impact expected on this activity	No safety objective.	/
MONA_03	Check current flight data	No safety impact expected on this activity	No safety objective.	/
MONA_04	Restore adherence to planned trajectory	No safety impact expected on this activity	No safety objective.	/

Ref	Operational Activity	Impact of Free Routing Operations	Safety Objective	Comments
MONA_05	Execute ATC clearance	No safety impact expected on this activity	No safety objective.	/
MONA_06	Correct ground data	No safety impact expected on this activity	No safety objective.	/
8 - STCA: Perform Short-Term Conflict Management				
STCA_01	Perform Short-Term Conflict Management	Tactical ATCOs confronted with a multitude of ever different trajectories. STCA needed, with settings adapted to FRA	SO-FP-030: The ATCOs shall be assisted by a Short-Term Conflict Alert system	This SO is considered as a baseline (no new functionality) => an **assumption** has to be defined: **A-02** "STCA settings may need to be adapted to Free Routing operations" (see Appendix C).
9 - APW: Perform airspace infringement management				
APW_01	Perform airspace infringement management	Tactical ATCOs confronted with a multitude of ever different trajectories. Unauthorized penetration warning (APW) needed, with settings adapted to FRA	SO-FP-031: The ATCOs shall be assisted by an Area Proximity Warning system	This SO is considered as a baseline (no new functionality) => an **assumption** has to be defined: **A-03** "APW settings may need to be adapted to Free Routing operations" (see Appendix C).
10 - ACAS: Perform aircraft collision avoidance				
ACAS_01	Perform aircraft collision avoidance	No impact on the aircraft collision avoidance is expected in free routing environment	No safety objective.	ACAS is mandatory in the airspace but no impact on FRA

Table 10: Solution Operational Activities & Safety Objectives (success approach)

*It is important to notice that the following Safety Objectives were identified during SESAR 1 safety assessment for Free Routing (**the coding of those following SOs is the one of SESAR 1 SAR**) but are no longer valid as part of the SESAR 2020 safety assessment because they are linked to operational processes out of scope of the Free Routing solution for SESAR 2020:*

- *SO linked to AFUA operational activity: SO_FRA_005/006/007/007b*
- *SO linked to DEM operational activity: SO_FRA_003, SO_FRA_009/010/011/012/013/014/015/017*
- *SO linked to CAP operational activity: SO_FRA_016*
- *SO linked to DCB operational activity: SO_FRA_017/018/019/020/021*
- *SO linked to dDCB operational activity: SO_FRA_022*

The following table synthesizes the SO identified for Free Routing within SESAR 2020:

ID	Description	Old Coding from SESAR 1
SO-FP-001	The ATCOs shall be able to perform coordination of flights across ACC/sector boundaries not necessarily supported by published coordination points	SO_FRA_023
SO-FP-002	The acceptable entry and exit conditions of a sector/ACC shall be described in LoA without reference to published route network or fixed coordination point	SO_FRA_024
SO-FP-003	The ATCOs (ATC Sector Planning and Executive Roles) shall be able to remove a sector from the ordered list of the flight sequence (list of sectors that are expected to assume the flight)	SO_FRA_027
SO-FP-004	In order to avoid more ATC induced conflicts, ATC Sector Planning Role should be informed of ATC Sector Executive Role actions	(new safety objective)
SO-FP-005	The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary	SO_FRA_028
SO-FP-006	The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector	SO_FRA_029
SO-FP-007	The ATCOs shall be able to detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest	SO_FRA_030

ID	Description	Old Coding from SESAR 1
SO-FP-008	The ATC Sector Planning Role shall be provided with tools to support information sharing between ATC Sector Planning and Executive Roles.	(new safety objective)
SO-FP-009	The ATC Sector Planning Role shall be provided with tools and procedures to support coordination of flights across ACC/sector boundaries with unnamed coordination points, with the identification of a flight to any adjacent sector and support the negotiation of coordinations	SO_FRA_025
SO-FP-010	The ATCOs should be able to assess alternative trajectories in support of the negotiation of coordination conditions with adjacent ATC sectors (planning what-if)	(new safety objective)
SO-FP-011	The ATCOs shall be able to detect tactical encounters between two or more flights not necessarily on a fixed ATS route segment	SO_FRA_033
SO-FP-012	The ATCOs (ATC Sector Planning and Executive Roles) should be provided with a tool detecting the potential crossing between the planned trajectory of the aircraft and active stack En Route in the sector	SO_FRA_032
SO-FP-013	The ATCOs (ATC Sector Planning and Executive Roles) shall be informed in due time of ARES activation status (active/not active/released) within the area of interest of the sector	SO_FRA_026
SO-FP-014	The ATCOs shall be able to detect predicted infringement of active ARES by flights along their planned trajectories within the ATC sector area of interest	SO_FRA_014
SO-FP-015	The ATCO of sector before FRA shall be aware of FRA lower limit and give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory	SO_FRA_040
SO-FP-016	The ATCOs shall be able to assess tactical trajectory revision options including alternative trajectories across ACC/sector boundaries (tactical what-if)	(new safety objective)
SO-FP-029	The ATCOs shall be provided with support to monitor trajectory adherence	SO_FRA_035
SO-FP-030	The ATCOs shall be assisted by a Short-Term Conflict Alert system	SO_FRA_036
SO-FP-031	The ATCOs shall be assisted by an Area Proximity Warning system	SO_FRA_037

ID	Description	Old Coding from SESAR 1
SO-FP-032	Flight planning rules applicable inside the free routing airspace (e.g. entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility or not to plan user defined points...) shall be defined and published in national AIS publication	SO_FRA_003

Table 11: List of Safety Objectives (success approach) for Normal Operations

3.7 Solution Operations under Abnormal Conditions

The purpose of this section is to assess the ability of the Free Route PJ.06-01 solution to work through (robustness), or at least recover from (resilience) any abnormal conditions, external to the System, that might be encountered relatively infrequently

3.7.1 Identification of Abnormal Conditions

The following list of abnormal conditions has been identified as relevant for the Free Route solution by operational experts:

- ABN-01: Bad weather (CBs, turbulences, icing)
- ABN-02: Severe ATC technical system failure - Total loss of surveillance system
- ABN-03: Severe ATC technical system failure - Total loss of air/ground communication system
- ABN-04: Severe ATC technical system failure - Total loss of FDPS
- ABN-05: Severe ATFCM technical system failure - Total loss of local DCB tool
- ABN_06: Aircraft in emergency
- ABN_07: Severe aircraft technical system failure - Radio communication failure
- ABN_08: Severe aircraft technical system failure - Loss RVSM capability
- ABN-09: Severe aircraft technical system failure - Transponder failure

Remark:

Due to the transversal nature of the Free Route Solution it is difficult to distinguish abnormal operational conditions (external to the scope of the Solution) and system-generated hazards (caused by implementation of the Free Route Solution). Consequently, both lists (list of abnormal operational conditions and list of hazards) include some ATC system failure but the following rules are applied:

- *Failures of new ATC system required when implementing Free Route operations are considered as failure mode or hazards (see section 3.8 for description of the methodology applied for hazard identification)*
- *Failures of existing ATC systems are considered as abnormal operational conditions*

3.7.2 Potential Mitigations of Abnormal Conditions

Ref	Abnormal Conditions	Operational Effect	Mitigation of Effects / [SO xx]
ABN-01	Bad weather (CBs, turbulences, icing)	Effects in planning phase No major difference between fixed route environment and free routing environment. In case of bad weather, some DCB measure might be implemented in planning phase, for instance reduction of the capacity (*existing mitigation means*). Free routing could alleviate the effect of avoidance of weather event because there are more available options in planning phase. Effects in execution phase Case of turbulences and icing : aircraft will change level (vertical deviation). There might be an issue if the aircraft has to go outside the vertical limit of the Free Routing Airspace (**SO-FP-015**) Case of CBs : Aircraft will possibly avoid the area with lateral deviation. Flight crew asks the ATCO before deviation. No change compared to the situation in fixed route environment.	**SO-FP-015**: The ATCO of sector before FRA shall be aware of FRA lower limit and give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory

Ref	Abnormal Conditions	Operational Effect	Mitigation of Effects / [SO xx]
ABN-02	Severe ATC technical system failure - Total loss of surveillance system	In case of failure of the surveillance system : - tracks are no more displayed to the ATCO (a symbol indicates the last position received for each aircraft), - radar separation (5NM) cannot be applied anymore - TCT and STCA are in degraded mode - Display of the planned trajectory is still possible - MTCD (based on flight plan trajectory) is still working At the moment of the failure, the only fall back consists in using 500ft vertical separation to manage the critical situation (existing mitigation means, not specific to free routing). Increase of the workload of the ATCO to manage the aircraft of the sector without surveillance display. Possible loss of separation between aircraft. When the short term situation has been managed, control services are provided in degraded mode: - ATCO can no more apply radar separation and have to go back to procedural separation (existing mitigation means) based on flight plan information, pilot reports and display of the trajectory - capacity thresholds are reduced (capacity reduction in case of ATC system failure might be different in free routing environment than in fixed route environment: **SO-FP-033**).	Use of 500 ft vertical separation (*existing mitigation means*) Procedural control (*existing mitigation means*) **SO-FP-033**: Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)
ABN-03	Severe ATC technical system failure - Total loss of air/ground communication system	In case of loss of radio, CPDLC can be used as a backup If CPDLC is not available, same procedure as in fixed route environment applies: - In the absence of ground instruction, aircraft will continue on their flight plan - ATCO will contact adjacent center to ask them to relay the messages to the aircraft (*existing mitigation means*) - Capacity of the sector/ACC is reduced (capacity reduction in case of ATC system failure might be different in free routing environment than in fixed route environment: **SO-FP-033**).	**SO-FP-033**: Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)

Ref	Abnormal Conditions	Operational Effect	Mitigation of Effects / [SO xx]
ABN-04	Severe ATC technical system failure - Total loss of FDPS	*Remark : Assessment of this hazard on a general basis appears to be very difficult considering that operational effects depend upon the local architecture of the ATC system.* Considering the increased importance of the trajectory derived information in free routing environment, the effect of this failure could be more severe in free routing environment than in fixed route environment. In case of failure of all FDPS (main and back-up), all trajectory derived information are impacted. Depending on local implementation, impacts could be: - No more flight strip, - Impossible to display the planned trajectory of the aircraft on the HMI - Detection tool based on flight plan information (MTCD and TCT) are unavailable or degraded - Degradation / loss or automatic coordination functions - Surveillance information are still displayed **Mitigation means shall be defined depending upon local architecture for the management of the short term degraded situation.** When the short term situation has been managed, control services are provided in degraded mode: - capacity thresholds are reduced (capacity reduction in case of ATC system failure might be different in free routing environment than in fixed route environment: **SO-FP-033**).	**SO-FP-033**: Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)

Ref	Abnormal Conditions	Operational Effect	Mitigation of Effects / [SO xx]
ABN-06	Aircraft in emergency	In case of emergency situation (such as loss of pressurization or loss of engine), the flight crew will apply the appropriate emergency procedure (same mitigation in fixed route environment and in free routing environment). In free routing environment, if the emergency procedure requires a descent, there will be less probability of having an aircraft below, since aircraft are not flying the same trajectories (no fixed route) On the other hand, as trajectories are much more variable, it's more difficult to check if there is an aircraft below. Considering both aspects, risk of collision with an aircraft below remains similar in these situations.	No specific safety objective for this abnormal condition in free routing environment
ABN-07	Severe aircraft technical system failure - Radio communication failure	In the absence of ground instruction, flight crew will follow the flight plan until the IAF. If the aircraft is being radar vectored: the standard procedure that might depend on the ICAO regional regulation has to be applied. No specificity in free routing environment.	No specific safety objective for this abnormal condition in free routing environment
ABN-08	Severe aircraft technical system failure - Loss RVSM capability	Same effects and mitigations as in fixed route environment: - Pilot announce the loss of RVSM capability to the ATCO - RVSM flight level cannot be used anymore	No specific safety objective for this abnormal condition in free routing environment
ABN-09	Severe aircraft technical system failure - Transponder failure	Impact on board: no difference in free routing environment and fixed route environment. Impact on ground: Loss of the fight track on the HMI (En Route HMI are only based on secondary radar). Same mitigations as for total loss of surveillance (see ABN_02 "Total loss of surveillance system")	See safety objectives associated to ABN_02 "Total loss of surveillance system"

Table 12: Additional Safety Objectives (success approach) for Abnormal Conditions

The following Safety Objective has been derived to mitigate the effects of the abnormal conditions:

ID	Description
SO-FP-033	Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)

Table 13: List of Safety Objectives (success approach) for Abnormal Operations

3.8 Mitigation of System-generated Risks (failure approach)

This section concerns Free Route operations in the case of internal failures. Before any conclusion can be reached concerning the adequacy of the safety specification of Free Route operations, at the OSED level, it is necessary to assess the possible adverse effects that failures internal to the end-to-end Solution System might have upon the provision of the relevant operational services described in section 3.6 and to derive safety objectives (failure approach) to mitigate against these effects

3.8.1 Identification and Analysis of System-generated Hazards

The identification and analysis of system generated hazard has been performed in accordance with the Safety Reference Material methodology, but with some specificities linked to the transversal nature of the Free Route Solution.

The **identification of the system-generated hazards** appeared to be complicated for the Free Route Solution considering that there is not really "end-to-end Solution System" but more a Free Route environment. This identification has been performed with the following approach:

- Use of a systematic approach for identification of a preliminary list of hazards. During this systematic approach two kind of hazards were identified
    - Non-compliance with flight planning rules applicable in the Free Routing Airspace (e.g. "*Aircraft entering the free routing airspace on a user defined route (not part of fixed route network) outside FRA activation period*")
    - Failure of the system/tool identified as required for free route operations in the success case (i.e. "*Loss of route adherence monitoring tool in FRA*")
- Review and update of the preliminary list of hazards during the "failure approach safety workshop" held with operational experts (see section 3.10 for additional details regarding the participants, during the safety workshop).

The **analysis of the hazards** included the following activities, for each hazard

- Identification of possible causes of the hazard and prevention mitigation means (mitigation to prevent the hazard occurring)
- Identification of operational effects of the hazard and protection mitigation means (mitigation to minimize the effects of this hazard)

- Identification of the precursor associated to the hazard and determination of the severity, according to the AIM barrier model.

These activities have been performed through a "failure approach safety workshop" held with operational experts (see section 3.10 for additional details regarding the participants, during the safety workshop).

The **main outputs** of these activities are:

- A list of new Safety Objectives, derived from mitigation means
- A list of hazards classified according to their severity, to be derived into Integrity & Reliability Safety Objectives (see section 3.8.2).

Table 14 below presents the summary of the hazard identification and assessment activity. These tables are organized as follows:

- Column 1 indicates the operational hazard reference (HZ-XXX)
- Column 2 provides the description of the operational hazard,
- Column 3 indicates the related Functionality & Performance Safety Objectives i.e. whose failure originated the hazard,
- Column 4 describes the assessed Operational Effects of each hazard, including the AIM precursor of the Mid Air Collision model corresponding to the hazard,
- Column 5 indicates the mitigations means for the hazards' effects, referred to the AIM MAC model barrier where they are allocated. F&P Safety Objectives that were derived during the success case are mentioned here. Additional F&P Safety Objectives that were not derived during the success case but have been proposed during the failure case are also included here and later presented in Table 15.
- Column 6 indicates the allocated severity as per MAC severity classification scheme,

Table 15 presents additional Functionality & Performance Safety Objectives that have been detected during the failure assessment, as functional mitigations for the effects of some hazards.

Table 16 presents the list of Integrity & Reliability Safety Objectives derived from the mitigation means during the failure approach.

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 001	Failure to apply the sector/ACC coordination procedure, either by planner ATCO or other actor in coordination not following LoA *(NOTE: Procedure for sector/ACC coordination without reference to fixed route network or fixed coordination point shall be defined and applied in free routing environment)*	SO-FP-001 SO-FP-002	Conflict generated from bad inter-sector planning or bad coordination. **ATC-induced pre-tactical conflict.**	Barrier B10 "Traffic Planning and Synchronisation", more particularly rerouting of the aircraft onto known points (*existing mitigation means*)	MAC-SC4a
HZ 002	ATCO Failure to remove a flight of her/his sector from the ordered list of sectors that are expected to assume a given flight	SO-FP-003	Conflict generated from bad inter-sector planning or bad coordination. **ATC-induced pre-tactical conflict.**	Barrier B10 "Traffic Planning and Synchronisation", more particularly rerouting of the aircraft onto known points (*existing mitigation means*)	MAC-SC4a

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 003	Planner controller not being informed of tactical controller actions (failure of tactical-planner information sharing tools)	SO-FP-008	Conflict generated from bad coordination. **ATC-induced pre-tactical conflict.**	Barrier B10 "Traffic Planning and Synchronisation", more particularly rerouting of the aircraft onto known points (*existing mitigation means*)	MAC-SC4a

HZ 004	Loss of display of the planned trajectory in FRA (tool/function unavailable)	SO-FP-005	Harder to perform the following activities: - determine flight direction - perform manual conflict detection - check trajectory adherence (though MONA is still working, it's the display that fails) Rerouting needed and to be coordinated with pilot to ensure consistency with planned trajectory (which may use unknown points) High workload increase of the planning and tactical controller: potential overload. All aircraft impacted, affecting traffic planning & synchronization tasks and leading to a planned tactical conflict, to be managed by the tactical controller aided by appropriate tools such as tactical conflict detection tool (SO-FP-011). It can also lead to induced tactical conflict and overload in other sectors. After management of the short term situation, capacity of the sector might need to be reduced to maintain an acceptable workload (SO-FP-033) **Planned tactical conflict.** **&** **Induced tactical conflict**	Barrier B11 "Short Term DCB", after management of the short term situation, more particularly reduction of capacity (SO-FP-033) & Barrier B10 "Traffic Planning and Synchronisation", more particularly rerouting of the aircraft onto known points (existing mitigation means) & Barrier B5-9 "Tactical Conflict Management", aided with appropriate tool, such as TCT (SO-FP-011) In cross-border, short term DCB will be less effective. Need to predefine scenarios for action on 'contingencies'. Scenarios to be agreed: development of LoA MONA and MTCD might be working, but the ATCO needs to know that at least these other ones are working or not: New F&P Safety Objective: Tools shall indicate readiness in the HMI.	MAC-SC4a
HZ 005	Discrepancy between ground and airborne trajectory in FRA	SO-FP-029	The trajectory displayed on the HMI is different from the trajectory inside the FMS of the aircraft. A discrepancy between the planned trajectory and the current position of the aircraft will be detected by the ATCO, possibly	Barrier B5-9 "Tactical Conflict Management", particularly	MAC-SC4a

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
			aided by route adherence monitoring tool (SO-FP-029), within the tactical conflict management task. The detection of this discrepancy without tool is more complicated in free routing environment than in fixed route environment due to the multiple possible trajectories within the sector. Within the frame of a discrepancy induced by the crew/aircraft, the situation will be more difficult to detect by the tactical controller and is more likely to affect the tactical conflict management task. **Induced tactical conflict.**	Route adherence monitoring tool - MONA (SO-FP-029)	

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 006	Loss of the mid-term conflict detection tool in FRA (tool unavailable) *Remark : This tool detects conflict at entry/exit flight level and within the sector. This tool considers conflicts between several aircraft and conflicts between aircraft and restricted airspace (including active En Route stack).*	SO-FP-007	MTCD tool unavailable: the mid-term conflict detection needs to be done manually. Conflict detection can be performed using the display of the planned trajectory (SO-FP-005) and the SEP tool (SO-FP-006), though in free route airspace conflict points are more widespread , strongly increasing workload. Conflict detection time horizon reduced for planner controller, so some conflicts are not detected by the planner, leading to a tactical conflict, to be managed by the tactical controller aided by appropriate tools such as tactical conflict detection tool (SO-FP-011).After management of the short term situation, capacity of the sector might need to be reduced to maintain an acceptable workload (SO-FP-033).MTCD detects conflicts for approximately next 10-20min, so there is time enough to check flights and detect conflicts manually. The result is a reduction in detection time, but most of them will be detected. **Planned tactical conflict**	Barrier B11 "Short Term DCB", more particularly reduction of capacity (SO-FP-033) & Barrier B10 "Traffic Planning and Synchronisation", more particularly, Manual mid-term conflict detection based on the display of the planned trajectory (SO-FP-005) and SEP (SO-FP-006) & Barrier B5-9 "Tactical Conflict Management", more particularly, tactical conflict management by the tactical controller aided by TCT (SO-FP-011) the ATCOs (Planner and Exec) need to know whether MTCD is working or not: New F&P Safety Objective: Tools shall indicate readiness in the HMI.	MAC-SC4b

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 007	Corruption of the mid-term conflict detection in FRA where one conflict is not detected by the tool *Remark: Very unlikely to have such a SW failure not detecting a mid-term conflict. It will be more a situation of lack of data with such an advance. The system does what it can with the available information (FP), but if things change later, it cannot detect the conflict.*	SO-FP-007	**Assumption:** planning controller performs "manual" mid-term conflict detection in parallel to the management of the conflicts detected by the mid-term conflict detection tool (**A-04**). In case of one conflict not detected by the tool, it will be detected by the planning controller based on the trajectory of the aircraft (SO-FP-005) and the SEP tool (SO-FP-006). Conflict detection time horizon is reduced, slightly increasing Planning Controller workload. In high / very high complexity, not all the conflicts will be detected manually by the planner. It is possible that a few will be missed, it can lead to a tactical conflict. **Planned tactical conflict**	Barrier B10 "Traffic Planning and Synchronisation", more particularly, manual mid-term conflict detection based on the display of the planned trajectory (SO-FP-005) and SEP (SO-FP-006) & Barrier B5-9 "Tactical Conflict Management", more particularly, tactical conflict management by the tactical controller aided by TCT (SO-FP-011)	MAC-SC4b
HZ 008	Corruption of the mid-term conflict detection in FRA where the tool detects a conflict that does not exist	SO-FP-007	*Same impact as in fixed route environment.* *No specific mitigation means in free routing environment.* *No effect. When the planner starts trying the supposed conflict, he will realize it was not such conflict.*	N/A	N/A

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 009	Loss of the inter sector/ACC coordination tool in FRA (Tool unavailable)	SO-FP-009	In case of unavailability of the coordination tool, the coordination is performed by phone for all aircraft entering or leaving the sector (existing mitigation means). Phone coordination is more complicated in free routing environment than in fixed route environment due to the absence of fixed coordination points, increasing workload of the planning controller. However, it is considered that the Planning Controller is able to manage the situation without affecting its traffic planning & synchronization tasks (all aircraft are correctly coordinated), preventing a tactical conflict, so the worst credible effect is a pre-tactical conflict. After management of the short term situation, capacity of the sector might need to be reduced to maintain an acceptable workload (SO-FP-033) **Pre-tactical conflict**	Barrier B11 "Short Term DCB", more particularly reduction of capacity (SO-FP-033) & Barrier B10 "Traffic Planning and Synchronisation", more particularly phone coordination (existing mitigation means)	MAC-SC5
HZ 010	Corruption of the inter sector/ACC coordination tool in FRA (coordination with a wrong sector)	SO-FP-009	*Same impact as in fixed route environment.* *No specific mitigation means in free routing environment.*	N/A	N/A

