D2.1 TAPAS Use Cases Description

Deliverable ID: D2.1

Dissemination Level: PU

Project Acronym: TAPAS

Grant: 892358

Call: H2020-SESAR-2019-2

Topic: SESAR-ER4-01-2019

Consortium Coordinator: CRIDA

Edition Date: 24 September 2020

Edition: 00.01.01

Template Edition: 02.00.02

Founding Members

EUROPEAN UNION   EUROCONTROL

SESAR
JOINT UNDERTAKING

Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
R. Rodríguez / **CRIDA**	WP2 Leader	24/09/2020
A. Olbés / **INDRA**	T2.2 Task Leader	22/07/2020

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
I. Crook / **ISA Software**	Contributor	25/08/2020
G. Vouros / **UPRC**	Contributor	27/07/2020
D. Scarlatti / **BRTE**	Contributor	22/07/2020
J.M. Cordero / **CRIDA**	Project Coordinator	10/08/2020
E. Iglesias / **CRIDA**	Contributor	10/08/2020
N. Valle / **CRIDA**	Contributor	10/08/2020
G. Andrienko / **Fraunhofer**	Contributor	17/08/2020

Approved for submission to the SJU By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
José Manuel Cordero / **CRIDA**	Project Coordinator	24/09/2020
Antonio Gracia / **BRTE**	Project Member	Silent Approval
Gennady Andrienko / **Fraunhofer**	Project Member	Silent Approval
Hugo Salinas / **INDRA**	Project Member	Silent Approval
Ian Crook / **ISA**	Project Member	25/08/2020
George Vouros / **UPRC**	Project Member	Silent Approval

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

Document History

Edition	Date	Status	Author	Justification
00.00.01	15/07/2020	Draft	R. Rodríguez	Operational Cases Description - First Draft

EUROPEAN UNION   EUROCONTROL

00.00.02	22/07/2020	Draft	A. Olbés	Technological Context Description – First Draft
00.00.03	24/07/2020	Draft	R. Rodríguez	Integration of First Review Comments
00.01.00	11/08/2020	Final	R. Rodríguez	Integration of Final Review Comments for approval and submission to SJU
00.01.01	24/09/2020	Final	R. Rodríguez	Integration of SJU review comments

Copyright Statement

TAPAS

TOWARDS AN AUTOMATED AND EXPLAINABLE ATM SYSTEM

Abstract

This document describes in detail the use cases to be developed under TAPAS project: (a) from the operational point of view; and (b) from the technological perspective. It also contains the operational context description in which TAPAS use cases are to be developed.

In particular, the following use cases are described:

- Conflict Detection and Resolution (CDR), during the tactical phase at the Executive Controller Controller Working Position,

- Conflict Detection and Resolution (CDR), during the tactical phase at the Planner Controller Controller Working Position, and

- Air Traffic Flow and Capacity Management (ATFCM), at pre-tactical phase.

Table of Contents

List of Figures

Founding Members

EUROPEAN UNION   EUROCONTROL

1 Executive Summary

This document describes in detail the use cases to be developed under TAPAS project: (a) from the operational point of view; and (b) from the technological perspective. It also contains the operational context description in which TAPAS use cases are to be developed.

In particular, the following use cases are described:

- Conflict Detection and Resolution (CDR), during the tactical phase at the Executive Controller Controller Working Position,

- Conflict Detection and Resolution (CDR), during the tactical phase at the Planner Controller Controller Working Position, and

- Air Traffic Flow and Capacity Management (ATFCM), at pre-tactical phase.

With regards to the operational context, four main concepts have been identified to impact the development of TAPAS Use Cases:

- Free-Route Operations;

- Trajectory Based Operations;

- Dynamic Airspace Configuration; and

- Flight Centric ATC.

2 Introduction

2.1 Purpose of the document

The main objective of this document is to perform a state-of-the-art analysis in terms of operational concept evolution and technology in order to develop and maintain a functional roadmap per each one of the operational use cases addressed by TAPAS.

In particular, TAPAS will consider the following three operational cases:

- Conflict Detection and Resolution (CDR), during the tactical phase at the Executive Controller Controller Working Position,

- Conflict Detection and Resolution (CDR), during the tactical phase at the Planner Controller Controller Working Position, and

- Air Traffic Flow and Capacity Management (ATFCM), at pre-tactical phase.