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 011	Loss of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector	SO-FP-006	MTCD will detect the conflicts, but the minimum separation display tool is also helpful to solve conflicts. In high / very high complexity, vectors will be harder without minimum separation display tool, only vertical separation, resulting in a very increased workload for the planner controller, but finally being able to solve the conflicts, which will result in Pre-tactical conflicts. **Pre-tactical conflict**	Barrier B11 "Short Term DCB", more particularly reduction of capacity (SO-FP-033) & Barrier B10 "Traffic Planning and Synchronisation", more particularly, using MTCD (SO-FP-007) and providing vertical separation (existing mitigation means)	MAC-SC5
HZ 012	Corruption of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector resulting in a wrong minimum separation calculation	SO-FP-006	MTCD will detect the conflicts, but the minimum separation display tool is also required to solve conflicts. Therefore, being corrupted, many of these conflicts will not be solved and become tactical conflicts. The Tactical Controller Tool will prevent the tactical conflict from becoming an imminent infringement. **Planned Tactical conflict**	Barrier B10 "Traffic Planning and Synchronisation", more particularly, using MTCD (SO-FP-007) & Barrier B5-9 "Tactical Conflict Management", more particularly, tactical conflict management by the tactical controller aided by TCT (SO-FP-011)	MAC-SC4b

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 013	Loss of the Planning the What-If Tool *Remark: Planning What-if assesses alternative trajectories in support to negotiation of coordination conditions.*	SO_FP_010	Increased workload for Planner ATCO Need to re-coordinate with next sector. Workload increase for both planner controllers. Possible pre-tactical conflict in the next sector. **Pre-tactical conflict**	Barrier B11 "Short Term DCB", more particularly reduction of capacity (SO-FP-033) & Barrier B10 "Traffic Planning and Synchronisation", more particularly, using MTCD by the planner controller of the next sector (SO-FP-007)	MAC-SC5
HZ 014	Corruption of the Planning What-If Tool *Remark: Planning What-if assesses alternative trajectories in support to negotiation of coordination conditions.*	SO_FP_010	Increased workload for Planner ATCO MTCD at next sector (and also in the traffic sector) will warn both planner controllers of the potential conflict. Need to re-coordinate. Workload increase for both planner controllers. Possible pre-tactical conflict in the next sector. **Pre-tactical conflict**	Barrier B10 "Traffic Planning and Synchronisation", more particularly, using MTCD by the planner controller of the next sector (SO-FP-007)	MAC-SC5

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 015	Loss of the Tactical Conflict Detection tool (CDT) in FRA	SO-FP-011	Unavailability of the Conflict Detection tool requires conflict detection by the Tactical Controller to be done "manually", using the display of the planned trajectory (SO-FP-005) and the surveillance display. Free routing airspace makes conflict points more widespread, so conflict identification is more complicated, increasing workload. Imminent Infringement will be the worst credible effect in high / very high complexity (CDT belongs to B5-9 barrier) After management of the short term situation (management of aircraft/conflict in the sector when failure occurs), capacity might need to be reduced to maintain an acceptable workload (SO-FP-033) **Imminent Infringement**	Barrier B11 "Short Term DCB", more particularly reduction of capacity (SO-FP-033) & Barrier B5-9 "Tactical Conflict Management", more particularly, manual tactical conflict detection based on the display of the planned trajectory (SO-FP-005) & Barrier B3 “STCA Warning” and “B4 ATCo Expedite”	MAC-SC3

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 016	Corruption of the Tactical Conflict Detection tool (CDT) in FRA where one conflict is not detected by the tool	SO-FP-011	**Assumption:** tactical controller performs "manual" tactical conflict detection in parallel to the management of the conflict detected by the tactical conflict detection tool (**A-05**). In case of a conflict not detected by the tool, it will be detected by the tactical controller during its manual conflict detection based on the trajectory of the aircraft (SO-FP-005). The time horizon of the conflict detection performed by the tactical controller is shorter than the one of the tool. Consequently, this hazard would lead to a loss of anticipation in the detection of one tactical conflict. The worst credible effect will be an imminent infringement. **Imminent Infringement**	Barrier B5-9 "Tactical Conflict Management", more particularly, manual tactical conflict detection based on the display of the planned trajectory (SO-FP-005) & Barrier B3 “STCA Warning” and “B4 ATCo Expedite”	MAC-SC3
HZ 017	Corruption of the Tactical Conflict Detection tool (CDT) in FRA where the tool detects a conflict that does not exist	SO-FP-011	*Similar impact as in fixed route environment.* *No specific mitigation means in free routing environment.*	N/A	N/A

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 018	Loss of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector	SO-FP-012	ATCO will normally avoid sending an aircraft through an active stack The worst credible effect will be an imminent infringement, ant then an STCA warning. **Imminent Infringement**	Barrier B5-9 "Tactical Conflict Management", more particularly, manual tactical conflict detection based on the display of the planned trajectory (SO-FP-005) and the CDT (SO-FP-011) & Barrier B3 “STCA Warning” and “B4 ATCo Expedite”	MAC-SC3
HZ 019	Corruption of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector	SO-FP-012	ATCO will normally avoid sending an aircraft through an active stack The worst credible effect will be an imminent infringement, ant then an STCA warning. **Imminent Infringement**	Barrier B5-9 "Tactical Conflict Management", more particularly, manual tactical conflict detection based on the display of the planned trajectory (SO-FP-005) and the CDT (SO-FP-011) & Barrier B3 “STCA Warning” and “B4 ATCo Expedite”	MAC-SC3

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 020	Loss of the tool informing the ATCOs (Planner and Executive) of ARES activation status (active/not active/released) within the area of interest of the sector	SO-FP-013	Similar impact as in fixed route environment. No specific mitigation means in free routing environment. ATCO will normally avoid sending an aircraft through an active stack. The worst credible effect will be an imminent infringement, ant then an STCA warning. **Planned Tactical conflict.**	Barrier B5-9 "Tactical Conflict Management", more particularly, manual tactical conflict detection based on the display of the planned trajectory (SO-FP-005) and the CDT (SO-FP-011) & Barrier B3 “STCA Warning” and “B4 ATCo Expedite” Barrier B5-9 "Tactical Conflict Management", more particularly, manual tactical conflict detection based on the display of the planned trajectory (SO-FP-005) and the CDT (SO-FP-011) & Barrier B3 “STCA Warning” and “B4 ATCo Expedite”	MAC-SC4b

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 021	Corruption of the tool informing the ATCOs (Planner and Executive) of ARES activation status (active/not active/released) within the area of interest of the sector, consisting in a late provision of information	SO-FP-013	The worst credible effect will be a Tactical conflict. APW will still work and detect the aircraft moving towards the area. The military may also warn about the situation. **Planned Tactical conflict.**	Barrier B10 "Traffic Planning and Synchronisation", more particularly, using MTCD (SO-FP-007) & Barrier B5-9 "Tactical Conflict Management", more particularly, tactical conflict management by the tactical controller aided by TCT (SO-FP-011)	MAC-SC4b
HZ 022	Loss of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller)	SO-FP-014	ATCO is aware of active area and the aircraft is aware too. The military will warn about the imminent infringement. ATCO expedite and STCA warning will prevent it from becoming an imminent collision. The worst credible effect is an Imminent infringement. **Imminent Infringement**	Barrier B5-9 "Tactical Conflict Management", more particularly, manual tactical conflict detection based on the display of the planned trajectory (SO-FP-005) and the CDT (SO-FP-011) & Barrier B3 “STCA Warning” and “B4 ATCo Expedite”	MAC-SC3

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 023	Corruption of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller)	SO-FP-014	The military will warn about the imminent infringement and ATCO expedite and STCA warning will prevent it from becoming an imminent collision. The worst credible effect is an Imminent infringement. **Imminent Infringement**	Barrier B5-9 "Tactical Conflict Management", more particularly, conflict detection based on the CDT (SO-FP-011) & Barrier B3 “STCA Warning” and “B4 ATCo Expedite”	MAC-SC3
HZ 024	Loss of the Tactical What-If/What-Else, where an ATCO is unable to assess tactical trajectory revision options, including alternative trajectory across sector boundaries	SO_FP_016	If What If is not working and ATCO knows it, he will not use it and will analyse and make trajectory revisions manually, resulting only in Increased workload. **Pre-tactical conflict**	Barrier B11 "Short Term DCB", more particularly reduction of capacity (SO-FP-033) & Barrier B10 "Traffic Planning and Synchronisation", more particularly, using MTCD (SO-FP-007)	MAC-SC5

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 025	Corruption of the Tactical What-If, where an ATCO is provided with a wrong assessment of tactical trajectory revision options, including alternative trajectory across sector boundaries	SO_FP_016	Induced tactical conflict ATCO may choose a revision believing it's free of conflict, when it is not. **ATC Induced tactical conflict**	Barrier B10 "Traffic Planning and Synchronisation", more particularly, using MTCD (SO-FP-007) & Barrier B5-9 "Tactical Conflict Management", more particularly, tactical conflict management by the tactical controller aided by TCT (SO-FP-011)	MAC-SC4a

HZ 029	Loss of the route adherence monitoring tool in FRA (tool unavailable)	SO-FP-029	In case of unavailability of the route adherence monitoring tool, there is no automatic detection of a gap between the planned trajectory and the current position of the aircraft. The ATCOs need to perform this detection manually, aided by the display of the planned trajectory (SO-FP-005). No effect if the aircraft is flying the planned trajectory. In case of deviation of the aircraft from the planned trajectory, this deviation is more difficult to detect in free routing environment than in fixed route environment due to the absence of traffic model (trajectories in the sector might be different from one day to the other) and requires additional workload for both Planning and Tactical ATCO. Considering that all aircraft are impacted by the hazard, it is likely that traffic planning & synchronization tasks are affected (failure to perform mid-term conflict detection) leading to a planned tactical conflict, to be managed by the tactical controller aided by appropriate tools such as tactical conflict detection tool (SO-FP-011). It will be detected before STCA, with about 5-7 min timeframe. Imminent infringement is prevented. After management of the short term situation (management of aircraft/conflict in the sector when failure occurs), capacity of the sector might need to be reduced to maintain an acceptable workload (SO-FP-033). **Planned Tactical conflict.**	Barrier B11 "Short Term DCB", more particularly reduction of capacity (SO-FP-033)&Barrier B5-9 "Tactical Conflict Management", more particularly, manual detection of a deviation from the planned route, based on the display of the planned trajectory (SO-FP-005)	MAC-SC4b
HZ 030	Aircraft flying below the FRA lower limit when reaching the point after	SO-FP-015	If the aircraft has not reached the FRA lower limit, it will be in a fixed route airspace when starting its user defined segment. The situation can be detected by the previous sector or by the planning controller when performing the entry coordination	Barrier B10 "Traffic Planning and Synchronisation", more particularly : Coordination with adjacent sectors (existing mitigation means)	MAC-SC5

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
	which user defined trajectory is filed		(existing mitigation means) Depending on the operational context (current workload, number of aircraft in the sector...) the planning controller either reroute the aircraft onto a fixed route either accept the user defined trajectory (existing mitigation means) In case of rerouting, the planning controller needs to manually update the trajectory and to coordinate the new trajectory with the next sector. The management of the situation slightly increases the workload of the planning and tactical controller (communication with pilot, communication with adjacent sectors). This situation does not lead to an overload because it does not affect all aircraft. Tactical conflict is prevented by Traffic Planning and Synchronisation. **Pre-tactical conflict**	Rerouting of the aircraft on a fixed route (existing mitigation means)	

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 031	Aircraft descending below the FRA lower limit before reaching the exit/arrival point	SO-FP-032	If the descent is caused by an airborne problem, the aircraft will follow the emergency procedure : no more severe in free routing environment than in fixed route environment Otherwise, the ATCO will coordinate with subjacent sector before clearing the aircraft below FRA lower limit (existing mitigation means). The management of the situation slightly increases the workload of the planning and tactical controller (communication with pilot, communication with adjacent sectors) of the subjacent sector. This situation does not lead to an overload because it does not affect all aircraft. Tactical conflict is prevented by Traffic Planning and Synchronisation. **Pre-tactical conflict**	Barrier B10 "Traffic Planning and Synchronisation", more particularly : Rerouting of the aircraft onto known points (existing mitigation means) Coordination with adjacent sectors (existing mitigation means)	MAC-SC5

HZ 032	Aircraft flying a segment longer than the maximum authorized length in the FRA	SO-FP-032	Flight plan will be rejected by the system if it contains unknown points. A means to prevent spurious rejection of flight plans is to enrich the FDPS database with all waypoints within the maximum length of the segments (**Additional F&P Safety Objective: SO-FP-034)** In case of flight plan rejected by the system, an aircraft will enter the sector without an associated flight plan (meaning no graphical support for the trajectory of the aircraft in the sector). This situation will be detected during the entry coordination by the planning controller (existing mitigation means). The planning controller will then reroute the aircraft onto known points (existing mitigation means) and manually create a flight plan. A coordination with the pilot is necessary to determine an acceptable trajectory/route, considering that ATCOs have no information of the planned trajectory of the aircraft. The management of the situation slightly increases the workload of the planning and tactical controller (communication with pilot, communication with adjacent sectors). This situation does not lead to an overload because it does not affect all aircraft. Tactical conflict is prevented by Traffic Planning and Synchronisation. **Pre-tactical conflict**	Barrier B10 "Traffic Planning and Synchronisation", more particularly : Rerouting of the aircraft onto known points (existing mitigation means) Coordination with adjacent sectors (existing mitigation means) ATCOs shall have included all points of interest within the FDPS database (e.g. all waypoints within the maximum length of the segments)(**SO-FP-034**)	MAC-SC5
HZ 033	Aircraft flying several segments shorter than	SO-FP-032	Operational effects depend on the way the flight plan with several short segments in the sector will be managed by the FDPS. Two cases can be anticipated: - First case : System can manage the flight plan and display	Barrier B10 "Traffic Planning and Synchronisation", more particularly : Rerouting of the aircraft onto known points (existing mitigation means)	MAC-SC5

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
	the minimum authorized length in the FRA		the trajectory in the sector - Second case : System cannot display the trajectory in the sector. No operational impact of the controller. This situation will be detected during the entry coordination by the planning controller (existing mitigation means). The planning controller will then manually create a flight plan an reroute the aircraft onto known points (existing mitigation means) The management of the situation slightly increases the workload of the planning and tactical controller (communication with pilot, communication with adjacent sectors). This situation does not lead to an overload because it does not affect all aircraft. Tactical conflict is prevented by Traffic Planning and Synchronisation. **Pre-tactical conflict**	Coordination with adjacent sectors (existing mitigation means)	

ID	Description	Related SO *(success approach)*	Operational Effects	Mitigations of Effects	Severity *(most probable effect)*
HZ 034	Aircraft flying a trajectory with user defined points (LAT/LON) whereas it is not allowed	SO-FP-032	Operational effects depends on the way the flight plan will be managed by the FDPS. In case of flight plan rejected by the FDPS, an aircraft will enter the sector without an associated flight plan (meaning no graphical support for the trajectory of the aircraft in the sector). In case of flight plan rejected by the FDPS, an aircraft will enter the sector without an associated flight plan (meaning no graphical support for the trajectory of the aircraft in the sector). This situation will be detected during the entry coordination by the planning controller (existing mitigation means). The planning controller will then manually create a flight plan and reroute the aircraft onto known points (existing mitigation means). The management of the situation slightly increases the workload of the planning and tactical controller (communication with pilot, communication with adjacent sectors). This situation does not lead to an overload because it does not affect all aircraft. **Pre-tactical conflict**	Barrier B10 "Traffic Planning and Synchronisation", more particularly : Barrier B10 "Traffic Planning and Synchronisation", more particularly : Coordination with adjacent sectors (existing mitigation means) Rerouting of the aircraft onto known points (existing mitigation means)	MAC-SC5

Table 14: System-Generated Hazards and Analysis

ID	Description
SO-FP-34	ATCOs shall have included all points of interest within the FDPS database (e.g. all waypoints within the maximum length of the segments)

Table 15: Additional Safety Objectives (functionality and performance) in the case of internal failures

3.8.2 Derivation of Safety Objectives (integrity/reliability)

Integrity & Reliability Safety Objectives are derived from the list of hazards identified in the previous section. These Safety Objectives are expressed as maximum frequency of occurrence for each hazard. They are directly derived from the severity of the hazard, using the following formula (extracted from the SRM Guidance Material [2]):

$$SO = \frac{MTFoO_{relevant\_severity\_class}}{N \times IM}$$

where:

- $MTFoO_{relevant\_severity\_class}$ stands for the Maximum Tolerable Frequency of Occurrence being the maximum probability of the hazard's effect as defined in document [2], expressed per flight hour. More particularly for MAC hazards, relevant values are
  - 1e-4 per flight hour for severity class MAC-SC3
  - 1e-3 per flight hour for severity class MAC-SC4a
  - 1e-2 per flight hour for severity class MAC-SC4b
  - 1e-1 per flight hour for severity class MAC-SC5
- N is the overall number of operational hazards for a given severity class at a given barrier as obtained from document [2]. More particularly for MAC hazards, relevant values are:
  - 25 hazards for severity class MAC-SC3
  - 30 hazards for severity class MAC-SC4a
  - 30 hazards for severity class MAC-SC4b
  - 100 hazards for severity class MAC-SC5
- IM is the Impact Modification factor to take account of additional information regarding the operational effect of the hazard, in particular related to the number of aircraft exposed to the operational hazard. This factor is not used for our analysis and considered as equal to 1.

ID	Safety Objectives
HZ 001	SO-IR-001 The frequency of occurrence of a failure to apply the sector/ACC coordination procedure, either by ATC Sector Planning Role or other actor in coordination not following LoA, shall not be greater than 3.33E-05 per flight hour
HZ 002	SO-IR-002 The frequency of occurrence of an ATCO failure to remove a flight of her/his sector from the ordered list of sectors that are expected to assume a given flight, shall not be greater than 3,33E-05 per flight hour
HZ 003	SO-IR-003 The frequency of occurrence of ATC Sector Planning Role not being informed of tactical controller actions (failure of tactical-planner information sharing tools), shall not be greater than 3.33E-05 per flight hour
HZ 004	SO-IR-004 The frequency of occurrence of a loss of display of the planned trajectory in FRA (tool/function unavailable), shall not be greater than 3,33E-05 per flight hour
HZ 005	SO-IR-005 The frequency of occurrence of a discrepancy between ground and airborne trajectory in FRA, shall not be greater than 3,33E-05 per flight hour
HZ 006	SO-IR-006 The frequency of occurrence of a loss of the mid-term conflict detection tool in FRA (tool unavailable), shall not be greater than 3,33E-04 per flight hour
HZ 007	SO-IR-007 The frequency of occurrence of a corruption of the mid-term conflict detection in FRA where one conflict is not detected by the tool, shall not be greater than 3,33E-04 per flight hour
HZ 008	N/A
HZ 009	SO-IR-008 The frequency of occurrence of a loss of the inter sector/ACC coordination tool in FRA (tool unavailable), shall not be greater than 1,00E-03 per flight hour
HZ 010	N/A
HZ 011	SO-IR-009 The frequency of occurrence of a loss of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector, shall not be greater than 1,00E-03 per flight hour

ID	Safety Objectives
HZ 012	SO-IR-010 The frequency of occurrence of a corruption of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector resulting in a wrong minimum separation calculation, shall not be greater than 3,33E-04 per flight hour
HZ 013	SO-IR-011 The frequency of occurrence of a loss of the ATC Sector Planning Role What-If Tool, shall not be greater than 1.00E-03 per flight hour
HZ 014	SO-IR-012 The frequency of occurrence of a corruption of the ATC Sector Planning Role What-If Tool, shall not be greater than 1.00E-03 per flight hour
HZ 015	SO-IR-013 The frequency of occurrence of a loss of the ATC Sector Executive Role Conflict Detection tool (CDT) in FRA, shall not be greater than 4.00E-06 per flight hour
HZ 016	SO-IR-014 The frequency of occurrence of a corruption of the ATC Sector Executive Role Conflict Detection tool (CDT) in FRA where one conflict is not detected by the tool, shall not be greater than 4.00E-06 per flight hour
HZ 017	N/A
HZ 018	SO-IR-015 The frequency of occurrence of a loss of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector, shall not be greater than 4,00E-06 per flight hour
HZ 019	SO-IR-016 The frequency of occurrence of a corruption of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector, shall not be greater than 4,00E-06 per flight hour
HZ 020	SO-IR-017 The frequency of occurrence of a loss of the tool informing the ATCOs (ATC Sector Planning and Executive Roles) of ARES activation status (active/not active/released) within the area of interest of the sector, shall not be greater than 3.33E-04 per flight hour
HZ 021	SO-IR-018 The frequency of occurrence of a corruption of the tool informing the ATCOs (ATC Sector Planning and Executive Roles) of ARES activation status (active/not active/released) within the area of interest of the sector, consisting in a late provision of information, shall not be greater than 3.33E-04 per flight hour

ID	Safety Objectives
HZ 022	SO-IR-019 The frequency of occurrence of a loss of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller), shall not be greater than 4,00E-06 per flight hour
HZ 023	SO-IR-020 The frequency of occurrence of a corruption of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller), shall not be greater than 4,00E-06 per flight hour
HZ 024	SO-IR-021 The frequency of occurrence of a loss of the ATC Sector Executive Role What-If/What-Else, where an ATCO is unable to assess tactical trajectory revision options, including alternative trajectory across sector boundaries, shall not be greater than 1.00E-03 per flight hour
HZ 025	SO-IR-022 The frequency of occurrence of a corruption of the ATC Sector Executive Role What-If, where an ATCO is provided with a wrong assessment of tactical trajectory revision options, including alternative trajectory across sector boundaries, shall not be greater than 3.33E-05 per flight hour
HZ 029	SO-IR-026 The frequency of occurrence of a loss of the route adherence monitoring tool in FRA (tool unavailable), shall not be greater than 3,33E-04 per flight hour while in high / very high complexity Free Routing Operations.
HZ 030	SO-IR-027 The frequency of occurrence of an aircraft flying below the FRA lower limit when reaching the point after which user defined trajectory is filed, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
HZ 031	SO-IR-028 The frequency of occurrence of an aircraft descending below the FRA lower limit before reaching the exit/arrival point, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
HZ 032	SO-IR-029 The frequency of occurrence of an aircraft flying a segment longer than the maximum authorized length in the FRA, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
HZ 033	SO-IR-030 The frequency of occurrence of an aircraft flying several segments shorter than the minimum authorized length in the FRA, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.

ID	Safety Objectives
HZ 034	SO-IR-031 The frequency of occurrence of an aircraft flying a trajectory with user defined points (LAT/LON) whereas it is not allowed, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.

Table 16: Safety Objectives (integrity/reliability)

3.9 Achievability of the Safety Criteria

The Safety Criteria set in section 3.5 have been achieved through the specification of safety objectives (Functionality & Performance and Integrity) in sections 3.6 to 3.8

The next version of SAR will proceed with the Safe design at SPR level, deriving the Safety Objectives into Safety Requirements

3.10 Validation & Verification of the Safety Specification

The consolidated lists of Safety Objectives are provided in Appendix A

The process by which these safety objectives were derived is presented in the previous sections 3.6 to 3.8. Starting with the inputs from the results of SESAR 1 Free Routing Safety Assessment Report, the derivation process was carried out through several safety workshops with concept and operational experts and a subsequent post-processing using the SRM methodology [1].