This document will describe in detail these three operational use cases based on state-of-the-art SESAR concept development and operational knowledge.

Complementary to the operational definition of the use cases, this document will collect and explore the technological constraints and possibilities that need to be considered for a realistic overview of the evolution possibilities. This technological view will be based on the industrial background of TAPAS consortium, as well as the knowledge of operational Air Traffic Control (ATC) and Air Traffic Management (ATM) tools and platforms, such as those intended to support the TAPAS cases studies, including industrial approaches to automation in ATM (with and without AI/ML techniques).

This document will be used within the project as the operational basis to which the subsequent work packages should refer to when deriving the AI transparency requirements and building the AI/ML models.

2.2 Intended Readership

This document is intended to be used by:

- SJU programme manager;

- TAPAS project members;

- SESAR2020 and international research community addressing automation in Air Traffic Management and Artificial Intelligence / Machine Learning.

2.3 Document Structure

This document is structured into the following sections:

- Section 1 is the Executive Summary and provides an overview of the TAPAS operational use cases.

- Section 2 is the Introduction that provides the purpose of the document, the intended readership, the document structure and the terminology and acronyms used throughout the document.

- Section 3 summarises the operational context of TAPAS under which the operational use cases are developed.

- Section 4 describes the TAPAS operational use cases, from both operational and technological point of view.

- Section 5 provides references used for the construction of the operational use cases.

2.4 Terminology and Acronyms

Term	Definition
3D	Three-Dimension
AI	Artificial Intelligence
ADS-C	Automatic Dependent Surveillance - Contract
ANSP	Air Navigation Service Provider
AoI	Area of Interest
AoR	Area of Responsibility
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATFCM	Air Traffic Flow and Capacity Management
ATM	Air Traffic Management
ATS	Air Traffic Services
CDR	Conflict Detection and Resolution
CHMI	Collaboration Human Machine Interface
CONOPS	Concept of Operation
CS	Configured Sector
CWP	Controller Working Position

DAC	Dynamic Airspace Configuration
DCB	Demand and Capacity Balancing
EAP	Extended ATC Planner
EASA	European Aviation Safety Agency
EC	Executive Controller
EPP	Extended Projected Profile
FAB	Functional Airspace Blocks
FCA	Flight Centric ATC
FDP	Flight Data Processor
FMP	Flow Management Position
FMS	Flight Management System
HEC	Hourly Entry Counts
ICAO	International Civil Aviation Organisation
INAP	Integrated Network ATC Planning
LTM	Local Traffic Manager
ML	Machine Learning
NM	Network Manager
NOP	Network Operations Plan
OCC	Occupancy Counts
PC	Planner Controller
RBT	Reference Business Trajectory
RMT	Reference Mission Trajectory
SESAR	Single European Sky ATM Research
SWIM	System Wide Information Management
TAPAS	Towards an Automated and Explainable ATM System
TBO	Trajectory Based Operations

3 TAPAS Operational Context

This section provides context for the reader about the operational environment in which the TAPAS use cases are included.

3.1 General Overview. Air Navigation Services

According to *ICAO Doc. 4444 – Procedures for Air Navigation Services*, Air Traffic Management is the "dynamic, integrated management of air traffic and airspace **including air traffic services, airspace management and air traffic flow management** — safely, economically and efficiently — through the provision of facilities and seamless services in collaboration with all parties and involving airborne and ground-based functions".