The safety objectives for normal operations (see section 3.6) were derived and verified before V3 validation activities through two "**success case safety workshops**". The participants to these safety workshops were:

- 1st Success Case Safety workshop participants – Lisbon, 20th September 2017:
  - Florence Serdot-Omer (DSNA) – PJ.06 Project Coordinator and Solution Leader
  - Manuel Dias (NAV PT) – PJ.06-01 Safety Expert / PJ.06 Safety PoC
  - Beatrice Raynaud (DSNA) - PJ.06-01 OSED/SPR/INTEROP V3 leader
  - Rémi Berrouet (DSNA) – PJ.06-01 Project Member and Safety Expert
  - Livia Bajzikova (DSNA) - PJ06-01 Project Member
  - Erik Langevi (Naviair) - PJ06-01 Project Member, Operational Expert / Safety PoC
  - Mariusz Krzyzanowski (PANSA) – PJ.06-02 Safety Expert
  - Karim Mehadhebi (DSNA) – ATM Systems and Safety Expert
  - Miguel Capote (INECO) – PJ.06-01 Safety Expert / PJ.06 Safety PCIT

- 2nd Success Case Safety workshop participants – Toulouse, 17th October 2017:
  - Florence Serdot-Omer (DSNA) – PJ.06 Project Coordinator and Solution Leader
  - Beatrice Raynaud (DSNA) - PJ.06-01 OSED/SPR/INTEROP V3 leader

- Charlotte Chambelin (DSNA) - PJ09 Project Member and Operational Expert
- Yannick Migliorini (DSNA) - PJ06 Project Member and Operational Expert
- Rémi Berrouet (DSNA) - PJ06 Project Member and Safety Expert

The safety objectives for abnormal conditions were derived from the results of SESAR 1 Free Routing Safety Assessment Report and the adaptation to SESAR 2020 PJ.06-01 Solution.

The safety objectives for system generated hazard were derived and verified before V3 validation activities through one "**failure case safety workshop**" involving the following participants:

- Failure Case Safety Workshop participants – Madrid, 30th October 2017:
  - Manuel Dias (NAV PT) – PJ.06-01 Safety Expert
  - Manuel Martínez (INDRA) – PJ.06-01 Performance PCIT
  - Fernando Ruiz-Artaza (ENAIRE) – PJ.06-01 Project Member, ATCO/Operational Expert
  - Miguel Ángel García-Hortal - ATCO/Operational Expert
  - Susana Díaz Villar - ATCO/Operational Expert
  - José Manuel Rísquez (INECO) – PJ06 Project Member / ENAIRE PoC
  - Miguel Capote (INECO) – PJ.06-01 Safety Expert / PJ.06 Safety PCIT

4 Safe Design at SPR Level

4.1 Scope

This section addresses the following activities:

- Description of the SPR-level model (of the end-to-end Solution ATM System - section 4.2
- derivation, from the Safety Objectives (Functionality and Performance) of section 3, of Safety Requirements for the SPR-level design - section 4.2
- analysis of the operation of the SPR-level design under normal operational conditions – section 4.3
- analysis of the operation of the SPR-level design under abnormal conditions of the Operational Environment - section 4.4
- assessment of the adequacy of the SPR-level design in the case of internal failures and mitigation of the System-generated hazards - section 4.5
- justification that the SAfety Criteria are capable of being satisfied in a typical implementation - section 4.6
- realism of the SPR-level design - section 4.7
- validation & verification of the Specification - section 4.8”

The PJ.06-01 Solution Functional Model

No functional model is developed for the PJ06-01. The safety activities at SPR level are based on the SPR-level model developed in section 4.2.1.

4.2 The PJ.06-01 Solution SPR-level Model

The figure below presents the SPR-level model of the PJ.06-01 solution. This model is a high-level architectural representation of the solution system design that is entirely independent of the eventual physical implementation. The model describes

- The functional block involved in the PJ-06-01 solution (orange blocks on the model). The functional blocks considered on this model are consistent with the ones in the EATMA model. The functional blocks are not system/tool. One tool can encompass several functional blocks (e.g. PC Aid tool encompass trajectory prediction and conflict management)

- The actors involved in the PJ-06-01 solution (blue blocks on the model)

Procedures are not presented on this model. However, they will be considered for the definition of the Safety Requirements.

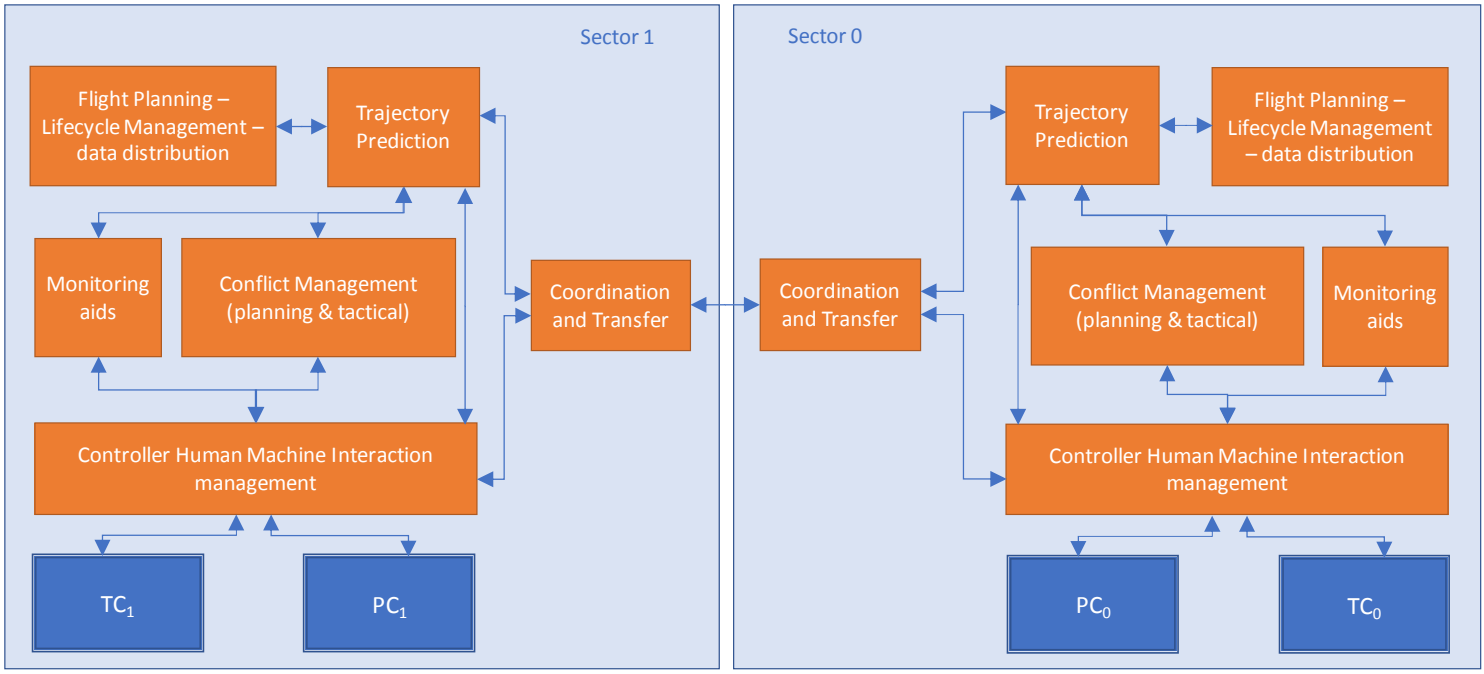


Figure 2: PJ.06-01 Solution SPR-level Model

4.2.1 Description of SPR-level Model

The different System element of the SPR-level model are:

- Flight Planning – Lifecycle Management – data distribution (FPM) functional block. This functional block is responsible for the management of the flight plan and its distribution to the appropriate controller working position within the ATSU.
- Trajectory Prediction (TP) functional block. This functional block is responsible for the prediction of the trajectory within the area of responsibility and area of interest based on the data from the flight plan (ADEP, ARES, waypoints, flight level…) and applicable constraints (e.g. agreed coordination level…). This functional block is also responsible for the prediction of alternate trajectory in support to what-if / what-else functionalities
- Conflict Management (CM) functional block. This functional block is responsible for the detection of planned and tactical conflict, based on trajectory prediction. This functional block is also responsible for the identification of possible conflict on alternate trajectory in support to what-if / what-else functionalities
- Monitoring aids (MONA) functional block. This functional block is responsible for the detection of deviation of the flight track from the cleared trajectory. This functional block covers the cleared level adherence monitoring and the route adherence monitoring.
- Coordination and Transfer (C&T) functional block. This functional block is responsible for the coordination and transfer of flight between adjacent sector/ATSU (including notification, coordination and transfer of responsibility). This functional block also support the negotiation of alternate entry/exit condition between adjacent sector/ATSU.

- Controller Human Machine Interaction management (HMI) functional block. This functional block is the human machine interface of the Air Traffic Controller, displaying appropriate information to the ATCo and allowing appropriate interactions.

- Planning Controller (PC). This actor is responsible for the implementation of the traffic planning and synchronization task.

- Tactical Controller (TC). This actor is responsible for the implementation of the tactical conflict management task.

More details about the dynamic aspects of this model and about the interaction between the different elements of the model can be found in section 4.3.1.

4.2.2 Task Analysis

Scenario for normal operation are described in section 4.3.1 and 4.3.2 (including description of the interactions between the different functional blocks and with actors) and have been taken into account during the derivation of safety requirement in section 4.2.3.

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

This section derives Safety Requirements on the elements of the SPR-level model from the Safety Objectives defined in section 3. In particular:

- Table 17 identifies the elements of the SPR-level model relating to each safety objective and derive associated safety requirements and/or assumptions. Assumptions are defined on elements out of scope of the solution PJ.06-01 or baseline functionalities

- Table 18 consolidate the safety requirements derived in Table 17

- Table 19 consolidate the assumptions derived in Table 17

This success approach analysis was carried out during a Safety Workshop held in June 3rd 2019.

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-001	The ATCOs shall be able to perform coordination of flights across ACC/sector boundaries not necessarily supported by published coordination points	PC TC	C&T	ATC operating procedures National AIS publication	SR_FP_OPS_022 - The ATCOs shall be able to perform coordination of flights across ACC/sector boundaries not necessarily supported by published coordination points SR_FP_OPS_009 – ATC operating procedures shall describe the acceptable entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point. SR_FP_SYS_001 – Coordination and Transfer function shall enable to perform coordination of flights across ACC/sector boundaries not necessarily supported by fixed coordination points SR_FP_OPS_018 - National AIS publication and RAD shall describe flight planning rules applicable inside the free routing airspace (entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility to plan user defined points...) without reference to published route network or fixed coordination point.

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-002	The acceptable entry and exit conditions of a sector/ACC shall be described in LoA without reference to published route network or fixed coordination point	PC TC	-	LoA ATC Operating procedures	SR_FP_OPS_016 - LoA shall describe the acceptable entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point. SR_FP_OPS_009 – ATC operating procedures shall describe the acceptable entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point. SR_FP_OPS_001 - ATCOs shall be trained/familiarized with new entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-003	The ATCOs (ATC Sector Planning and Executive Roles) shall be able to remove a sector from the ordered list of the flight sequence (list of sectors that are expected to assume the flight)	PC TC	C&T TP HMI	ATC operating procedures	SR_FP_SYS_023 - The ATCOs (ATC Sector Planning and Executive Roles) shall be able to remove a sector from the ordered list of the flight sequence (list of sectors that are expected to assume the flight) SR_FP_SYS_003 - Coordination and Transfer function shall enable to remove a sector from the ordered list of the flight sequence (SKIP function) SR_FP_SYS_008 - Trajectory Prediction function shall enable to remove a sector from the ordered list of the flight sequence (SKIP function) SR_FP_SYS_029 – Controller Human Machine Interaction function shall enable ATCo to request the removal a sector from the ordered list of the flight sequence (SKIP function) SR_FP_OPS_010 - ATC operating procedures shall describe the usage of SKIP function (i.e. ability to remove a sector from the ordered list of the flight sequence) in Free Routing environment (e.g. which sector initiate the SKIP, skipped sector remains responsible of the flight…) SR_FP_OPS_002 - ATCOs shall be trained/familiarized to use the SKIP function (i.e. ability remove a sector from the ordered list of the flight sequence) in Free Routing environment SR_FP_OPS_046 - Structurally limited FRA airspace design shall reduce the need for sector skipping

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-004	In order to avoid more ATC induced conflicts, ATC Sector Planning Role should be informed of ATC Sector Executive Role actions	TC_0 PC_0	HMI		SR_FP_OPS_024 - In order to avoid more ATC induced conflicts, ATC Sector Planning Role shall be informed of ATC Sector Executive Role actions and vice versa SR_FP_SYS_016 - Controller Human Machine interaction management function shall include a function to highlight fights (e.g. point-out function) from PC to TC and vice versa SR_FP_OPS_017 - ATC shall be trained to ensure information of ATC Sector Planning Role about ATC Sector Executive Role actions
SO-FP-005	The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary	TC_0 PC_0	FPM TP HMI		SR_FP_OPS_025 - The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary SR_FP_SYS_010 - Flight Planning Management function shall provide flight plan data within the area of interest of the sector SR_FP_SYS_004 - Trajectory Prediction function shall perform planned trajectory prediction of a selected flight within the area of interest of the sector SR_FP_SYS_017 - Controller Human Machine interaction management function shall be able to display the planned trajectory of a selected flight beyond the ATSU boundary to PC and TC SR_FP_SYS_030 - Controller Human Machine interaction management function shall automatically display the planned trajectory for a short period of time (e.g. 2 or 3 seconds) when assuming a flight

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-006	The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories* within the area of interest of the sector *NOTE: planned trajectories, not heading (as LAD)	TC_0 PC_0	FPM TP HMI		SR_FP_OPS_026 - The ATCOs (ATC Sector Planning and Executive Roles) shall be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector SR_FP_SYS_010 - Flight Planning Management function shall provide flight plan data within the area of interest of the sector SR_FP_SYS_004 - Trajectory Prediction function shall perform planned trajectory prediction of a selected flight within the area of interest of the sector. SR_FP_SYS_009 - Conflict Detection function shall determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector. SR_FP_SYS_018 - Controller Human Machine interaction management function shall be able to display to PC and TC predicted separation between flights on their planned trajectories within the area of interest of the sector.

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-007	The ATCOs shall be able to detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest	TC_0 PC_0	FPM TP CM HMI	ATC operating procedures	SR_FP_OPS_027 - The ATCOs shall be able to detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest SR_FP_SYS_010 - Flight Planning Management function shall provide flight plan data within the area of interest of the sector. SR_FP_SYS_004 - Trajectory Prediction function shall perform planned trajectory prediction of a selected flight within the area of interest of the sector. SR_FP_SYS_011 - Conflict Management function shall detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest. SR_FP_SYS_019 - Controller Human Machine interaction management function shall be able to display to PC and TC mid-term encounters between flights along their planned trajectories within the ATC sector area of interest. SR_FP_OPS_003 - ATCOs shall be trained/familiarized on the planned conflict detection tool and its features (i.e. tool displaying all possible planned conflict or only “proven” ones) ,its particular parameter settings, time horizon and limitations. SR_FP_SYS_031 - Controller Human Machine interaction management function shall enable TC to de-activate the display of mid-term encounters between flights along their planned trajectories

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-008	The ATC Sector Planning Role shall be provided with tools to support information sharing between ATC Sector Planning and Executive Roles.	TC_0 PC_0	HMI		SR_FP_OPS_028 - The ATC Sector Planning Role shall be provided with tools to support information sharing between ATC Sector Planning and Executive Roles SR_FP_SYS_016 - Controller Human Machine interaction management function shall include a function to highlight fights (e.g. point-out function) from PC to TC and vice versa

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-009	The ATC Sector Planning Role shall be provided with tools and procedures to support coordination of flights across ACC/sector boundaries with unnamed coordination points, with the identification of a flight to any adjacent sector and support the negotiation of coordinations	PC TC	C&T HMI	LoA ATC operating procedures	SR_FP_OPS_029 - The ATC Sector Planning Role shall be provided with tools and procedures to support coordination of flights across ACC/sector boundaries with unnamed coordination points, with the identification of a flight to any adjacent sector and support the negotiation of coordinations SR_FP_OPS_009 - ATC operating procedures shall describe the acceptable entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point. SR_FP_SYS_001 - Coordination and Transfer function (e.g. LoA, operating procedure…) shall enable the PC to perform coordination of flights across ACC/sector boundaries not necessarily supported by fixed coordination points SR_FP_SYS_022 - Controller Human Machine Interaction management function shall enable the input of new proposed exit conditions by the Controller for flights exiting his/her sector. SR_FP_SYS_002 – Coordination and Transfer function shall support the ATCO in the management of proposed coordination condition (negotiation of coordination conditions) SR_FP_SYS_023 – Controller Human Machine Interaction management function shall enable the PC to accept or reject a proposed coordination condition SR_FP_SYS_024 – Controller Human Machine Interaction management function shall enable the input of new proposed exit conditions by the Controller for flights not yet assumed SR_FP_OPS_004 – Planning Controller shall be trained/familiarized on the coordination negotiation tool and associated operating procedures

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-010	The ATCOs should be able to assess alternative trajectories in support of the negotiation of coordination conditions with adjacent ATC sectors (planning what-if)	TC_0 PC_0	TP CM HMI		SR_FP_OPS_030 - The ATCOs shall be able to assess alternative trajectories in support of the negotiation of coordination conditions with adjacent ATC sectors (planning what-if) SR_FP_SYS_020 - Controller Human Machine interaction management function shall enable the input of alternate entry/exit conditions by the Controller. SR_FP_SYS_005 – Trajectory Prediction function shall perform alternate planned trajectory prediction of a selected flight, based on Controller input. SR_FP_SYS_012 – Conflict Management function shall detect planned conflict of a selected flight along its alternate planned trajectory, based on Controller input. SR_FP_SYS_021 - Controller Human Machine interaction management function shall display planned conflict of a selected flight along its alternate planned trajectory, based on Controller input.

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-011	The ATCOs shall be able to detect tactical encounters between two or more flights not necessarily on a fixed ATS route segment	TC_0 PC_0	FPM TP CM HMI	ATC operating procedures National AIS publication	SR_FP_OPS_031 - The ATCOs shall be able to detect tactical encounters between two or more flights not necessarily on a fixed ATS route segment SR_FP_SYS_010 - Flight Planning Management function shall provide flight plan data within the area of interest of the sector SR_FP_SYS_006 - Trajectory Prediction function shall perform tactical trajectory prediction of a selected flight not necessarily on a fixed ATS route network SR_FP_SYS_013 - Conflict Management function shall detect tactical encounters between two or more flights not necessarily on a fixed ATS route network SR_FP_SYS_025 - Controller Human Machine interaction management function shall be able to display tactical encounters between two or more flights not necessarily on a fixed ATS route network SR_FP_OPS_005 – Tactical Controller shall be trained/familiarized on the detection of tactical encounters between two or more flights not necessarily on a fixed ATS route network, with or without tactical detection tool (depending on tools locally available) SR_FP_OPS_019: National AIS publication and RAD shall define sufficient flight planning restrictions enabling the provision of safe and efficient Air Traffic Control service by the ATCo in tactical phase. (i.e. trade off between structural limitation of the FRA and available tool, particularly for optional tools)

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-012	The ATCOs (ATC Sector Planning and Executive Roles) should be provided with a tool detecting the potential crossing between the planned trajectory of the aircraft and active En Route stack in the sector	TC_0 PC_0	Safety Net	ATC operating procedures	SR_FP_OPS_032 - The ATCOs (ATC Sector Planning and Executive Roles) shall be provided with a tool detecting the potential crossing between the planned trajectory of the aircraft and active stack En Route in the sector A-07 - ATC supervisor updates the En Route stack activation status on the ATC system. SR_FP_SYS_034 - Area Proximity Warning function shall detect imminent infringement of active En Route stack by flights along their tactical trajectories within the ATC sector area of interest SR_FP_OPS_006 - ATCOs shall be trained/familiarized to the detection of potential crossing between active En Route stack and the planned trajectory of flights not necessarily on a fixed ATS route segment

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-013	The ATCOs (ATC Sector Planning and Executive Roles) shall be informed in due time of ARES activation status (active/not active/released) within the area of interest of the sector	PC TC	Airspace management HMI	ATC operating procedures National AIS publication	SR_FP_OPS_033 - The ATCOs (ATC Sector Planning and Executive Roles) shall be informed in due time of ARES activation status (active/not active/released) within the area of interest of the sector SR_FP_SYS_033 - Airspace management function shall provide in due time the ARES activation status (active/not active/released) within the area of interest of the sector SR_FP_SYS_026 - Controller Human Machine interaction management function shall be able to display in due time the ARES activation status (active/not active/released) within the area of interest of the sector SR_FP_OPS_014 - ATC operating procedures to deviate flights around active ARES shall be adapted to free route environment (e.g. time to start deviating…) SR_FP_OPS_020 - National AIS publication and RAD shall describe flight planning rules applicable inside the free routing airspace to avoid flight planning through active ARES *Note 1: The ARES activation status is provided by the airspace management function. This function is not presented on the model for simplification purpose.* *Note 2: It is considered that some flight planning restriction are published when necessary to ensure that Airspace Users will not plan flights through active military areas*

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-014	The ATCOs shall be able to detect predicted infringement of active ARES by flights along their planned trajectories within the ATC sector area of interest	PC TC	Safety nets HMI	ATC operating procedures	SR_FP_OPS_034 - The ATCOs shall be able to detect predicted infringement of active ARES by flights along their planned trajectories within the ATC sector area of interest SR_FP_OPS_038 - The ATCOs shall be assisted by an Area Proximity Warning system SR_FP_SYS_035 - Area Proximity Warning shall be adapted (tool parameters) to Free Routing environment SR_FP_OPS_014 - ATC operating procedures to deviate flights around active ARES shall be adapted to free route environment (e.g. time to start deviating…)
SO-FP-015	The ATCO of sector before FRA shall be aware of FRA lower limit and give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory	PC TC		ATC operating procedures	SR_FP_OPS_007 - ATCOs of sector before FRA shall be trained/familiarized on FRA lower limit to give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-016	The ATCOs shall be able to assess tactical trajectory revision options including alternative trajectories across ACC/sector boundaries (tactical what-if)	TC_0 PC_0	TP CM HMI		SR_FP_OPS_035 - The ATCOs shall be able to assess tactical trajectory revision options including alternative trajectories across ACC/sector boundaries (tactical what-if) SR_FP_SYS_027 - Controller Human Machine interaction management function shall display the possible tactical trajectory revision options to the Tactical Controller. SR_FP_SYS_007 - Trajectory Prediction function shall perform alternate tactical trajectory prediction of the displayed trajectory revision options across ATSU/sector boundaries. SR_FP_SYS_014 - Conflict Management function shall detect tactical conflicts of the displayed trajectory revision options across ATSU/sector boundaries SR_FP_SYS_028 - Controller Human Machine interaction management function shall enable selection and implementation of the possible trajectory revisions by the Tactical Controller.

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-029	The ATCOs shall be provided with support to monitor trajectory adherence		FPM TP MONA HMI		SR_FP_OPS_036 - The ATCOs shall be provided with support to monitor trajectory adherence SR_FP_SYS_010 - Flight Planning Management function shall provide flight plan data within the area of interest of the sector SR_FP_SYS_004 - Trajectory Prediction function shall perform planned trajectory prediction of a selected flight within the area of interest of the sector SR_FP_SYS_015 - Monitoring Aids function shall detect lateral or vertical deviation of the flight from their planned trajectory SR_FP_SYS_032 - Controller Human Machine interaction management function shall display an alert in case of detection of deviation of a flight from its planned trajectory
SO-FP-030	The ATCOs shall be assisted by a Short-Term Conflict Alert system	-	-	-	SR_FP_OPS_037 - The ATCOs shall be assisted by a Short-Term Conflict Alert system
SO-FP-031	The ATCOs shall be assisted by an Area Proximity Warning system				SR_FP_OPS_038 - The ATCOs shall be assisted by an Area Proximity Warning system SR_FP_SYS_035 - Area Proximity Warning shall be adapted (tool parameters) to Free Routing environment

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-032	Flight planning rules applicable inside the free routing airspace (e.g. entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility or not to plan user defined points...) shall be defined and published in national AIS publication			National AIS publication (AIP, AIC…)	SR_FP_OPS_018 - National AIS publication and RAD shall describe flight planning rules applicable inside the free routing airspace (entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility to plan user defined points...) without reference to published route network or fixed coordination point. SR_FP_OPS_019 - National AIS publication and RAD shall define sufficient flight planning restrictions enabling the provision of safe and efficient Air Traffic Control service by the ATCo in tactical phase (i.e. trade-off between structural limitation of the FRA and available tool, particularly for optional tools)

Safety Objective		Maps on to			Safety Requirement
ID	Description	People (roles)	Tools function (functional block)	Procedures	
SO-FP-033	Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)			ATC operating procedures	SR_FP_OPS_039 - Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…) SR_FP_OPS_015 - ATC contingency procedure (e.g. procedure in case of loss of surveillance, air/ground communication, FDPS, conflict detection tool…) shall be adapted to Free Routing operations SR_FP_OPS_008 - ATCOs shall be trained/familiarized to updated contingency procedure in Free Routing environment (e.g. procedure in case of loss of surveillance, air/ground communication, FDPS, conflict detection tool…)
SO-FP-034	ATCOs shall have included all points of interest within the FDPS database (e.g. all waypoints within the maximum length of the segments)				SR_FP_OPS_021 - En-Route ATS Provider shall ensure consistency between flight planning rules applicable inside the free routing airspace and limitation of the system database to ensure that system will know all the waypoints of interest

Table 17: Mapping of Safety Objectives to SPR-level Model Elements

SPR-level Model element	Safety Requirement		Derived from
	Ref	Requirement	
Coordination and Transfer	SR_FP_SYS_001	Coordination and Transfer function (e.g. LoA, operating procedure…) shall enable the PC to perform coordination of flights across ACC/sector boundaries not necessarily supported by fixed coordination points	SO-FP-001 SO-FP-009
	SR_FP_SYS_002	Coordination and Transfer function shall support the ATCO in the management of proposed coordination condition (negotiation of coordination conditions)	SO-FP-009

SPR-level Model element	Safety Requirement		Derived from
	Ref	Requirement	
	SR_FP_SYS_003	Coordination and Transfer function shall enable to remove a sector from the ordered list of the flight sequence (SKIP function)	SO-FP-003
Trajectory Prediction	SR_FP_SYS_004	Trajectory Prediction function shall perform planned trajectory prediction of a selected flight within the area of interest of the sector	SO-FP-005 SO-FP-006 SO-FP-007 SO-FP-029
	SR_FP_SYS_005	Trajectory Prediction function shall perform alternate planned trajectory prediction of a selected flight, based on Controller input.	SO-FP-010
	SR_FP_SYS_006	Trajectory Prediction function shall perform tactical trajectory prediction of a selected flight not necessarily on a fixed ATS route network	SO-FP-011
	SR_FP_SYS_007	Trajectory Prediction function shall perform alternate tactical trajectory prediction of the displayed trajectory revision options across ATSU/sector boundaries	SO-FP-016
	SR_FP_SYS_008	Trajectory Prediction function shall enable to remove a sector from the ordered list of the flight sequence (SKIP function)	SO-FP-003
	SR_FP_SYS_009	Conflict Detection function shall determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector.	SO-FP-006
Flight Planning Management	SR_FP_SYS_010	Flight Planning Management function shall provide flight plan data within the area of interest of the sector	SO-FP-005 SO-FP-006 SO-FP-007 SO-FP-011 SO-FP-029
Conflict Management	SR_FP_SYS_011	Conflict Management function shall detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest	SO-FP-007
	SR_FP_SYS_012	Conflict Management function shall detect planned conflict of a selected flight along its alternate planned trajectory, based on Controller input.	SO-FP-010
	SR_FP_SYS_013	Conflict Management function shall detect tactical encounters between two or more flights not necessarily on a fixed ATS route network	SO-FP-011
	SR_FP_SYS_014	Conflict Management function shall detect tactical conflicts of the displayed trajectory revision options across ATSU/sector boundaries	SO-FP-016
Monitoring Aids	SR_FP_SYS_015	Monitoring aids function shall detect lateral or vertical deviation of the flight from their planned trajectory	SO-FP-029

SPR-level Model element	Safety Requirement		Derived from
	Ref	Requirement	
Controller Human Machine Interaction management	SR_FP_SYS_016	Controller Human Machine interaction management function shall include a function to highlight fights (e.g. point-out function) from PC to TC and vice versa.	SO-FP-004 SO-FP-008
	SR_FP_SYS_017	Controller Human Machine interaction management function shall be able to display the planned trajectory of a selected flight beyond the ATSU boundary to PC and TC	SO-FP-005
	SR_FP_SYS_018	Controller Human Machine interaction management function shall be able to display to PC and TC predicted separation between flights on their planned trajectories within the area of interest of the sector.	SO-FP-006
	SR_FP_SYS_019	Controller Human Machine interaction management function shall be able to display to PC and TC mid-term encounters between flights along their planned trajectories within the ATC sector area of interest.	SO-FP-007
	SR_FP_SYS_020	Controller Human Machine interaction management function shall enable the input of alternate entry/exit conditions by the Controller.	SO-FP-010
	SR_FP_SYS_021	Controller Human Machine interaction management function shall display planned conflict of a selected flight along its alternate planned trajectory, based on Controller input.	SO-FP-010
	SR_FP_SYS_022	Controller Human Machine Interaction management function shall enable the input of new proposed exit conditions by the Controller for flights exiting his/her sector	SO-FP-009 SO-FP-010
	SR_FP_SYS_023	Controller Human Machine Interaction management function shall enable the PC to accept or reject a proposed coordination condition	SO-FP-009
	SR_FP_SYS_024	Controller Human Machine Interaction management function shall enable the input of new proposed exit conditions by the Controller for flights not yet assumed	SO-FP-009 SO-FP-010
	SR_FP_SYS_025	Controller Human Machine interaction management function shall be able to display tactical encounters between two or more flights not necessarily on a fixed ATS route network	SO-FP-011
	SR_FP_SYS_026	Controller Human Machine interaction management function shall be able to display in due time the ARES activation status (active/not active/released) within the area of interest of the sector	SO-FP-013
	SR_FP_SYS_027	Controller Human Machine interaction management function shall display the possible tactical trajectory revision options to the Tactical Controller	SO-FP-016

SPR-level Model element	Safety Requirement		Derived from
	Ref	Requirement	
	SR_FP_SYS_028	Controller Human Machine interaction management function shall enable selection and implementation of the possible trajectory revisions by the Tactical Controller	SO-FP-016
	SR_FP_SYS_029	Controller Human Machine Interaction function shall enable ATCo to request the removal a sector from the ordered list of the flight sequence (SKIP function)	SO-FP-003
	SR_FP_SYS_030	Controller Human Machine interaction management function shall automatically display the planned trajectory for a short period of time (e.g. 2 or 3 seconds) when assuming a flight	SO-FP-005
	SR_FP_SYS_031	Controller Human Machine interaction management function shall enable TC to de-activate the display of mid-term encounters between flights along their planned trajectories	SO-FP-007
	SR_FP_SYS_032	Controller Human Machine interaction management function shall display an alert in case of detection of deviation of a flight from its planned trajectory	SO-FP-029
Airspace management	SR_FP_SYS_033	Airspace management function shall provide in due time the ARES activation status (active/not active/released) within the area of interest of the sector	SO-FP-013
Safety Net	SR_FP_SYS_034	Area Proximity Warning function shall detect imminent infringement of active En Route stack by flights along their tactical trajectories within the ATC sector area of interest	SO-FP-012
	SR_FP_SYS_035	Area Proximity Warning shall be adapted (tool parameters) to Free Routing environment	SO-FP-014 SO-FP-031
ATCo	SR_FP_OPS_001	ATCOs shall be trained/familiarized with new entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point	SO-FP-002
	SR_FP_OPS_002	ATCOs shall be trained/familiarized to use the SKIP function (i.e. ability remove a sector from the ordered list of the flight sequence) in Free Routing environment	SO-FP-003
	SR_FP_OPS_003	ATCOs shall be trained/familiarized on the planned conflict detection tool and its features (i.e. tool displaying all possible planned conflict or only “proven” ones), its particular parameter settings, time horizon and limitations.	SO-FP-007
	SR_FP_OPS_004	Planning Controller shall be trained/familiarized on the coordination negotiation tool and associated operating procedures	SO-FP-009
	SR_FP_OPS_005	Tactical Controller shall be trained/familiarized on the detection of tactical encounters between two or more flights not necessarily on a fixed ATS route network, with or without tactical detection tool (depending on tools locally available)	SO-FP-011

SPR-level Model element	Safety Requirement		Derived from
	Ref	Requirement	
	SR_FP_OPS_006	ATCOs shall be trained/familiarized to the detection of potential crossing between active En Route stack and the planned trajectory of flights not necessarily on a fixed ATS route segment	SO-FP-012
	SR_FP_OPS_007	ATCOs of sector before FRA shall be trained/familiarized on FRA lower limit to give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory	SO-FP-015
	SR_FP_OPS_008	ATCOs shall be trained/familiarized to updated contingency procedure (e.g. procedure in case of loss of surveillance, air/ground communication, FDPS, conflict detection tool…) in Free Routing environment	SO-FP-033
	SR_FP_OPS_022	The ATCOs shall be able to perform coordination of flights across ACC/sector boundaries not necessarily supported by published coordination points	SO-FP-001
	SR_FP_OPS_023	The ATCOs (ATC Sector Planning and Executive Roles) shall be able to remove a sector from the ordered list of the flight sequence (list of sectors that are expected to assume the flight)	SO-FP-003
	SR_FP_OPS_024	In order to avoid more ATC induced conflicts, ATC Sector Planning Role shall be informed of ATC Sector Executive Role actions and vice versa	SO-FP-004
	SR_FP_OPS_025	The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary	SO-FP-005
	SR_FP_OPS_026	The ATCOs (ATC Sector Planning and Executive Roles) shall be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector	SO-FP-006
	SR_FP_OPS_027	The ATCOs shall be able to detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest	SO-FP-007
	SR_FP_OPS_028	The ATC Sector Planning Role shall be provided with tools to support information sharing between ATC Sector Planning and Executive Roles	SO-FP-008
	SR_FP_OPS_029	The ATC Sector Planning Role shall be provided with tools and procedures to support coordination of flights across ACC/sector boundaries with unnamed coordination points, with the identification of a flight to any adjacent sector and support the negotiation of coordinations	SO-FP-009

SPR-level Model element	Safety Requirement		Derived from
	Ref	Requirement	
	SR_FP_OPS_030	The ATCOs shall be able to assess alternative trajectories in support of the negotiation of coordination conditions with adjacent ATC sectors (planning what-if)	SO-FP-010
	SR_FP_OPS_031	The ATCOs shall be able to detect tactical encounters between two or more flights not necessarily on a fixed ATS route segment	SO-FP-011
	SR_FP_OPS_032	The ATCOs (ATC Sector Planning and Executive Roles) shall be provided with a tool detecting the potential crossing between the planned trajectory of the aircraft and active stack En Route in the sector	SO-FP-012
	SR_FP_OPS_033	The ATCOs (ATC Sector Planning and Executive Roles) shall be informed in due time of ARES activation status (active/not active/released) within the area of interest of the sector	SO-FP-013
	SR_FP_OPS_034	The ATCOs shall be able to detect predicted infringement of active ARES by flights along their planned trajectories within the ATC sector area of interest	SO-FP-014
	SR_FP_OPS_035	The ATCOs shall be able to assess tactical trajectory revision options including alternative trajectories across ACC/sector boundaries (tactical what-if)	SO-FP-016
	SR_FP_OPS_036	The ATCOs shall be provided with support to monitor trajectory adherence	SO-FP-029
	SR_FP_OPS_037	The ATCOs shall be assisted by a Short-Term Conflict Alert system	SO-FP-030
	SR_FP_OPS_038	The ATCOs shall be assisted by an Area Proximity Warning system	SO-FP-014 SO-FP-031
	SR_FP_OPS_039	Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)	SO-FP-033
ATC operating procedures	SR_FP_OPS_009	ATC operating procedures shall describe the acceptable entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point.	SO-FP-001 SO-FP-002 SO-FP-009
	SR_FP_OPS_010	ATC operating procedures shall describe the usage of SKIP function (i.e. ability to remove a sector from the ordered list of the flight sequence) in Free Routing environment (e.g. which sector initiate the SKIP, skipped sector remains responsible of the flight…)	SO-FP-003
	SR_FP_OPS_014	ATC operating procedures to deviate flights around active ARES shall be adapted to free route environment (e.g. time to start deviating…)	SO-FP-013 SO-FP-014

SPR-level Model element	Safety Requirement		Derived from
	Ref	Requirement	
	SR_FP_OPS_015	ATC contingency procedure (e.g. procedure in case of loss of surveillance, air/ground communication, FDPS, conflict detection tool…) shall be adapted to Free Routing operations	SO-FP-033
	SR_FP_OPS_016	LoA shall describe the acceptable entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point	SO-FP-002
	SR_FP_OPS_017	ATC shall be trained to ensure information of ATC Sector Planning Role about ATC Sector Executive Role actions	SO-FP-004
Aeronautical documentation	SR_FP_OPS_018	National AIS publication and RAD shall describe flight planning rules applicable inside the free routing airspace (entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility to plan user defined points...) without reference to published route network or fixed coordination point.	SO-FP-001
	SR_FP_OPS_019	National AIS publication and RAD shall define sufficient flight planning restrictions enabling the provision of safe and efficient Air Traffic Control service by the ATCo in tactical phase. (i.e. trade off between structural limitation of the FRA and available tool, particularly for optional tools)	SO-FP-011
	SR_FP_OPS_020	National AIS publication and RAD shall describe flight planning rules applicable inside the free routing airspace to avoid flight planning through active ARES	SO-FP-013
ATS Provider	SR_FP_OPS_021	En-Route ATS Provider shall ensure consistency between flight planning rules applicable inside the free routing airspace and limitation of the system database to ensure that system will know all the waypoints of interest	SO-FP-034
	SR_FP_OPS_046	Structurally limited FRA airspace design shall reduce the need for sector skipping	SO-FP-003

Table 18: Derivation of Safety Requirements (functionality and performance) from Safety Objectives

SPR-level Model element	Assumptions		Derived from
	Ref	Assumption	

Operating Procedure	A-07	ATC supervisor updates the En Route stack activation status on the ATC system	SO-FP-012

Table 19: Assumptions made in deriving the above Safety Requirements

4.2.4 Traceability

Table 20 below presents the mapping between the relevant OI steps and the SPR-level Model

OI step code	OI step title	Related Barrier in AIM	Related SPR-level Model Element(s)
AOM-0505	Free Routing for Flights both in cruise and vertically evolving within high and very high complexity environments in Upper En Route airspace	Traffic planning and synchronisation Tactical conflict management	Flight Planning – Lifecycle Management – data distribution (FPM)
		Traffic planning and synchronisation Tactical conflict management	Trajectory Prediction (TP)
		Tactical conflict management	Monitoring aids (MONA)
		Traffic planning and synchronisation Tactical conflict management	Conflict Management (CM)
		Traffic planning and synchronisation Tactical conflict management	Controller Human Machine Interaction management (HMI)
		Traffic planning and synchronisation	Coordination and Transfer (C&T)
		Traffic planning and synchronisation Tactical conflict management	Planning Controller
		Traffic planning and synchronisation Tactical conflict management	Tactical Controller

Table 20: Traceability between OI steps and SPR-level Model Elements

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

This section is concerned with ensuring that the SPR-level design is complete, correct and internally coherent with respect to the Safety Requirements (success approach) derived for the normal operating conditions that were used to develop the corresponding Safety Objectives (success approach) in section 3.6.2.

This section includes interaction diagram presenting the dynamic exchanging between the elements of the SPR-level model in support to the different operational scenario.

4.3.1 Scenarios for Normal Operations

The REF _Ref14363243 \h Table 21 below lists the scenario or operational activities considered when deriving the safety requirements. This list of scenario is based on the operational activities considered during the safety activities at OSED level (see section REF _Ref14363458 \r \h 3.6.1). No detailed analysis has been conducted for the operational activities linked to airborne and ground safety net as Free Routing has no major impact on these activities/tools.

ID	Scenario	Rationale for the Choice
SEP_PLAN	Provide Planning Separation Assurance	See section 3.6.1
SEP_TACT	Provide Tactical Separation Assurance	See section 3.6.1
COOR	Coordination and transfer	See section 3.6.1
MONA	Ensure Trajectory Adherence	See section 3.6.1

Table 21: Operational Scenarios – Normal Conditions

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

All of the above operational scenarios (as per Table 21) are assessed through a thread analysis. Thread Analysis presents the actions of the individual elements of the SPR-level Model, and the interactions between those elements.

The safety requirements defined in section 4.2.3 reflects the main equipment functions and human tasks described in this thread analysis.

The Threads tell us more about the intended operation of the Solution ATM System than could the SPR-level Model or Safety Requirements on their own; therefore, they are regarded as an integral part of the design and are to be considered as being Safety Requirements in their own right.

4.3.2.1 Scenario # 1 "Provide Planning Separation Assurance"

This scenario includes two sub-tasks:

- Planned conflict detection
- Alternate entry/exit trajectory assessment

Figure 3 presents the interaction between the elements of the functional model supporting these tasks. The exchanges of information / data are detailed below.

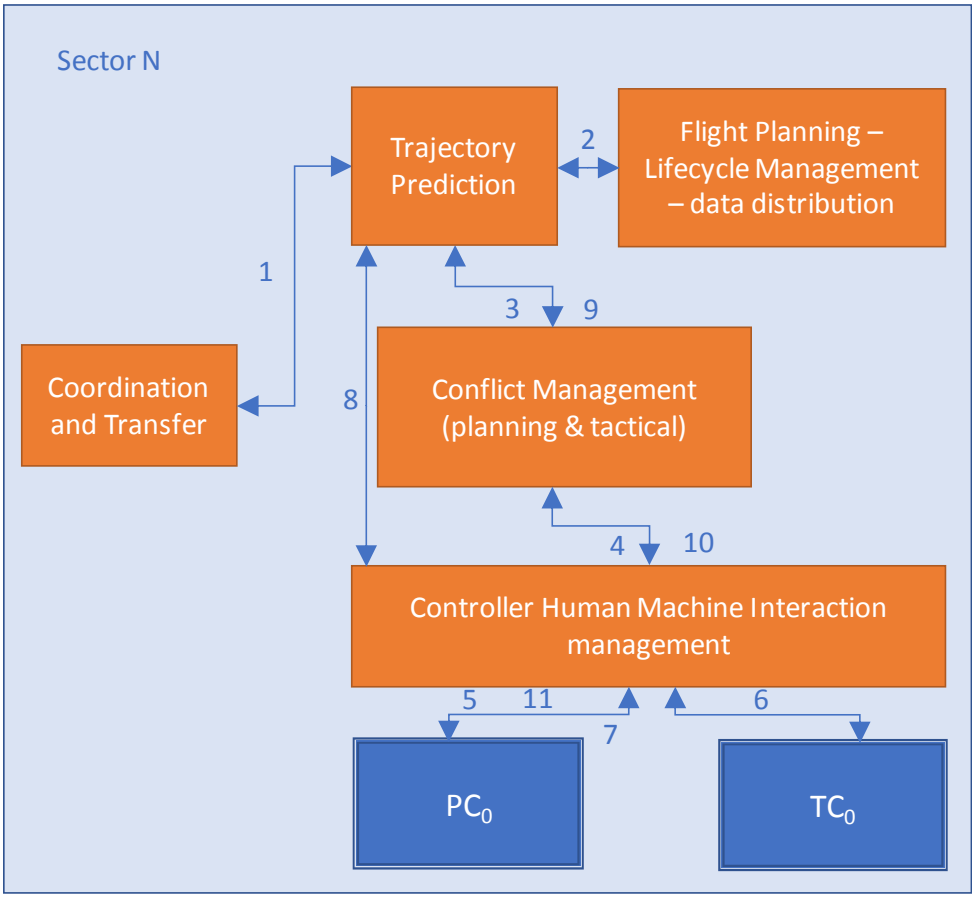


Figure 3: "Provide Planning Separation Assurance" interaction diagram

INTERFACES FOR PLANNED CONFLICT DETECTION

1. C&T => TP : Agreed coordination data
2. FPM => TP: Flight plan data
3. TP => CM: Trajectory prediction (planned trajectory)
4. CM => HMI: Planned conflicts (between flights or with active stack or with ARES)
5. HMI => PCN: Planned conflicts (display)
6. HMI => TCN: Planned conflicts (display)

INTERFACES FOR ALTERNATE ENTRY/EXIT TRAJECTORIES ASSESSMENT (PLANNING WHAT-IF)

7. PC or TC => HMI : Alternate entry / exit conditions
8. HMI => TP: Alternate entry / exit conditions
9. TP => CM: Alternate trajectory prediction (planned trajectory)
10. CM => HMI: Planned conflicts for alternate trajectory
11. HMI => PCN: Planned conflicts for alternate trajectory (display)

4.3.2.2 Scenario # 2 "Provide Tactical Separation Assurance"

This scenario includes two sub-tasks:

- Tactical conflict detection
- Alternate trajectory assessment

Figure 4 presents the interaction between the elements of the functional model supporting these tasks. The exchanges of information / data are detailed below.