Within the Air Navigation Services domain, the TAPAS project will focus specifically on Air Traffic Fow and Capacity Management (ATFCM) and Air Traffic Control (ATC) Services. The first, is defined in *ICAO Annex 11 – Air Navigation Services* as *"a service established with the objective of contributing to a safe, orderly and expeditious flow of air traffic by ensuring that ATC capacity is utilized to the maximum extent possible and that the traffic volume is compatible with the capacities declared by the appropriate ATS authority";* whilst the latter is defined as *"a service provided for the purpose of: a) preventing collisions: 1) between aircraft, and 2) on the maneuvering area between aircraft and obstructions; and b) expediting and maintaining an orderly flow of air traffic".*
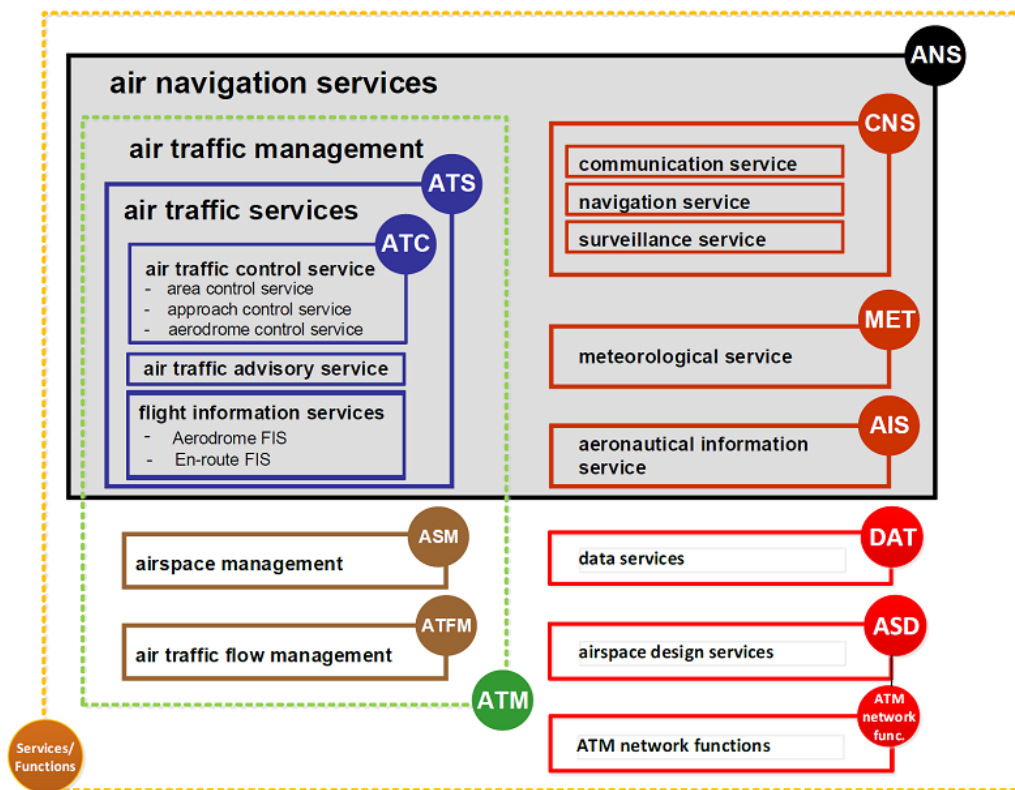

Figure 1. Air Navigation Services (EASA)

3.2 Operational Environment

In this section, the descriptions of the operational concepts that support the TAPAS Use Cases are presented. To this end, the vision of the SESAR programme has been considered.

3.2.1 Transversal Topics

3.2.1.1 Trajectory Based Operations

The concept of Trajectory Based Operations (TBO), which is one of the main pillars that supports the SESAR target concept as stated in the ATM Master Plan, consists in allowing airspace users to fly their preferred trajectories in order to deliver passengers and goods on time to their destination as cost-efficiently as possible .

TBO relies on a full integration of flight information, enabling the ATM system to have a synchronised view of the flight data by all the stakeholders involved. The sharing of a common reference trajectory information via ground-ground and air-ground System Wide Information Management (SWIM) throughout the Business / Mission Trajectory lifecycle will significantly improve ATM accuracy, predictability and reliability.

According to the SESAR Concept Of Operations (CONOPS), high quality 4D trajectories data will be made automatically available to all relevant stakeholders by means of cutting-edge ground-ground trajectory exchange mechanisms. This will improve common situational awareness, automation and global performance. It is also expected that TBO will enable increased collaboration and operational predictability, by means of enhanced collaborative decision-making processes [1].

Finally, TBO will lead to efficiency gains, not only at the individual aircraft level, but for the network as a whole. In this way, TBO will facilitate a fundamental shift away from flight management through Air Traffic Control tactical interventions towards a more strategic focus on trajectory planning and intervention by exception [5].