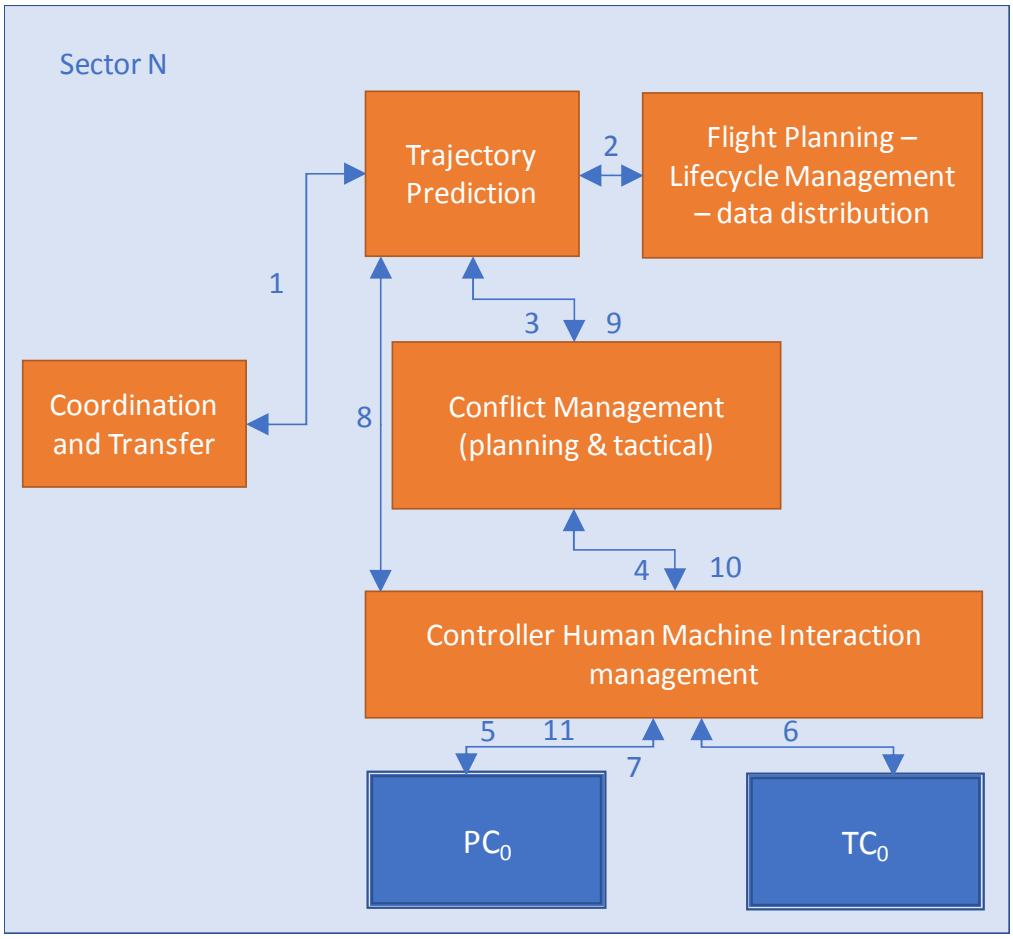


Figure 4: "Provide Tactical Separation Assurance" interaction diagram

INTERFACES FOR TACTICAL CONFLICT DETECTION

1. C&T => TP : Agreed coordination data
2. FPM => TP: Flight plan data
3. TP => CM: Trajectory prediction (tactical trajectory)
4. CM => HMI: Tactical conflicts (between flights or with active stack or with ARES)
5. HMI => PCN: Tactical conflicts (display)
6. HMI => TCN: Tactical conflicts (display)

INTERFACES FOR ALTERNATE TRAJECTORIES ASSESSMENT (TACTICAL WHAT-IF)

7. TC => HMI : Trajectory revision option
8. HMI => TP: Trajectory revision option
9. TP => CM: Alternate trajectory prediction (tactical trajectory)
10. CM => HMI: Tactical conflicts for alternate trajectory
11. HMI => PCN: Tactical conflicts for alternate trajectory (display)

4.3.2.3 Scenario # 3 “Coordination and transfer”

This scenario includes two sub-tasks:

- Standard coordination
- Negotiation of alternate coordination conditions

Figure 5 presents the interaction between the elements of the functional model supporting these tasks. The exchanges of information / data are detailed below.

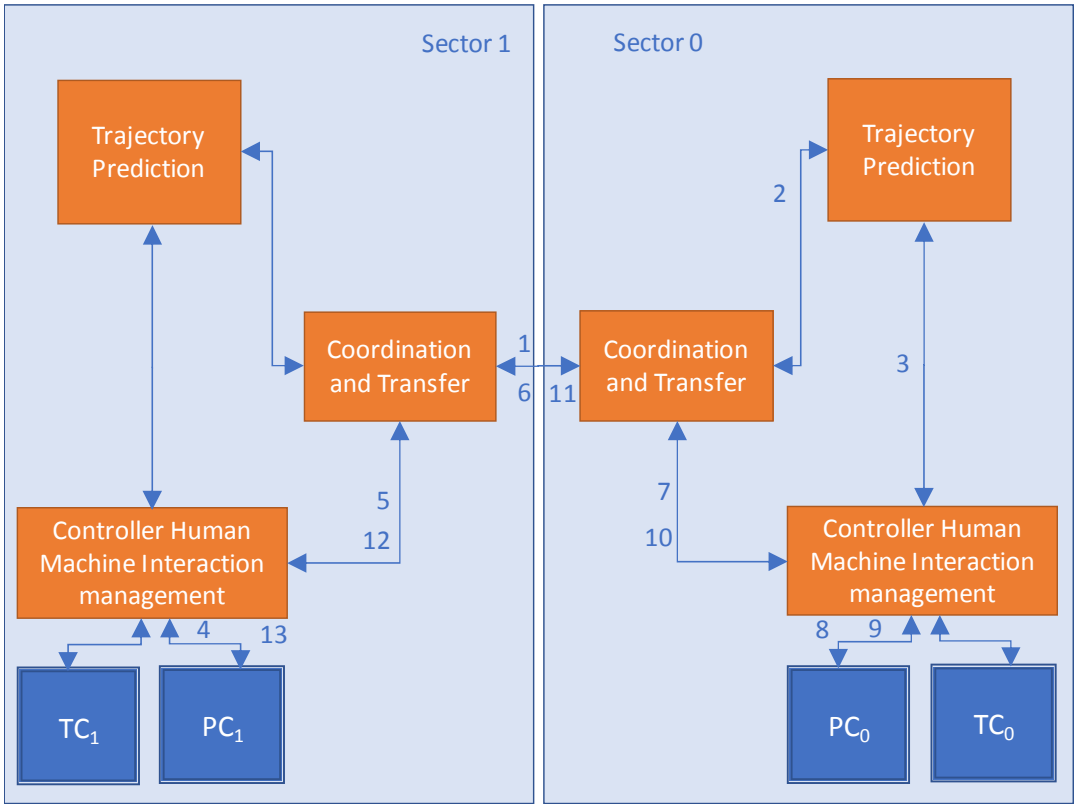


Figure 5: "Coordination and transfer" interaction diagram

INTERFACES FOR STANDARD COORDINATION (i.e. compliant with conditions defined within LoA)

1. C&T$_1$ => C&T$_0$: Agreed coordination data (i.e. coordination point, level at the COP, estimate at the COP…)
2. C&T$_0$ =>TP$_0$: Agreed coordination data
3. C&T$_0$ => TP$_0$: Trajectory prediction (based on coordination data)

INTERFACES FOR NEGOTIATION OF COORDINATION CONDITIONS

4. PC1 => HMI1: Proposed coordination condition (e.g. exit level)
5. HMI1 => C&T1: Proposed coordination condition
6. C&T1 => C&T0: Proposed coordination condition
7. C&T0 => HMI0: Proposed coordination condition
8. HMI0 => PC0: Proposed coordination condition (display)
9. PC0 => HMI0: Acceptance or rejection of proposed coordination condition
10. HMI0 => C&T0: Acceptance or rejection of proposed coordination condition
11. C&T0 => C&T1: Acceptance or rejection of proposed coordination condition

12. C&T1 => HMI1: Acceptance or rejection of proposed coordination condition

13. HMI1 => PC1: Acceptance or rejection of proposed coordination condition (display)

4.3.2.4 Scenario # 4 "Ensure Trajectory Adherence"

This scenario includes the cleared level adherence monitoring and route adherence monitoring.

Figure 6 presents the interaction between the elements of the functional model supporting these tasks. The exchanges of information / data are detailed below. Surveillance data processing system is not presented on this figure for simplification purpose. It is considered as an input to the monitoring aid function.

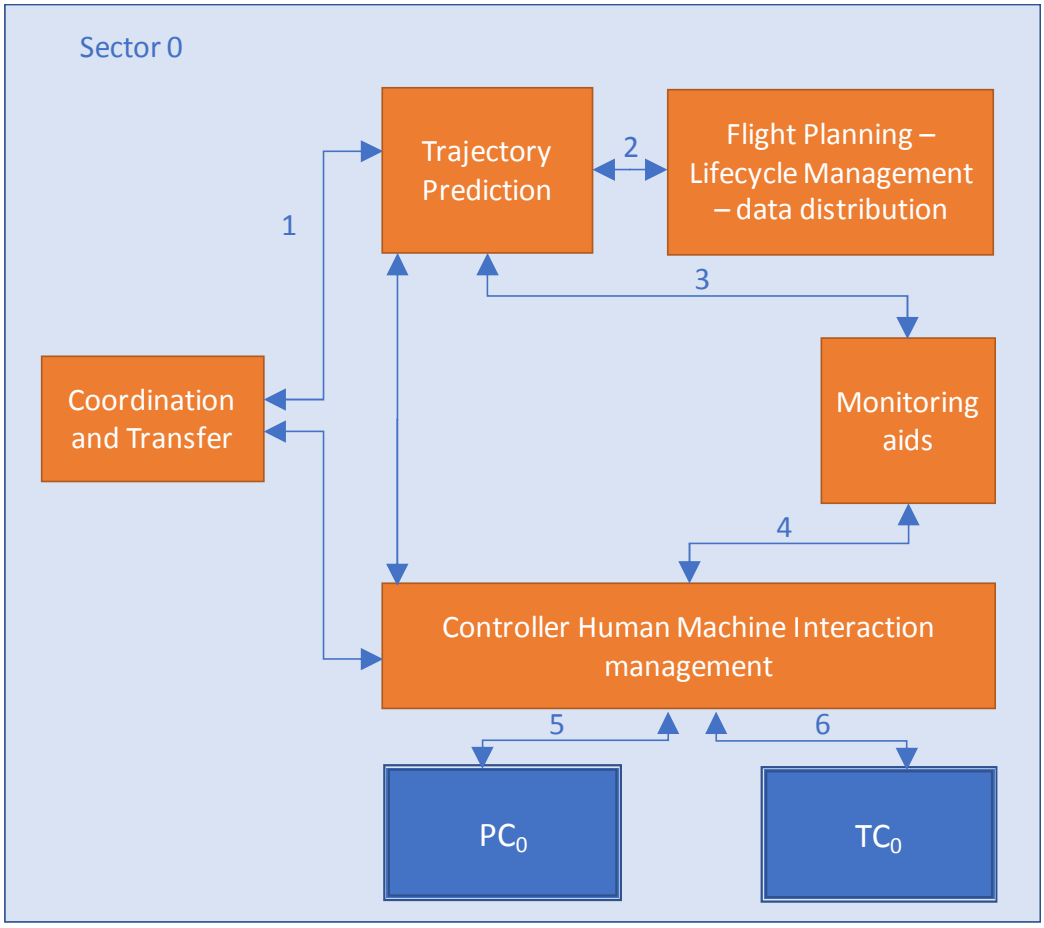


Figure 6: "Ensure trajectory adherence" interaction diagram

INTERFACES FOR MONITORING AIDS

1. C&T => TP : Agreed coordination data

2. FPM => TP: Flight plan data

3. TP => MON: Trajectory prediction (planned trajectory)

4. MON => HMI: Route/level adherence monitoring alert
5. HMI => PCN: Route/level adherence monitoring alert (display)
6. HMI => TCN: Route/level adherence monitoring alert (display)

4.3.3 Effects on Safety Nets – Normal Operational Conditions

Safety Objectives related to Safety Nets have already been defined during safety activities at the OSED level (see section 3.6) and then further derived into safety requirements and/or assumption in section 4.2.3. No addition assessment is conducted regarding the effect of the PJ.06-01 solution on the safety nets.

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

No dynamic analysis is performed for the solution PJ.06-01.

Scenario for normal operation are assessed in section 4.3.2 (including description of the dynamic interactions between the different functional blocks). This assessment has been taken into account during the derivation of safety requirement in section 4.2.3.

In addition, Dynamic aspects of the Free Routing solution have been assessed through Real Time Simulations (See VALP and VALR). Results from the Real Time Simulation have been taken into account for the definition and/or refinement of the safety requirements related to normal operational conditions.

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

All the requirements listed in section 4.2 have been derived based on the analysis of the SPR-level model and particularly based on the interaction diagram presented in section 4.3.2. No additional safety requirements in normal operational conditions is defined.

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

This section is concerned with ensuring that the SPR-level Design is complete, correct and internally coherent with respect to the Safety Requirements (Functionality and Performance) derived for the abnormal operating conditions that were used to derive the corresponding Safety Objectives (success approach) in section 3.6.2.

4.4.1 Scenarios for Abnormal Conditions

No specific scenario is developed for Abnormal Conditions in addition to the ones defined in section 4.3.1.

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

The Table 22 below, presents each of the above abnormal conditions from section 3.7 and presents:

- The Safety Objectives (Functionality and Performance) to mitigate the consequences of the abnormal condition, if any, as derived in section 3.7
- The mapping between the Safety Objective and the elements of the SPR-level model
- The Safety Requirements (Functionality and Performance), derived from the Safety Objectives

Ref	Abnormal Conditions / SO	Maps on to	Mitigations (SR and/or Assumptions)
ABN-01 Bad weather (CBs, turbulences, icing)	**SO-FP-015**: The ATCO of sector before FRA shall be aware of FRA lower limit and give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory	ATCo (PC and TC)	SR_FP_OPS_007 - ATCOs shall be trained/familiarized to give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory
ABN-02 Severe ATC technical system failure - Total loss of surveillance system	**SO-FP-033**: Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)	Operating Procedures ATCo (PC and TC)	SR_FP_OPS_015 - ATC contingency procedure (e.g. procedure in case of loss of surveillance, air/ground communication, FDPS, conflict detection tool…) shall be adapted to Free Routing operations SR_FP_OPS_008 - ATCOs shall be trained/familiarized to updated contingency procedure (e.g. procedure in case of loss of surveillance, air/ground communication, FDPS, conflict detection tool…) in Free Routing environment

Ref	Abnormal Conditions / SO	Maps on to	Mitigations (SR and/or Assumptions)
ABN-03 Severe ATC technical system failure - Total loss of air/ground communication system	**SO-FP-033**: Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)	Operating Procedures ATCo (PC and TC)	See Safety Requirements identified for ABN-02
ABN-04 Severe ATC technical system failure - Total loss of FDPS	**SO-FP-033**: Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)	Operating Procedures ATCo (PC and TC)	See Safety Requirements identified for ABN-02
ABN-06 Aircraft in emergency	No specific safety objective for this abnormal condition in free routing environment	N/A	N/A
ABN-07 Severe aircraft technical system failure - Radio communication failure	No specific safety objective for this abnormal condition in free routing environment	N/A	N/A
ABN-08 Severe aircraft technical system failure - Loss RVSM capability	No specific safety objective for this abnormal condition in free routing environment	N/A	N/A

Ref	Abnormal Conditions / SO	Maps on to	Mitigations (SR and/or Assumptions)
ABN-09 Severe aircraft technical system failure - Transponder failure	**SO-FP-033**: Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)	Operating Procedures ATCo (PC and TC)	See Safety Requirements identified for ABN-02

Table 22: Safety Requirements or Assumptions to mitigate abnormal conditions

4.4.3 Thread Analysis of the SPR-level Model - Abnormal Conditions

No thread analysis is developed for Abnormal Conditions in addition to the ones defined in section 4.3.2.

4.4.4 Effects on Safety Nets – Abnormal Operational Conditions

Safety Objectives related to Safety Nets have already been defined during safety activities at the OSED level (see section 3.6) and then further derived into safety requirements and/or assumption in section 4.2.3. No addition assessment is conducted regarding the effect of the PJ.06-01 solution on the safety nets.

4.4.5 Dynamic Analysis of the SPR-level Model – Abnormal Operational Conditions

No dynamic analysis is performed for the solution PJ.06-01.

Scenario for normal operation are assessed in section 4.3.2 (including description of the dynamic interactions between the different functional blocks). This assessment has been taken into account during the derivation of safety requirement in section 4.2.3.

In addition, Dynamic aspects of the Free Routing solution have been assessed through Real Time Simulations (See VALP and VALR). Results from the Real Time Simulation have been take into account for the definition and/or refinement of the safety requirements related to normal operational conditions.

4.4.6 Additional Safety Requirements – Abnormal Operational Conditions

All the requirements listed in section 4.2 have been derived based on the analysis of the SPR-level model and particularly based on the interaction diagram presented in section 4.3.2. No additional safety requirements in abnormal operational conditions is defined.

4.5 Design Analysis – Case of Internal System Failures

This section determines how the concept system (people, procedures and equipment) for the Free Route solution can be made safe, by apportioning the Safety Objectives related to the identified hazards into Safety Requirements to the elements of the system.

For that purpose, causes of hazards are identified and listed, allowing the derivation of qualitative Safety Requirements (Functionality and Performance) as barriers to prevent those causes. When possible and applicable to the Solution scope, quantitative Safety Requirements (Integrity and Reliability) are also determined by apportioning the respective Safety Objective to the identified causes.

Mitigations are also determined to reduce the effects of hazards, in the form of additional qualitative Safety Requirements (Functionality and Performance)

This failure case analysis was carried out during a safety workshop held in June 4th 2019.

4.5.1 Causal Analysis

System-generated hazards have been analysed in order to determine their causes and possible barriers to prevent them. The analysis was carried out during a specific failure case session of the Safe Design at SPR level Safety Workshop, and is captured in the next table:

ID	Hz Description	Causes	Possible barriers
HZ 001	Failure to apply the sector/ACC coordination procedure, either by planner ATCO or other actor in coordination not following LoA.	<u>Human:</u> coordination error - Coordinating against LoA - Most common error: ATCOs (PC and TC) forget to update the system (If ATCO forgets e.g. to descend a flight, he will detect it. CFL changed, but not XFL, and detected by the next sector PC and by the system) (Other e.g.: Direct not implemented in the system) - TC does not follow exit conditions. E.g., forgets to descend the flight or give direct, so the flight does not descend according to LoA - Errors when transferring from FRA to fixed route. More delicate situation. <u>Equipment:</u> - Failure of C&T (Coordination and Transfer Function) - Messages lost - TP failure, causing the next sector not being identified (for another), and not following LoA: ATCO identifies it and corrects it before. In the end he follows LoA <u>Procedures:</u> - Error in LoA / procedures / RAD / AIP. Acceptable entry/exit conditions not well described. More errors initially, during transition, will be corrected over time. - Absence of CoP (Coordination Points) at the boundaries. - LoA not well implemented in tools	- Training: highlight the importance of focusing on correctly transferring and always updating the system with changes. - Specific training for the new LoAs induced by FRA implementation, mostly on transition phase (to avoid coordinations against LoA) - Supervisor involvement: time to notice certain events (e.g. ARES activation) shall be increased. - New LoAs defined according to FRA. - Feedback from ATCOs on incidents will be considered when defining the new LoAs

ID	Hz Description	Causes	Possible barriers
HZ 002	ATCO failure to remove a flight of her/his sector from the ordered list of sectors that are expected to assume it a given flight. (Failure to skip sector)	Human: - Skipping is done by the planner. PC error - TC error (if the PC is busy, TC can do the skipping) Equipment: - Wrong list of sectors in the FDP *Note: Assumption A-10: It is assumed that the ATCOs (Planning Controller and Tactical Controller) are able to remove a flight of her/his sector from the ordered list of sectors that are expected to assume a given flight (i.e. SKIP functionality)*	- Airspace design: sectors shaped to avoid corners where flows cross sectors on very short segments. - Structurally limited FRA with certain areas as 'Non plannable'. Mandatory points too (to avoid flying over delicate corners) - Training to ATCOS on well-established skipping procedures. - HMI support to provide awareness on skipping: different colours for skipped traffics.

ID	Hz Description	Causes	Possible barriers
HZ 003	Planner controller not being informed of tactical controller actions (failure of tactical-planner information sharing tools)	Human: - Highlighting the wrong traffic or not highlighting it. - TC overloaded with no time to delegate functions to PC. In that case, if PC is not proactive, TC takes all the workload. - Opposite case: PC implements a re-routing in the system (e.g. 'elastic vector' or 'graphical rerouting', to avoid an activated military area) and the TC is too busy and does not tell the aircraft to reroute. Equipment: - HMI (Controller Human Machine Interaction Management): Point out fails	- Training on the HMI and teamwork (TC/PC). Focus on importance of updating the system
HZ 004	Loss of display of the planned trajectory in FRA (tool/function unavailable) Another Hz: wrong trajectory displayed	Equipment: - FPM (Flight Planning Management function) - rare - Loss of correlation (Most common, but may affect only 1 flight) - TP (Trajectory Prediction function) - HMI (Controller Human Machine interaction management function	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.

ID	Hz Description	Causes	Possible barriers
HZ 005	Discrepancy between ground and airborne trajectory in FRA	Human: - Flight crew has not updated the FMS - ATCOs have not updated the system - the activated flight plan is not the correct one, can be a previous one. (e.g.: repetitive short distance flights, air-shuttle flights, photographic flight, long-haul flights with an uploaded flight plan that has not been updated)	- Training: importance to update system - R/T coordination to confirm flight plan, and detect which side is wrong
HZ 006	Loss of the mid-term conflict detection tool in FRA (tool unavailable)	Human: The function may fail because of human error as well: ATCO not implementing a rerouting in the system. Aircraft is instructed to reroute but the MTCD can't detect it (it works with Flight Plan). Only Conformance Monitoring will detect the deviation, but the conflict won't be detected in time. TCT can detect the conflict (based on tactical trajectory) with a smaller time horizon (7 min or less) Equipment: - FPM - TP - CM: most common - HMI	- To prevent human error: training on MTCD tool, its particular parameter settings, time horizon and limitations.

HZ 007	Corruption of the mid-term conflict detection in FRA where one conflict is not detected by the tool *Remark: Very unlikely to have such a SW failure not detecting a mid-term conflict. It will be more a situation of lack of data with such an advance. The system does what it can with the available information (FP), but if things change later, it cannot detect the conflict.*	<u>Human:</u> - Inadequate parameter setting: too many irrelevant conflicts displayed or the opposite - Time Horizon (around 15min): tool does not detect conflicts beyond the time horizon. - Conflict detection sources: TCT vs MTCD. PCs would get nervous at exes when seeing an MTCD conflict not detected by TCT. Traffic picture is different for PC/MTCD than for TC/TCT. PCs should be aware of that. <u>Equipment:</u> - FPM - TP - CM: most common - HMI	- Training on the use of tool, so the ATCO is familiarised with the parameter setting. - Training on the time horizon - Training: ATCOs need to be aware of MTCD limitations: it is based on flight plan and the real trajectory can be modified. *Note: ATCOs generally prefer an excess rather than a lack of alerts. If conflicts are not detected, they stop relying on the tool. On the other hand, too many alerts reduce situational awareness. This means a trade-off, as being conservative on MTCD parameters will lead to an excess of alerts.* - The source of indicated conflict shall be easily indicated by the system (conflict detected by TCD vs. detected by MTCD)

ID	Hz Description	Causes	Possible barriers
HZ 008	Corruption of the mid-term conflict detection in FRA where the tool detects a conflict that does not exist	Equipment: - FPM - TP - CM: most common - HMI	N/A (equipment failure)
HZ 009	Loss of the inter sector/ACC coordination tool in FRA (Tool unavailable)	Human: - Pointing out the wrong aircraft Equipment: - C&T - HMI: most common	Possible mitigation (once the tool is lost): - Specific procedure to be applied in case the inter sector/ACC coordination tool is lost: e.g. defining points (non-plannable) to be used in these situations
HZ 010	Corruption of the inter sector/ACC coordination tool in FRA (coordination with a wrong sector)	Equipment: - C&T - HMI: most common	N/A (equipment failure)

ID	Hz Description	Causes	Possible barriers
HZ 011	Loss of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector	Equipment: - FPM - TP - HMI	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.
HZ 012	Corruption of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector resulting in a wrong minimum separation calculation	Equipment: - FPM - TP - HMI	N/A (equipment failure)

ID	Hz Description	Causes	Possible barriers
HZ 013	Loss of the Planning the What-If Tool.	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.
HZ 014	Corruption of the Planning What-If Tool.	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure)
HZ 015	Loss of the Tactical Conflict Detection tool (CDT) in FRA	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.

ID	Hz Description	Causes	Possible barriers
HZ 016	Corruption of the Tactical Conflict Detection tool (CDT) in FRA where one conflict is not detected by the tool	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure)
HZ 017	Corruption of the Tactical Conflict Detection tool (CDT) in FRA where the tool detects a conflict that does not exist	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure)
HZ 018	Loss of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.

ID	Hz Description	Causes	Possible barriers
HZ 019	Corruption of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure)
HZ 020	Loss of the tool informing the ATCOs (Planner and Executive) of ARES activation status (active/not active/released) within the area of interest of the sector	- Equipment: - FPM - TP - HMI	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.
HZ 021	Corruption of the tool informing the ATCOs (Planner and Executive) of ARES activation status (active/not active/released) within the area of interest of the sector, consisting in a late provision of information	- Equipment: - FPM - TP - HMI	N/A (equipment failure)

ID	Hz Description	Causes	Possible barriers
HZ 022	Loss of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller)	- Equipment: - FPM - TP - HMI	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.
HZ 023	Corruption of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller)	- Equipment: - FPM - TP - HMI	N/A (equipment failure)
HZ 024	Loss of the Tactical What-If/What-Else, where an ATCO is unable to assess tactical trajectory revision options, including alternative trajectory across sector boundaries	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.

ID	Hz Description	Causes	Possible barriers
HZ 025	Corruption of the Tactical What-If, where an ATCO is provided with a wrong assessment of tactical trajectory revision options, including alternative trajectory across sector boundaries	Equipment: - FPM - TP - CM - HMI	N/A (equipment failure)
HZ 029	Loss of the route adherence monitoring tool in FRA (tool unavailable)	Equipment: - FPM - Monitoring Aids - HMI	N/A (equipment failure) Possible mitigation (once the tool is lost): - ATCOs to be trained on FRA operations without availability of the different tools.

ID	Hz Description	Causes	Possible barriers
HZ 030	Aircraft flying below the FRA lower limit when reaching the point after which user defined trajectory is filed	Human: - Pilot error: not selecting the right ROC - Induced conflict: not clearing the traffic to the right level, in order to solve another conflict, induces the conflict. Equipment: - Aircraft capabilities: aircraft can't climb to that level in time. - FMS error	- Specific training to ATCOs on how to deal with situations where aircraft are flying below the FRA lower limit at entry or exit. - Procedure for ATCO to reroute, update the flight plan and coordinate with the next sector in case an aircraft is flying below the FRA lower limit when reaching the point after which the user defined trajectory is filed.
HZ 031	Aircraft descending below the FRA lower limit before reaching the exit/arrival point	Human: - Pilot error. - Error from other ATCOs. Equipment: - FMS error	- Specific training to ATCOs on how to deal with situations where aircraft are flying below the FRA lower limit at entry or exit.

ID	Hz Description	Causes	Possible barriers
HZ 032	Aircraft flying a segment longer than the maximum authorized length in the FRA	Human: - Pilot error. - Error from other ATCOs. Procedures: - Error in National AIS publication (AIP, AIC…)	N/A
HZ 033	Aircraft flying several segments shorter than the minimum authorized length in the FRA	Human: - Pilot error. - Error from other ATCOs. Procedures: - Error in National AIS publication (AIP, AIC…)	N/A
HZ 034	Aircraft flying a trajectory with user defined points (LAT/LON) whereas it is not allowed	Human: - Pilot error. - Error from other ATCOs.	N/A

Table 23: Causal Analysis of Hazards

[…]

4.5.2 Formalization of Mitigations

Following the Causal Analysis, the barriers and mitigations proposed for the hazards are captured in the next table in the form of Functionality & Performance Safety Requirements, additional to those determined during the design analysis for the success case in normal and abnormal operation conditions.

Safety Requirement		Derived from
Ref	**Requirement**	
SR_FP_OPS_040	ATCOs shall be trained/familiarized on the importance of always updating the system with changes.	Hz-001 Hz-003 Hz-005
SR_FP_OPS_042	Supervisor shall inform ATCOs of specific operational events (e.g. ARES activation) with sufficient anticipation.	Hz-001
SR_FP_OPS_046	Structurally limited FRA airspace design shall reduce the need for sector skipping.	Hz-002
SR_FP_OPS_049	Specific coordination procedures shall be defined for the case of inter sector/ACC coordination tool is lost. (e.g. defining non-plannable points to be used in those situations)	Hz-009
SR_FP_SYS_036	Controller Human Machine interaction management function shall support sector skipping by providing additional awareness on skipped traffics (e.g. different colours)	Hz-002
SR_FP_SYS_037	Controller Human Machine interaction management function shall display the source of the conflicts calculated by the system, i.e., TCT or MTCD	Hz-007

Table 24: Functionality & Performance Safety Requirements for the failure case.

In addition, mitigations to hazards' effects described in Section 3.8.1 have been traced to the success approach Safety Requirements obtained in Section 4.2.3. The following table relates those Functionality & Performance Safety Requirements to the hazards that they can mitigate:

Hz	SR (F&P) mitigating hazard's effects	Related SO (F&P)
Hz-004	SR_FP_OPS_005, SR_FP_OPS_008, SR_FP_OPS_015, SR_FP_OPS_019, SR_FP_OPS_031, SR_FP_OPS_039,	SO-FP-011, SO-FP-033

Hz	SR (F&P) mitigating hazard's effects	Related SO (F&P)
	SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_013, SR_FP_SYS_025	
Hz-005	SR_FP_SYS_015, SR_FP_SYS_032	SO-FP-029
Hz-006	SR_FP_OPS_008, SR_FP_OPS_015, SR_FP_OPS_025, SR_FP_OPS_026, SR_FP_OPS_039, SR_FP_SYS_009, SR_FP_SYS_010, SR_FP_SYS_017, SR_FP_SYS_018, SR_FP_SYS_030	SO-FP-005, SO-FP-006, SO-FP-029, SO-FP-033
Hz-007	SR_FP_OPS_025, SR_FP_OPS_026, SR_FP_SYS_009, SR_FP_SYS_010, SR_FP_SYS_017, SR_FP_SYS_018, SR_FP_SYS_030	SO-FP-005, SO-FP-006
Hz-009	SR_FP_OPS_008, SR_FP_OPS_015, SR_FP_OPS_039	SO-FP-033
Hz-011	SR_FP_OPS_003, SR_FP_OPS_008, SR_FP_OPS_015, SR_FP_OPS_027, SR_FP_OPS_039, SR_FP_SYS_004, SR_FP_SYS_010, SR_FP_SYS_011, SR_FP_SYS_019, SR_FP_SYS_031	SO-FP-007, SO-FP-033
Hz-012	SR_FP_OPS_003, SR_FP_OPS_005, SR_FP_OPS_019, SR_FP_OPS_027, SR_FP_OPS_031, SR_FP_SYS_004, SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_011, SR_FP_SYS_013, SR_FP_SYS_019, SR_FP_SYS_025, SR_FP_SYS_031	SO-FP-007, SO-FP-011
Hz-013	SR_FP_OPS_003, SR_FP_OPS_008, SR_FP_OPS_015, SR_FP_OPS_027, SR_FP_OPS_039, SR_FP_SYS_004, SR_FP_SYS_010, SR_FP_SYS_011, SR_FP_SYS_019, SR_FP_SYS_031	SO-FP-007, SO-FP-033
Hz-014	SR_FP_OPS_003, SR_FP_OPS_027, SR_FP_SYS_004, SR_FP_SYS_010, SR_FP_SYS_011, SR_FP_SYS_019, SR_FP_SYS_031	SO-FP-007
Hz-015	SR_FP_OPS_008, SR_FP_OPS_015, SR_FP_OPS_025, SR_FP_OPS_039, SR_FP_SYS_010, SR_FP_SYS_017, SR_FP_SYS_030	SO-FP-005, SO-FP-033
Hz-016	SR_FP_OPS_025, SR_FP_SYS_010, SR_FP_SYS_017, SR_FP_SYS_030	SO-FP-005
Hz-018	SR_FP_OPS_005, SR_FP_OPS_019, SR_FP_OPS_025, SR_FP_OPS_031, SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_013, SR_FP_SYS_017, SR_FP_SYS_025, SR_FP_SYS_030	SO-FP-005, SO-FP-011

Hz	SR (F&P) mitigating hazard's effects	Related SO (F&P)
Hz-019	SR_FP_OPS_005, SR_FP_OPS_019, SR_FP_OPS_025, SR_FP_OPS_031, SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_013, SR_FP_SYS_017, SR_FP_SYS_025, SR_FP_SYS_030	SO-FP-005, SO-FP-011
Hz-020	SR_FP_OPS_005, SR_FP_OPS_019, SR_FP_OPS_025, SR_FP_OPS_031, SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_013, SR_FP_SYS_017, SR_FP_SYS_025, SR_FP_SYS_030	SO-FP-005, SO-FP-011
Hz-021	SR_FP_OPS_003, SR_FP_OPS_0052, SR_FP_OPS_019, SR_FP_OPS_027, SR_FP_OPS_031, SR_FP_SYS_004, SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_011, SR_FP_SYS_013, SR_FP_SYS_019, SR_FP_SYS_025, SR_FP_SYS_031	SO-FP-007, SO-FP-011
Hz-022	SR_FP_OPS_005, SR_FP_OPS_019, SR_FP_OPS_025, SR_FP_OPS_031, SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_013, SR_FP_SYS_017, SR_FP_SYS_025, SR_FP_SYS_030	SO-FP-005, SO-FP-011
Hz-023	SR_FP_OPS_005, SR_FP_OPS_019, SR_FP_OPS_031, SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_013, SR_FP_SYS_025	SO-FP-011
Hz-024	SR_FP_OPS_003, SR_FP_OPS_008, SR_FP_OPS_015, SR_FP_OPS_027, SR_FP_OPS_039, SR_FP_SYS_004, SR_FP_SYS_010, SR_FP_SYS_011, SR_FP_SYS_019, SR_FP_SYS_031	SO-FP-007, SO-FP-033
Hz-025	SR_FP_OPS_003, SR_FP_OPS_005, SR_FP_OPS_019, SR_FP_OPS_027, SR_FP_OPS_031, SR_FP_SYS_004, SR_FP_SYS_006, SR_FP_SYS_010, SR_FP_SYS_011, SR_FP_SYS_013, SR_FP_SYS_019, SR_FP_SYS_025, SR_FP_SYS_031	SO-FP-007, SO-FP-011
Hz-029	SR_FP_OPS_008, SR_FP_OPS_015, SR_FP_OPS_025, SR_FP_OPS_039, SR_FP_SYS_010, SR_FP_SYS_017, SR_FP_SYS_030	SO-FP-005, SO-FP-033
Hz-032	SR_FP_OPS_021	SO-FP-034

Table 25: Mitigation of Hazards' Effects with success case Functionality & Performance Safety Requirements.

4.5.3 Safety Requirements (integrity/reliability)

Integrity Safety Objectives from Section 3.8.2 are incorporated as quantitative Integrity & Reliability Safety Requirements (these safety objectives are not further allocated on the components of the SPR-level model because such allocation could depend on local implementation):

Hz	SR	Safety Requirement (Integrity/Reliability)
Hz-001	SR_IR_OPS_001	The frequency of occurrence of a failure to apply the sector/ACC coordination procedure, either by ATC Sector Planning Role or other actor in coordination not following LoA, shall not be greater than 3.33E-05 per flight hour
Hz-002	SR_IR_OPS_002	The frequency of occurrence of an ATCO failure to remove a flight of her/his sector from the ordered list of sectors that are expected to assume a given flight, shall not be greater than 3,33E-05 per flight hour
Hz-003	SR_IR_SYS_003	The frequency of occurrence of ATC Sector Planning Role not being informed of tactical controller actions (failure of tactical-planner information sharing tools), shall not be greater than 3.33E-05 per flight hour
Hz-004	SR_IR_SYS_004	The frequency of occurrence of a loss of display of the planned trajectory in FRA (tool/function unavailable), shall not be greater than 3,33E-05 per flight hour
Hz-005	SR_IR_SYS_005	The frequency of occurrence of a discrepancy between ground and airborne trajectory in FRA, shall not be greater than 3,33E-05 per flight hour
Hz-006	SR_IR_SYS_006	The frequency of occurrence of a loss of the mid-term conflict detection tool in FRA (tool unavailable), shall not be greater than 3,33E-04 per flight hour
Hz-007	SR_IR_SYS_007	The frequency of occurrence of a corruption of the mid-term conflict detection in FRA where one conflict is not detected by the tool, shall not be greater than 3,33E-04 per flight hour
Hz-009	SR_IR_SYS_008	The frequency of occurrence of a loss of the inter sector/ACC coordination tool in FRA (tool unavailable), shall not be greater than 1,00E-03 per flight hour
Hz-011	SR_IR_SYS_009	The frequency of occurrence of a loss of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector, shall not be greater than 1,00E-03 per flight hour

Hz	SR	Safety Requirement (Integrity/Reliability)
Hz-012	SR_IR_SYS_010	The frequency of occurrence of a corruption of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector resulting in a wrong minimum separation calculation, shall not be greater than 3,33E-04 per flight hour
Hz-013	SR_IR_SYS_011	The frequency of occurrence of a loss of the ATC Sector Planning Role What-If Tool, shall not be greater than 1.00E-03 per flight hour
Hz-014	SR_IR_SYS_012	The frequency of occurrence of a corruption of the ATC Sector Planning Role What-If Tool, shall not be greater than 1.00E-03 per flight hour
Hz-015	SR_IR_SYS_013	The frequency of occurrence of a loss of the ATC Sector Executive Role Conflict Detection tool (CDT) in FRA, shall not be greater than 4.00E-06 per flight hour
Hz-016	SR_IR_SYS_014	The frequency of occurrence of a corruption of the ATC Sector Executive Role Conflict Detection tool (CDT) in FRA where one conflict is not detected by the tool, shall not be greater than 4.00E-06 per flight hour
Hz-018	SR_IR_SYS_015	The frequency of occurrence of a loss of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector, shall not be greater than 4,00E-06 per flight hour
Hz-019	SR_IR_SYS_016	The frequency of occurrence of a corruption of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector, shall not be greater than 4,00E-06 per flight hour
Hz-020	SR_IR_SYS_017	The frequency of occurrence of a loss of the tool informing the ATCOs (ATC Sector Planning and Executive Roles) of ARES activation status (active/not active/released) within the area of interest of the sector, shall not be greater than 3.33E-04 per flight hour
Hz-021	SR_IR_SYS_018	The frequency of occurrence of a corruption of the tool informing the ATCOs (ATC Sector Planning and Executive Roles) of ARES activation status (active/not active/released) within the area of interest of the sector, consisting in a late provision of information, shall not be greater than 3.33E-04 per flight hour

Hz	SR	Safety Requirement (Integrity/Reliability)
Hz-022	SR_IR_SYS_019	The frequency of occurrence of a loss of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller), shall not be greater than 4,00E-06 per flight hour
Hz-023	SR_IR_SYS_020	The frequency of occurrence of a corruption of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller), shall not be greater than 4,00E-06 per flight hour
Hz-024	SR_IR_SYS_021	The frequency of occurrence of a loss of the ATC Sector Executive Role What-If/What-Else, where an ATCO is unable to assess tactical trajectory revision options, including alternative trajectory across sector boundaries, shall not be greater than 1.00E-03 per flight hour
Hz-025	SR_IR_SYS_022	The frequency of occurrence of a corruption of the ATC Sector Executive Role What-If, where an ATCO is provided with a wrong assessment of tactical trajectory revision options, including alternative trajectory across sector boundaries, shall not be greater than 3.33E-05 per flight hour
HZ-029	SR_IR_SYS_026	The frequency of occurrence of a loss of the route adherence monitoring tool in FRA (tool unavailable), shall not be greater than 3,33E-04 per flight hour while in high / very high complexity Free Routing Operations.
HZ-030	SR_IR_OPS_027	The frequency of occurrence of an aircraft flying below the FRA lower limit when reaching the point after which user defined trajectory is filed, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
HZ-031	SR_IR_OPS_028	The frequency of occurrence of an aircraft descending below the FRA lower limit before reaching the exit/arrival point, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
HZ-032	SR_IR_OPS_029	The frequency of occurrence of an aircraft flying a segment longer than the maximum authorized length in the FRA, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
HZ-033	SR_IR_OPS_030	The frequency of occurrence of an aircraft flying several segments shorter than the minimum authorized length in the FRA, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.

Hz	SR	Safety Requirement (Integrity/Reliability)
HZ-034	SR_IR_OPS_031	The frequency of occurrence of an aircraft flying a trajectory with user defined points (LAT/LON) whereas it is not allowed, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.

Table 26: Integrity & Reliability Safety Requirements

4.6 Achievability of the SAfety Criteria

The Safety Criteria set in section 3.5 have been achieved through the Safety Objectives identified in sections 3.6 to 3.8 have been derived into safety requirements (Functionality & Performance and Integrity) in sections 4.2 to 4.5.

The Safety Criteria should be achieved by implementing these safety requirements.

4.7 Realism of the SPR-level Design

4.7.1 Achievability of Safety Requirements / Assumptions

The Safety Requirements identified in section 4.2 to 4.5 have been determined and validated through safety workshop, based on the results of the validation activities as explained in section 4.8. The involvement of operational and technical experts during these workshops endure the achievability of the safety requirements and assumptions.

Some of these safety requirements have been evaluated during the validation activities, even if no formal traceability between the safety requirements and the safety validation objectives has been developed.

4.7.2 “Testability” of Safety Requirements

The testability of safety requirements has not been formally assessed. However, as mentioned in previous section, the involvement of validation experts during the safety workshop contributes to the demonstration of the testability of the safety requirements.

4.8 Validation & Verification of the Safe Design at SPR Level

The consolidated lists of Safety Requirements are provided in Appendix B.

The process by which these safety objectives were derived is presented in the previous sections 4.2 to 4.5. Starting with the safety objectives from sections 3.6 to 3.8, an SPR level model was developed and an initial set of safety requirements was proposed by allocating the safety objective onto the components of the SPR level model.

The Safety Requirements (functional, performance and integrity) were then reviewed and completed during a safety workshops with concept, operational and validation experts and a subsequent post-processing using the SRM methodology [1].

The participants to this safety workshops were:

- SPR-level Safety workshop participants – Madrid, 3rd and 4th July 2019:
    - Florence Serdot-Omer (DSNA) – PJ.06 Project Coordinator and Solution Leader
    - Pilar Calzon Robledo (INECO) - PJ.06-01 SPR coordinator
    - Miguel Capote (INECO) – PJ.06-01 Safety Expert / PJ.06 Safety PCIT
    - Nicolas Giraudon (DSNA) – PJ.06-01 Safety Expert
    - Manuel Martínez (INDRA) – PJ.06-01 TS/IRS Task Leader
    - Fernando Ruiz-Artaza (ENAIRE) – PJ.06-01 Operational Expert
    - Raquel García Lasheras (CRIDA) – PJ.06-01 Thread 2 Validation Task Leader
    - Marco Paino (Technosky) – PJ.06-01 VALR Task Leader
    - Marta García (INECO) – PJ.06-01 Project Contributor
    - Eva López Calleja (INECO) – PJ.06-01 Project Contributor

Both aspects, success case and failure case, were addressed during this workshop. However, some of the hazards from the failure case were not fully reviewed/validated and would need to be further assessed within the frame of implementation activities, considering local environment.

Additionally, a Requirements Consolidation Workshop was carried out at Solution level to crosscheck and validate all the Safety, Performance, Human Performance, Interoperability, and Operational Requirements.

References

Safety

[1] SESAR, Safety Reference Material, Edition 4.0, April 2016

[2] SESAR, Guidance to Apply the Safety Reference Material, Edition 3.0, April 2016

[3] SESAR Safety Plan SESAR Solution PJ.06-01 SAP_00_00_01

[4] SESAR Solution PJ.06-01 SPR-INTEROP/OSED for V3 - Part II - Safety Assessment Report

[5] SESAR, Final Guidance Material to Execute Proof of Concept, Ed00.04.00, August 2015

[6] SESAR, Resilience Engineering Guidance, May 2016

Other

[7] SESAR 2020 D2.1.030"PJ06-01 SPR-INTEROP/OSED for V3 – Part I, v00.03.00

[8] SESAR 2020 PJ19: Validation Targets (2017), 21.04.2017

[9] Project Handbook, 31 October 2016

[10] PJ06 SESAR 2020 Project Management Plan

[11] PJ19.4 D4.1 Performance Framework

[12] DS17b from eATM portal (https://www.eatmportal.eu)

Appendix A Safety Objectives

Safety Objectives (Functionality and Performance)

ID	Description
SO-FP-001	The ATCOs shall be able to perform coordination of flights across ACC/sector boundaries not necessarily supported by published coordination points
SO-FP-002	The acceptable entry and exit conditions of a sector/ACC shall be described in LoA without reference to published route network or fixed coordination point
SO-FP-003	The ATCOs (ATC Sector Planning and Executive Roles) shall be able to remove a sector from the ordered list of the flight sequence (list of sectors that are expected to assume the flight)
SO-FP-004	In order to avoid more ATC induced conflicts, ATC Sector Planning Role should be informed of ATC Sector Executive Role actions
SO-FP-005	The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary
SO-FP-006	The ATCOs (ATC Sector Planning and Executive Roles) should be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector
SO-FP-007	The ATCOs shall be able to detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest
SO-FP-008	The ATC Sector Planning Role shall be provided with tools to support information sharing between ATC Sector Planning and Executive Roles.
SO-FP-009	The ATC Sector Planning Role shall be provided with tools and procedures to support coordination of flights across ACC/sector boundaries with unnamed coordination points, with the identification of a flight to any adjacent sector and support the negotiation of coordinations
SO-FP-010	The ATCOs should be able to assess alternative trajectories in support of the negotiation of coordination conditions with adjacent ATC sectors (planning what-if)
SO-FP-011	The ATCOs shall be able to detect tactical encounters between two or more flights not necessarily on a fixed ATS route segment
SO-FP-012	The ATCOs (ATC Sector Planning and Executive Roles) should be provided with a tool detecting the potential crossing between the planned trajectory of the aircraft and active stack En Route in the sector
SO-FP-013	The ATCOs (ATC Sector Planning and Executive Roles) shall be informed in due time of ARES activation status (active/not active/released) within the area of interest of the sector

ID	Description
SO-FP-014	The ATCOs shall be able to detect predicted infringement of active ARES by flights along their planned trajectories within the ATC sector area of interest
SO-FP-015	The ATCO of sector before FRA shall be aware of FRA lower limit and give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory
SO-FP-016	The ATCOs shall be able to assess tactical trajectory revision options including alternative trajectories across ACC/sector boundaries (tactical what-if)
SO-FP-029	The ATCOs shall be provided with support to monitor trajectory adherence
SO-FP-030	The ATCOs shall be assisted by a Short-Term Conflict Alert system
SO-FP-031	The ATCOs shall be assisted by an Area Proximity Warning system
SO-FP-032	Flight planning rules applicable inside the free routing airspace (e.g. e.g. entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility or not to plan user defined points...) shall be defined and published in national AIS publication
SO-FP-033	Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)
SO-FP-034	ATCOs shall have included all points of interest within the FDPS database (e.g. all waypoints within the maximum length of the segments)

Table 27: Consolidated List of Safety Objectives (Functionality & Performance)

Safety Objectives (Integrity)

ID	Description
SO-IR-001	The frequency of occurrence of a failure to apply the sector/ACC coordination procedure, either by ATC Sector Planning Role or other actor in coordination not following LoA, shall not be greater than 3.33E-05 per flight hour
SO-IR-002	The frequency of occurrence of an ATCO failure to remove a flight of her/his sector from the ordered list of sectors that are expected to assume a given flight, shall not be greater than 3,33E-05 per flight hour
SO-IR-003	The frequency of occurrence of ATC Sector Planning Role not being informed of tactical controller actions (failure of tactical-planner information sharing tools), shall not be greater than 3.33E-05 per flight hour

ID	Description
SO-IR-004	The frequency of occurrence of a loss of display of the planned trajectory in FRA (tool/function unavailable), shall not be greater than 3,33E-05 per flight hour
SO-IR-005	The frequency of occurrence of a discrepancy between ground and airborne trajectory in FRA, shall not be greater than 3,33E-05 per flight hour
SO-IR-006	The frequency of occurrence of a loss of the mid-term conflict detection tool in FRA (tool unavailable), shall not be greater than 3,33E-04 per flight hour
SO-IR-007	The frequency of occurrence of a corruption of the mid-term conflict detection in FRA where one conflict is not detected by the tool, shall not be greater than 3,33E-04 per flight hour
SO-IR-008	The frequency of occurrence of a loss of the inter sector/ACC coordination tool in FRA (tool unavailable), shall not be greater than 1,00E-03 per flight hour
SO-IR-009	The frequency of occurrence of a loss of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector, shall not be greater than 1,00E-03 per flight hour
SO-IR-010	The frequency of occurrence of a corruption of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector resulting in a wrong minimum separation calculation, shall not be greater than 3,33E-04 per flight hour
SO-IR-011	The frequency of occurrence of a loss of the ATC Sector Planning Role What-If Tool, shall not be greater than 1.00E-03 per flight hour
SO-IR-012	The frequency of occurrence of a corruption of the ATC Sector Planning Role What-If Tool, shall not be greater than 1.00E-03 per flight hour
SO-IR-013	The frequency of occurrence of a loss of the ATC Sector Executive Role Conflict Detection tool (CDT) in FRA, shall not be greater than 4.00E-06 per flight hour
SO-IR-014	The frequency of occurrence of a corruption of the ATC Sector Executive Role Conflict Detection tool (CDT) in FRA where one conflict is not detected by the tool, shall not be greater than 4.00E-06 per flight hour
SO-IR-015	The frequency of occurrence of a loss of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector, shall not be greater than 4,00E-06 per flight hour
SO-IR-016	The frequency of occurrence of a corruption of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector, shall not be greater than 4,00E-06 per flight hour

ID	Description
SO-IR-017	The frequency of occurrence of a loss of the tool informing the ATCOs (ATC Sector Planning and Executive Roles) of ARES activation status (active/not active/released) within the area of interest of the sector, shall not be greater than 3.33E-04 per flight hour
SO-IR-018	The frequency of occurrence of a corruption of the tool informing the ATCOs (ATC Sector Planning and Executive Roles) of ARES activation status (active/not active/released) within the area of interest of the sector, consisting in a late provision of information, shall not be greater than 3.33E-04 per flight hour
SO-IR-019	The frequency of occurrence of a loss of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller), shall not be greater than 4,00E-06 per flight hour
SO-IR-020	The frequency of occurrence of a corruption of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller), shall not be greater than 4,00E-06 per flight hour
SO-IR-021	The frequency of occurrence of a loss of the ATC Sector Executive Role What-If/What-Else, where an ATCO is unable to assess tactical trajectory revision options, including alternative trajectory across sector boundaries, shall not be greater than 1.00E-03 per flight hour
SO-IR-022	The frequency of occurrence of a corruption of the ATC Sector Executive Role What-If, where an ATCO is provided with a wrong assessment of tactical trajectory revision options, including alternative trajectory across sector boundaries, shall not be greater than 3.33E-05 per flight hour
SO-IR-026	The frequency of occurrence of a loss of the route adherence monitoring tool in FRA (tool unavailable), shall not be greater than 3,33E-04 per flight hour while in high / very high complexity Free Routing Operations.
SO-IR-027	The frequency of occurrence of an aircraft flying below the FRA lower limit when reaching the point after which user defined trajectory is filed, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
SO-IR-028	The frequency of occurrence of an aircraft descending below the FRA lower limit before reaching the exit/arrival point, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
SO-IR-029	The frequency of occurrence of an aircraft flying a segment longer than the maximum authorized length in the FRA, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.
SO-IR-030	The frequency of occurrence of an aircraft flying several segments shorter than the minimum authorized length in the FRA, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.

ID	Description
SO-IR-031	The frequency of occurrence of an aircraft flying a trajectory with user defined points (LAT/LON) whereas it is not allowed, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.

Table 28: Consolidated List of Safety Objectives (Integrity)

Appendix B Consolidated List of Safety Requirements

Safety Requirements (Functionality and Performance)

The Table 29 below lists the Functionality and Performance Safety Requirements identified in section 4.

Safety Requirement		Derived from
Ref	Requirement	
SR_FP_SYS_001	Coordination and Transfer function (e.g. LoA, operating procedure…) shall enable the PC to perform coordination of flights across ACC/sector boundaries not necessarily supported by fixed coordination points	SO-FP-001 SO-FP-009
SR_FP_SYS_002	Coordination and Transfer function shall support the ATCO in the management of proposed coordination condition (negotiation of coordination conditions)	SO-FP-009
SR_FP_SYS_003	Coordination and Transfer function shall enable to remove a sector from the ordered list of the flight sequence (SKIP function)	SO-FP-003
SR_FP_SYS_004	Trajectory Prediction function shall perform planned trajectory prediction of a selected flight within the area of interest of the sector	SO-FP-005 SO-FP-006 SO-FP-007 SO-FP-029
SR_FP_SYS_005	Trajectory Prediction function shall perform alternate planned trajectory prediction of a selected flight, based on Controller input.	SO-FP-010
SR_FP_SYS_006	Trajectory Prediction function shall perform tactical trajectory prediction of a selected flight not necessarily on a fixed ATS route network	SO-FP-011
SR_FP_SYS_007	Trajectory Prediction function shall perform alternate tactical trajectory prediction of the displayed trajectory revision options across ATSU/sector boundaries	SO-FP-016
SR_FP_SYS_008	Trajectory Prediction function shall enable to remove a sector from the ordered list of the flight sequence (SKIP function)	SO-FP-003

Safety Requirement		Derived from
Ref	Requirement	
SR_FP_SYS_009	Conflict Detection function shall determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector.	SO-FP-006
SR_FP_SYS_010	Flight Planning Management function shall provide flight plan data within the area of interest of the sector	SO-FP-005 SO-FP-006 SO-FP-007 SO-FP-011 SO-FP-029
SR_FP_SYS_011	Conflict Management function shall detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest	SO-FP-007
SR_FP_SYS_012	Conflict Management function shall detect planned conflict of a selected flight along its alternate planned trajectory, based on Controller input.	SO-FP-010
SR_FP_SYS_013	Conflict Management function shall detect tactical encounters between two or more flights not necessarily on a fixed ATS route network	SO-FP-011
SR_FP_SYS_014	Conflict Management function shall detect tactical conflicts of the displayed trajectory revision options across ATSU/sector boundaries	SO-FP-016
SR_FP_SYS_015	Monitoring aids function shall detect lateral or vertical deviation of the flight from their planned trajectory	SO-FP-029
SR_FP_SYS_016	Controller Human Machine interaction management function shall include a function to highlight fights (e.g. point-out function) from PC to TC and vice versa.	SO-FP-004 SO-FP-008
SR_FP_SYS_017	Controller Human Machine interaction management function shall be able to display the planned trajectory of a selected flight beyond the ATSU boundary to PC and TC	SO-FP-005
SR_FP_SYS_018	Controller Human Machine interaction management function shall be able to display to PC and TC predicted separation between flights on their planned trajectories within the area of interest of the sector.	SO-FP-006

Safety Requirement		Derived from
Ref	Requirement	
SR_FP_SYS_019	Controller Human Machine interaction management function shall be able to display to PC and TC mid-term encounters between flights along their planned trajectories within the ATC sector area of interest.	SO-FP-007
SR_FP_SYS_020	Controller Human Machine interaction management function shall enable the input of alternate entry/exit conditions by the Controller.	SO-FP-010
SR_FP_SYS_021	Controller Human Machine interaction management function shall display planned conflict of a selected flight along its alternate planned trajectory, based on Controller input.	SO-FP-010
SR_FP_SYS_022	Controller Human Machine Interaction management function shall enable the input of new proposed exit conditions by the Controller for flights exiting his/her sector	SO-FP-009 SO-FP-010
SR_FP_SYS_023	Controller Human Machine Interaction management function shall enable the PC to accept or reject a proposed coordination condition	SO-FP-009
SR_FP_SYS_024	Controller Human Machine Interaction management function shall enable the input of new proposed exit conditions by the Controller for flights not yet assumed	SO-FP-009 SO-FP-010
SR_FP_SYS_025	Controller Human Machine interaction management function shall be able to display tactical encounters between two or more flights not necessarily on a fixed ATS route network	SO-FP-011
SR_FP_SYS_026	Controller Human Machine interaction management function shall be able to display in due time the ARES activation status (active/not active/released) within the area of interest of the sector	SO-FP-013
SR_FP_SYS_027	Controller Human Machine interaction management function shall display the possible tactical trajectory revision options to the Tactical Controller	SO-FP-016
SR_FP_SYS_028	Controller Human Machine interaction management function shall enable selection and implementation of	SO-FP-016

Safety Requirement		Derived from
Ref	Requirement	
	the possible trajectory revisions by the Tactical Controller	
SR_FP_SYS_029	Controller Human Machine Interaction function shall enable ATCo to request the removal a sector from the ordered list of the flight sequence (SKIP function)	SO-FP-003
SR_FP_SYS_030	Controller Human Machine interaction management function shall automatically display the planned trajectory for a short period of time (e.g. 2 or 3 seconds) when assuming a flight	SO-FP-005
SR_FP_SYS_031	Controller Human Machine interaction management function shall enable TC to de-activate the display of mid-term encounters between flights along their planned trajectories	SO-FP-007
SR_FP_SYS_032	Controller Human Machine interaction management function shall display an alert in case of detection of deviation of a flight from its planned trajectory	SO-FP-029
SR_FP_SYS_033	Airspace management function shall provide in due time the ARES activation status (active/not active/released) within the area of interest of the sector	SO-FP-013
SR_FP_SYS_034	Area Proximity Warning function shall detect imminent infringement of active En Route stack by flights along their tactical trajectories within the ATC sector area of interest	SO-FP-012
SR_FP_SYS_035	Area Proximity Warning shall be adapted (tool parameters) to Free Routing environment	SO-FP-014 SO-FP-031
SR_FP_SYS_036	Controller Human Machine interaction management function shall support sector skipping by providing additional awareness on skipped traffics (e.g. different colours)	Hz-002
SR_FP_SYS_037	Controller Human Machine interaction management function shall display the source of the conflicts calculated by the system, i.e., TCD or MTCD	Hz-007
SR_FP_OPS_001	ATCOs shall be trained/familiarized with new entry and exit conditions of a sector/ATSU, in free routing	SO-FP-002

Safety Requirement		Derived from
Ref	Requirement	
	environment, without reference to published route network or fixed coordination point	
SR_FP_OPS_002	ATCOs shall be trained/familiarized to use the SKIP function (i.e. ability remove a sector from the ordered list of the flight sequence) in Free Routing environment	SO-FP-003
SR_FP_OPS_003	ATCOs shall be trained/familiarized on the planned conflict detection tool and its features (i.e. tool displaying all possible planned conflict or only “proven” ones), its particular parameter settings, time horizon and limitations.	SO-FP-007
SR_FP_OPS_004	Planning Controller shall be trained/familiarized on the coordination negotiation tool and associated operating procedures	SO-FP-009
SR_FP_OPS_005	Tactical Controller shall be trained/familiarized on the detection of tactical encounters between two or more flights not necessarily on a fixed ATS route network, with or without tactical detection tool (depending on tools locally available)	SO-FP-011
SR_FP_OPS_006	ATCOs shall be trained/familiarized to the detection of potential crossing between active En Route stack and the planned trajectory of flights not necessarily on a fixed ATS route segment	SO-FP-012
SR_FP_OPS_007	ATCOs of sector before FRA shall be trained/familiarized on FRA lower limit to give appropriate clearance to make it possible for the aircraft to reach FRA lower level limit before the first point of their user-defined trajectory	SO-FP-015
SR_FP_OPS_008	ATCOs shall be trained/familiarized to updated contingency procedure in Free Routing environment (e.g. procedure in case of loss of surveillance, air/ground communication, FDPS, conflict detection tool…)	SO-FP-033
SR_FP_OPS_009	ATC operating procedures shall describe the acceptable entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point.	SO-FP-001 SO-FP-002 SO-FP-009

Safety Requirement		Derived from
Ref	Requirement	
SR_FP_OPS_010	ATC operating procedures shall describe the usage a SKIP function (i.e. ability to remove a sector from the ordered list of the flight sequence) in Free Routing environment (e.g. which sector initiate the SKIP, skipped sector remains responsible of the flight…)	SO-FP-003
SR_FP_OPS_014	ATC operating procedures to deviate flights around active ARES shall be adapted to free route environment (e.g. time to start deviating…)	SO-FP-013 SO-FP-014
SR_FP_OPS_015	ATC contingency procedure (e.g. procedure in case of loss of surveillance, air/ground communication, FDPS, conflict detection tool…) shall be adapted to Free Routing operations	SO-FP-033
SR_FP_OPS_016	LoA shall describe the acceptable entry and exit conditions of a sector/ATSU, in free routing environment, without reference to published route network or fixed coordination point	SO-FP-002
SR_FP_OPS_017	ATC shall be trained to ensure information of ATC Sector Planning Role about ATC Sector Executive Role actions	SO-FP-004
SR_FP_OPS_018	National AIS publication and RAD shall describe flight planning rules applicable inside the free routing airspace (entry/exit conditions from/to adjacent airspace, transition conditions from/to lower/upper airspace, period of availability of the airspace, min/max length of the segments, possibility to plan user defined points…) without reference to published route network or fixed coordination point.	SO-FP-001
SR_FP_OPS_019	National AIS publication and RAD shall define sufficient flight planning restrictions enabling the provision of safe and efficient Air Traffic Control service by the ATCo in tactical phase (i.e. trade off between structural limitation of the FRA and available tool, particularly for optional tools)	SO-FP-011
SR_FP_OPS_020	National AIS publication and RAD shall describe flight planning rules applicable inside the free routing airspace to avoid flight planning through active ARES	SO-FP-013

Safety Requirement		Derived from
Ref	Requirement	
SR_FP_OPS_021	En-Route ATS Provider shall ensure consistency between flight planning rules applicable inside the free routing airspace and limitation of the system database to ensure that system will know all the waypoints of interest	SO-FP-034
SR_FP_OPS_022	The ATCOs shall be able to perform coordination of flights across ACC/sector boundaries not necessarily supported by published coordination points	SO-FP-001
SR_FP_OPS_023	The ATCOs (ATC Sector Planning and Executive Roles) shall be able to remove a flight of her/his sector from the ordered list of sectors that are expected to assume a given flight	SO-FP-003
SR_FP_OPS_024	In order to avoid more ATC induced conflicts, ATC Sector Planning Role shall be informed of ATC Sector Executive Role actions and vice versa	SO-FP-004
SR_FP_OPS_025	The ATCOs shall be able to display the planned trajectory of a selected flight beyond the sector/ACC boundary	SO-FP-005
SR_FP_OPS_026	The ATCOs (ATC Sector Planning and Executive Roles) shall be provided with support tool to determine the minimal predicted separation between flights on their planned trajectories within the area of interest of the sector	SO-FP-006
SR_FP_OPS_027	The ATCOs shall be able to detect mid-term encounters between flights along their planned trajectories within the ATC sector area of interest	SO-FP-007
SR_FP_OPS_028	The ATC Sector Planning Role shall be provided with tools to support information sharing between ATC Sector Planning and Executive Roles	SO-FP-008
SR_FP_OPS_029	The ATC Sector Planning Role shall be provided with tools and procedures to support coordination of flights across ACC/sector boundaries with unnamed coordination points, with the identification of a flight to any adjacent sector and support the negotiation of coordinations	SO-FP-009

Safety Requirement		Derived from
Ref	Requirement	
SR_FP_OPS_030	The ATCOs shall be able to assess alternative trajectories in support of the negotiation of coordination conditions with adjacent ATC sectors (planning what-if)	SO-FP-010
SR_FP_OPS_031	The ATCOs shall be able to detect tactical encounters between two or more flights not necessarily on a fixed ATS route segment	SO-FP-011
SR_FP_OPS_032	The ATCOs (ATC Sector Planning and Executive Roles) shall be provided with a tool detecting the potential crossing between the planned trajectory of the aircraft and active stack En Route in the sector	SO-FP-012
SR_FP_OPS_033	The ATCOs (ATC Sector Planning and Executive Roles) shall be informed in due time of ARES activation status (active/not active/released) within the area of interest of the sector	SO-FP-013
SR_FP_OPS_034	The ATCOs shall be able to detect predicted infringement of active ARES by flights along their planned trajectories within the ATC sector area of interest	SO-FP-014
SR_FP_OPS_035	The ATCOs shall be able to assess tactical trajectory revision options including alternative trajectories across ACC/sector boundaries (tactical what-if)	SO-FP-016
SR_FP_OPS_036	The ATCOs shall be provided with support to monitor trajectory adherence	SO-FP-029
SR_FP_OPS_037	The ATCOs shall be assisted by a Short-Term Conflict Alert system	SO-FP-030
SR_FP_OPS_038	The ATCOs shall be assisted by an Area Proximity Warning system	SO-FP-031
SR_FP_OPS_039	Air Navigation Service Provider shall adapt capacity of the sectors in case of ATC technical failure (loss of surveillance, air/ground communication, FDPS…)	SO-FP-033
SR_FP_OPS_040	ATCOs shall be trained/familiarized on the importance of always updating the system with changes.	Hz-001 Hz-003

Safety Requirement		Derived from
Ref	Requirement	
		Hz-005
SR_FP_OPS_042	Supervisors involvement shall be increased for FRA operation, e.g., by increasing time to inform ATCOs of ARES activation	Hz-001
SR_FP_OPS_046	Structurally limited FRA airspace design shall reduce the need for sector skipping.	Hz-002 SO-FP-003
SR_FP_OPS_049	Specific coordination procedures shall be defined for the case of inter sector/ACC coordination tool is lost.	Hz-009

Table 29: Safety Requirements (Functionality and Performance)

Safety Requirements (Integrity)

The Table 30 below lists the Integrity and Reliability Safety Requirements identified in section 4.

Safety Requirement		Derived from
Ref	Requirement	
SR_IR_OPS_001	The frequency of occurrence of a failure to apply the sector/ACC coordination procedure, either by ATC Sector Planning Role or other actor in coordination not following LoA, shall not be greater than 3.33E-05 per flight hour	Hz-001
SR_IR_OPS_002	The frequency of occurrence of an ATCO failure to remove a flight of her/his sector from the ordered list of sectors that are expected to assume a given flight, shall not be greater than 3,33E-05 per flight hour	Hz-002
SR_IR_SYS_003	The frequency of occurrence of ATC Sector Planning Role not being informed of tactical controller actions (failure of tactical-planner information sharing tools), shall not be greater than 3.33E-05 per flight hour	Hz-003

Safety Requirement		Derived from
Ref	Requirement	
SR_IR_SYS_004	The frequency of occurrence of a loss of display of the planned trajectory in FRA (tool/function unavailable), shall not be greater than 3,33E-05 per flight hour	Hz-004
SR_IR_SYS_005	The frequency of occurrence of a discrepancy between ground and airborne trajectory in FRA, shall not be greater than 3,33E-05 per flight hour	Hz-005
SR_IR_SYS_006	The frequency of occurrence of a loss of the mid-term conflict detection tool in FRA (tool unavailable), shall not be greater than 3,33E-04 per flight hour	Hz-006
SR_IR_SYS_007	The frequency of occurrence of a corruption of the mid-term conflict detection in FRA where one conflict is not detected by the tool, shall not be greater than 3,33E-04 per flight hour	Hz-007
SR_IR_SYS_008	The frequency of occurrence of a loss of the inter sector/ACC coordination tool in FRA (tool unavailable), shall not be greater than 1,00E-03 per flight hour	Hz-009
SR_IR_SYS_009	The frequency of occurrence of a loss of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector, shall not be greater than 1,00E-03 per flight hour	Hz-011
SR_IR_SYS_010	The frequency of occurrence of a corruption of the tool determining the minimum predicted separation between flights on their planned trajectories within the area of interest of the sector resulting in a wrong minimum separation calculation, shall not be greater than 3,33E-04 per flight hour	Hz-012
SR_IR_SYS_011	The frequency of occurrence of a loss of the ATC Sector Planning Role What-If Tool, shall not be greater than 1.00E-03 per flight hour	Hz-013
SR_IR_SYS_012	The frequency of occurrence of a corruption of the ATC Sector Planning Role What-If Tool, shall not be greater than 1.00E-03 per flight hour	Hz-014
SR_IR_SYS_013	The frequency of occurrence of a loss of the ATC Sector Executive Role Conflict Detection tool (CDT) in FRA, shall not be greater than 4.00E-06 per flight hour	Hz-015

Safety Requirement		Derived from
Ref	Requirement	
SR_IR_SYS_014	The frequency of occurrence of a corruption of the ATC Sector Executive Role Conflict Detection tool (CDT) in FRA where one conflict is not detected by the tool, shall not be greater than 4.00E-06 per flight hour	Hz-016
SR_IR_SYS_015	The frequency of occurrence of a loss of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector, shall not be greater than 4,00E-06 per flight hour	Hz-018
SR_IR_SYS_016	The frequency of occurrence of a corruption of the tool detecting potential crossings between the planned trajectory of the aircraft and the active stack En Route in the sector, shall not be greater than 4,00E-06 per flight hour	Hz-019
SR_IR_SYS_017	The frequency of occurrence of a loss of the tool informing the ATCOs (ATC Sector Planning and Executive Roles) of ARES activation status (active/not active/released) within the area of interest of the sector, shall not be greater than 3.33E-04 per flight hour	Hz-020
SR_IR_SYS_018	The frequency of occurrence of a corruption of the tool informing the ATCOs (ATC Sector Planning and Executive Roles) of ARES activation status (active/not active/released) within the area of interest of the sector, consisting in a late provision of information, shall not be greater than 3.33E-04 per flight hour	Hz-021
SR_IR_SYS_019	The frequency of occurrence of a loss of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller), shall not be greater than 4,00E-06 per flight hour	Hz-022
SR_IR_SYS_020	The frequency of occurrence of a corruption of the prediction of infringement of active ARES (within the area of interest) by flights (Conflict Detection / Resolution Aid to Planning Controller), shall not be greater than 4,00E-06 per flight hour	Hz-023
SR_IR_SYS_021	The frequency of occurrence of a loss of the ATC Sector Executive Role What-If/What-Else, where an ATCO is unable to assess tactical trajectory revision options, including alternative trajectory across sector boundaries, shall not be greater than 1.00E-03 per flight hour	Hz-024

Safety Requirement		Derived from
Ref	Requirement	
SR_IR_SYS_022	The frequency of occurrence of a corruption of the ATC Sector Executive Role What-If, where an ATCO is provided with a wrong assessment of tactical trajectory revision options, including alternative trajectory across sector boundaries, shall not be greater than 3.33E-05 per flight hour	Hz-025
SR_IR_SYS_026	The frequency of occurrence of a loss of the route adherence monitoring tool in FRA (tool unavailable), shall not be greater than 3,33E-04 per flight hour while in high / very high complexity Free Routing Operations.	HZ-029
SR_IR_OPS_027	The frequency of occurrence of an aircraft flying below the FRA lower limit when reaching the point after which user defined trajectory is filed, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.	HZ-030
SR_IR_OPS_028	The frequency of occurrence of an aircraft descending below the FRA lower limit before reaching the exit/arrival point, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.	HZ-031
SR_IR_OPS_029	The frequency of occurrence of an aircraft flying a segment longer than the maximum authorized length in the FRA, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.	HZ-032
SR_IR_OPS_030	The frequency of occurrence of an aircraft flying several segments shorter than the minimum authorized length in the FRA, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.	HZ-033
SR_IR_OPS_031	The frequency of occurrence of an aircraft flying a trajectory with user defined points (LAT/LON) whereas it is not allowed, shall not be greater than 1,00E-03 per flight hour while in high / very high complexity Free Routing Operations.	HZ-034

Table 30: Safety Requirements (Integrity and Reliability)

Appendix C Assumptions, Safety Issues & Limitations

Assumptions log

The following Assumptions were necessarily raised in deriving the above Functional and Performance Safety Requirements:

Ref	Assumption	Validation
A-01	ANSP, Airspace Users and Network Manager need to have the same level of information in flight planning phase regarding flight profile and routing in Free Routing Airspace	
A-04	Planning controller performs "manual" mid-term conflict detection in parallel to the management of the conflicts detected by the mid-term conflict detection tool	
A-05	Tactical controller performs "manual" tactical conflict detection in parallel to the management of the conflict detected by the tactical conflict detection tool	
A-09	ATC supervisor updates the En Route stack activation status on the ATC system	
A-10	It is assumed that the ATCOs (Planning Controller and Tactical Controller) are able to remove a flight of her/his sector from the ordered list of sectors that are expected to assume a given flight (i.e. SKIP functionality)	

Table 31: Assumptions log

Safety Issues log

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

Ref	Safety issue	Resolution
I-01	Risk of an increased number of coordinations (due to more traffic close to boundaries) and those coordinations will be more difficult to manage, increasing workload	

Ref	Safety issue	Resolution
I-02	Will it be more difficult to keep a good situational awareness for both Executive and Planner ATCOs due to more atypical situations in FRA, combined with possible peak of high workload at sector level?	
I-03	Will it be more difficult to keep a good situational awareness for ATCO while handover/split/collapse situations due to an increase of more unusual aircrafts behaviour in FRA?	

Table 32: Safety Issues log

Operational Limitations log

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

Ref	Operational Limitations	Resolution

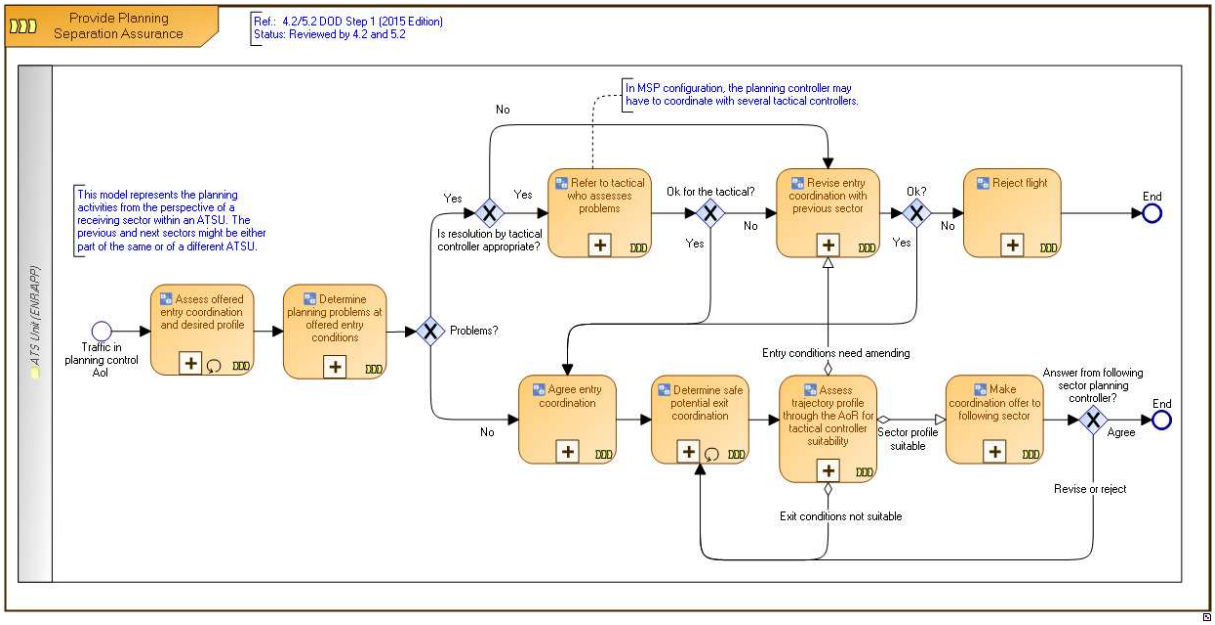
Table 33: Operational Limitations log

Appendix D Key Additional Information

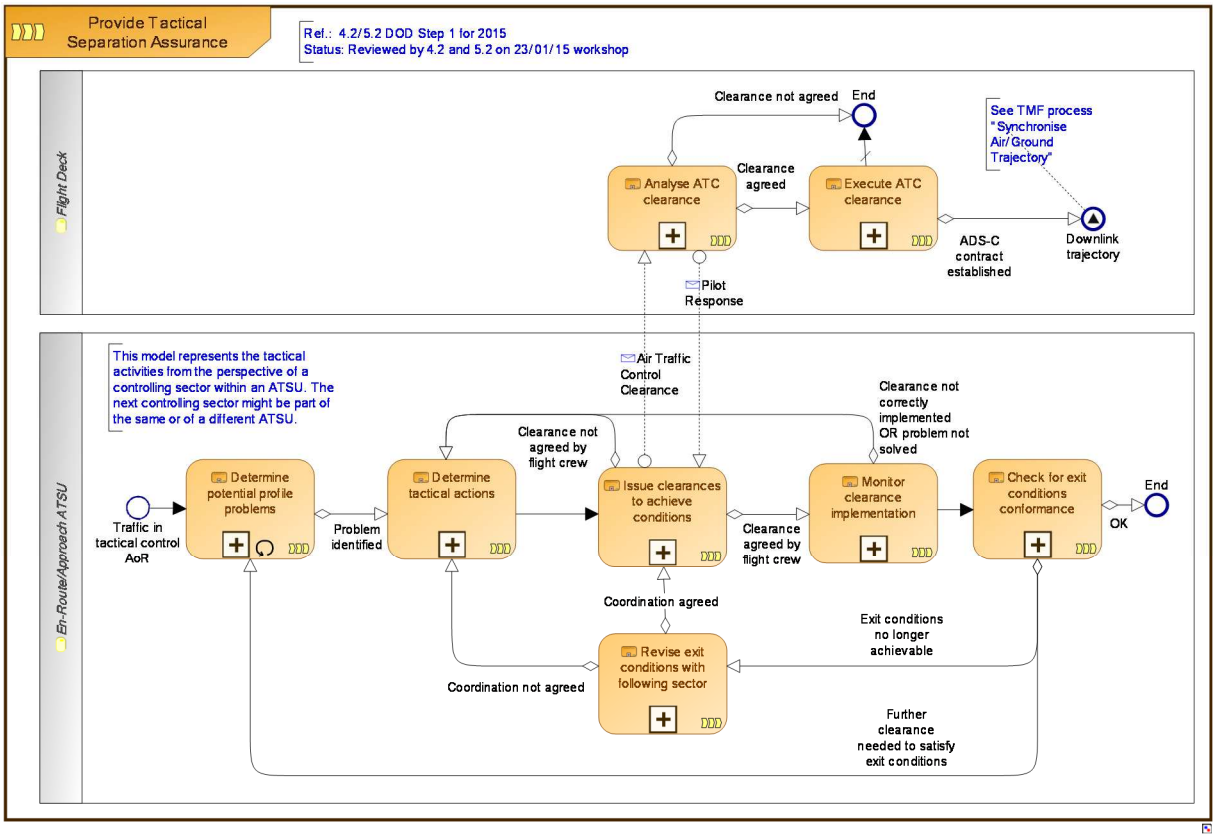
Operational processes impacted by PJ.06-01 Solution

The following diagrams are extracted from applicable EATMA models [12].

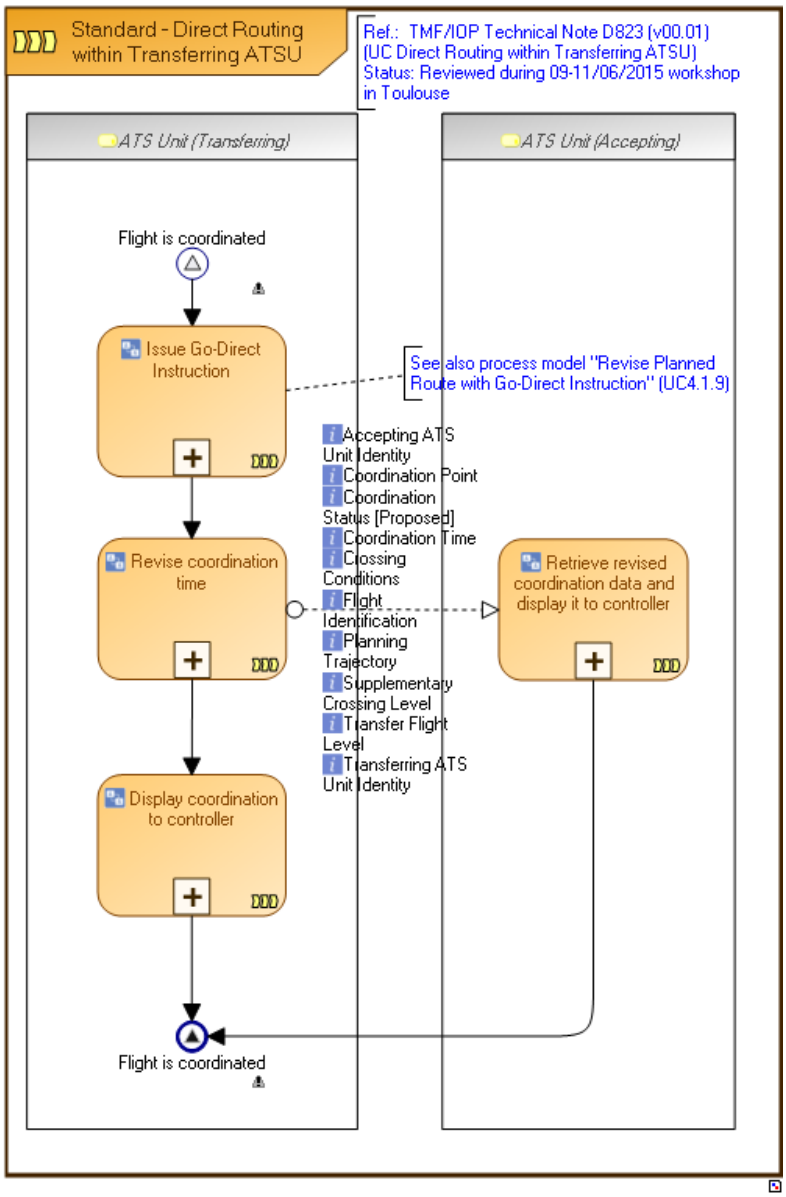
Provide Planning Separation Assurance (SEP_PLAN)



Provide Tactical Separation Assurance (SEP_TACT)



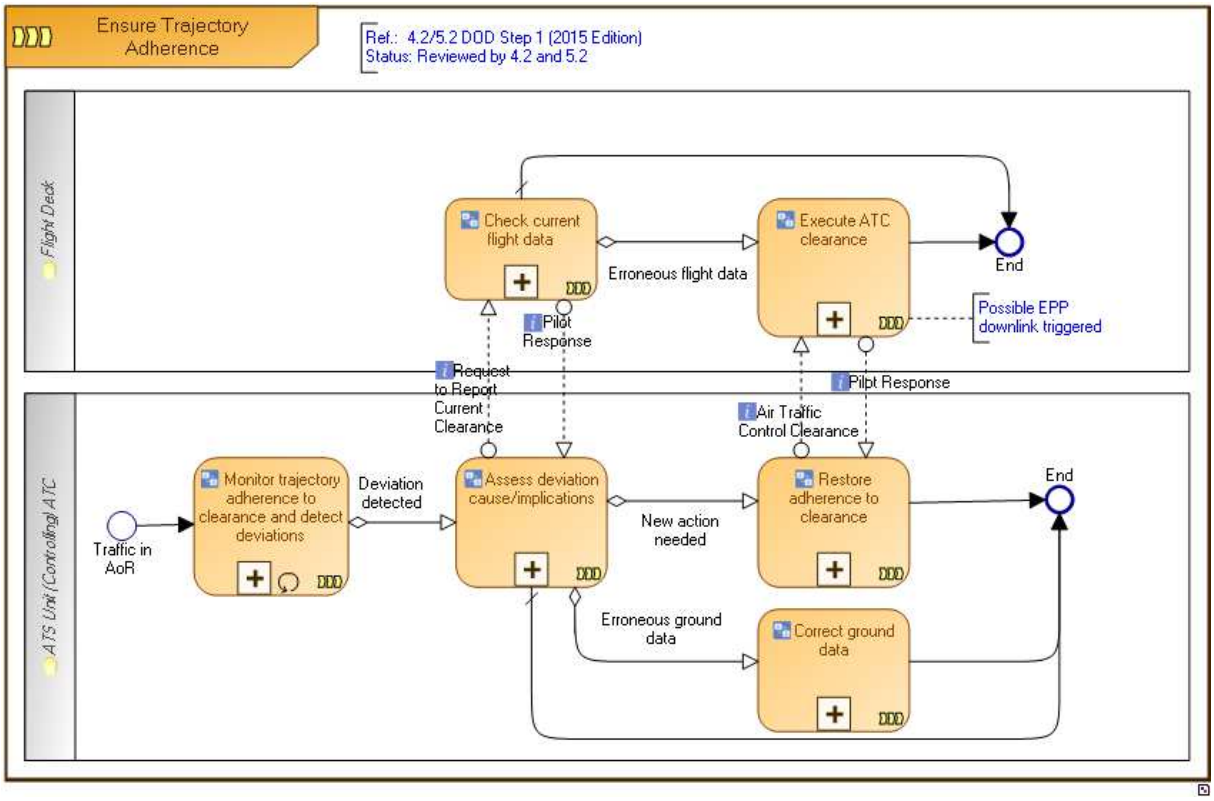
Coordination and Transfer (COR)



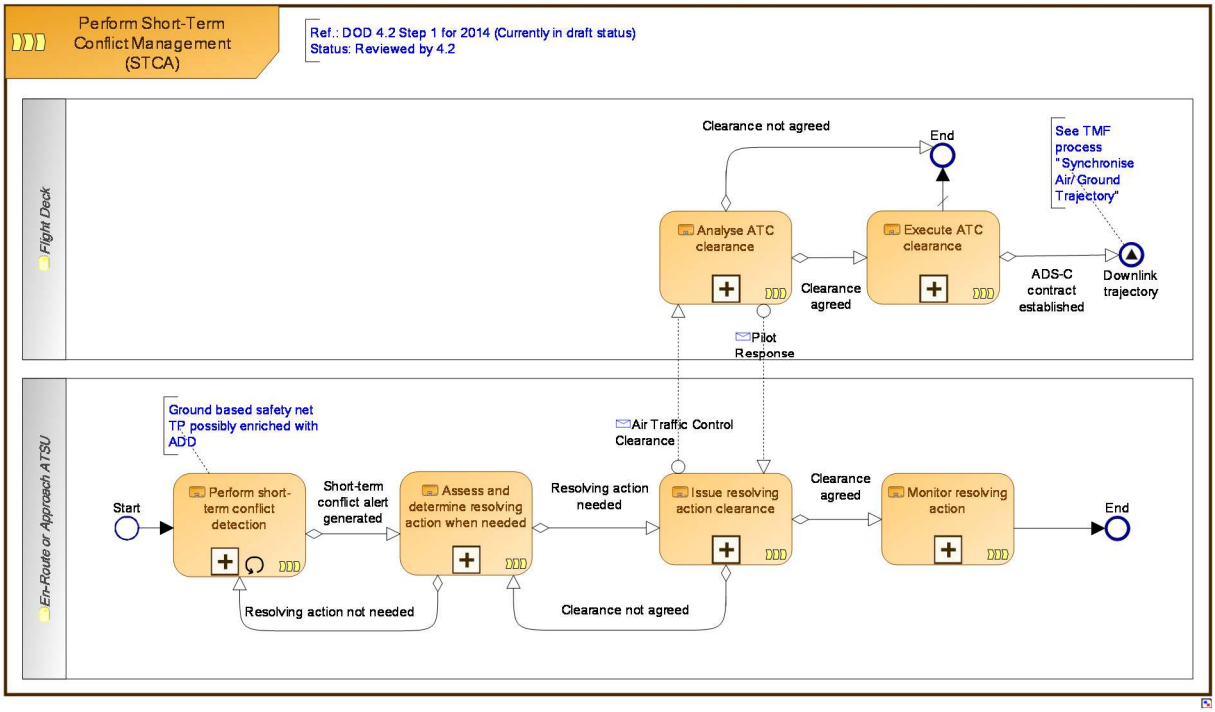
Airspace design & management (DES)

No existing EATMA model.

Ensure Trajectory Adherence (MONA)



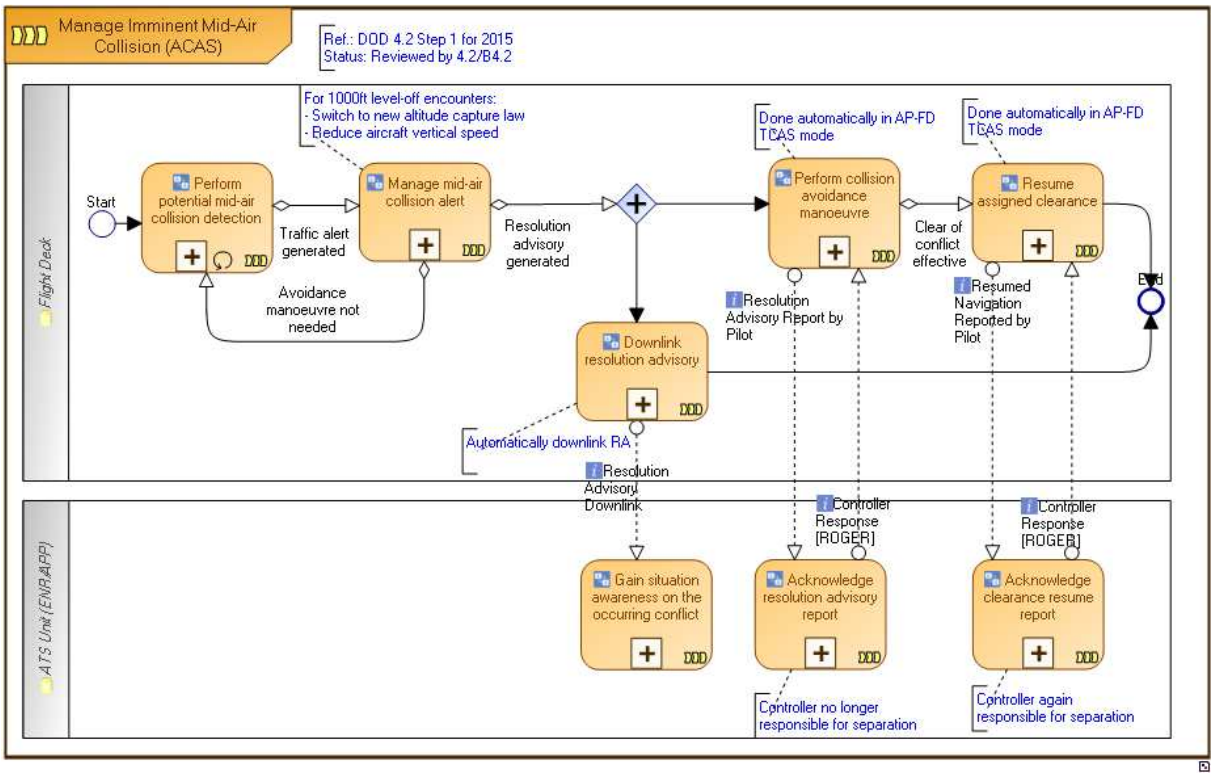
Perform Short-Term Conflict Management (STCA)



Perform airspace infringement management (APW)

No existing EATMA model.

Perform aircraft collision avoidance (ACAS)



-END OF DOCUMENT-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