3.2.1.2 Free-Route Operations

Free Route Operations, that is, flights following as direct routes as possible between the origin and destination, are enabled by the introduction of higher levels of automation in support of the following processes [2]:

- Wide implementation of automated tools for conflict detection and resolution, flight monitoring, and electronic coordination;

- Enhanced ATFCM with Integrated Network ATC Planning (INAP) offering a more optimised granularity level for complexity management and Dynamic Airspace Configuration (DAC) management;

- Advanced processes for airspace management, including Dynamic Airspace Configuration;

- Flight and flow centric operations.

The result is an airspace that is managed as a continuum, allowing a better use of airspace capacity, and supporting an optimum demand-capacity balancing process by offering much more flexibility for flight profiles optimisation based on user preferred trajectories.

With free route airspace in high and very high complexity cross-border environments, the use of Conflict Detection and Resolution support tools is considered mandatory to support the Planning and Tactical Separation assurance.

3.2.2 Dynamic Airspace Configuration Concept

DAC is part of the SESAR 2020 Advanced Demand and Capacity Balancing concept, with enhanced and fully integrated processes that ensures that all levels of the network are able to manage their operations across all ATM phases to meet performance targets in a seamless and fully collaborative basis [3].

In comparison with a sectorisation based on a fixed route network, with little flexibility to meet demand requirements, the DAC concept introduces the idea of User Preferred Routes and new type of flexible airspace reservations (Dynamic Mobile Areas - DMA). The objective is to develop airspace designs and sector configuration schemes in order to optimise the use of the available capacity and balance the Air Traffic Controller (ATCo) workload avoiding unnecessary intervention on the traffic flows.

In the DAC environment, the number of controlled sectors and their shape can be adapted to the current traffic situation at all ATM planning phases, from long term to execution. Thus, the DAC process aims at identifying an optimised sector configuration based on the traffic demand and predicted complexity, ATCos availability, and predefined performance targets.

The DAC concept comprises the following two main processes:

- Airspace design (in the long to medium term planning phases), supported by automated tools for the definition of airspace structures and elementary sectors according to DAC design principles.

- Sector Configuration Management (in the short term planning phase and during execution), to help determine the optimum sector configuration that meets predicted demand for a given period, considering multiple optimisation criteria and constraints (such as sector overload, ATCo workload balancing, number of active sectors, available workforce etc.).

In order to achieve the DAC concept, a DAC toolbox is defined around three axes to support Air Navigation Service Providers (ANSPs) in the management of airspace capacity and to facilitate Free Routing Trajectories through varying degrees of sector dynamicity and automation:

- **Design and Configuration Axis** - introduces five different airspace design elements, which can be configured into six different configurations, resulting in a Configured Sector (CS).

  - Elementary Sector (ES), which is an ATC workable 3D airspace, that is, it can be controlled by Air Traffic Controllers and they cannot be split further down into controllable sectors.

  - Airspace Blocks, which are primary volume of airspace that has to be configured to build workable sectors.

  - Shareable Airspace Block, which is a non-workable (that is, they cannot be controlled by ATCOs) volume of airspace that can be dynamically configured in a pre-defined

way to any adjacent Elementary Sector or Airspace Block to build a Configured Sector.

- o Flexible Boundaries, which are sector boundaries that can be modified or refined to facilitate and optimise Free Routing Trajectories.

- o Vertical Sharable Airspace Modules, which are non-workable volumes of airspace vertically split in 1000 feet segments.

- o Configured Sector, which is the result of the Sector Configuration process and in which the ATCo is providing Air Traffic Services.

In addition, the following conceptual elements are defined:

- o Dynamic Mobile Areas: these are an integral part of the Mission Trajectory described by a 4D data set (geographical position x, y, z; time; velocity), where the velocity parameter is equal to zero. Therefore, DMA constitutes a defined 3D volume of airspace that satisfies specific requirements from different Airspace Users.

  There are two types of DMAs that have been identified within SESAR Wave 1 concept:

  - ▪ DMA Type 1 is a volume of airspace of defined dimensions as integral part of Mission Trajectory at flexible geographical locations agreed upon a CDM process, satisfying Airspace Users requirements in terms of a time and/or distance constraint parameters from a reference point as specified by the AU (e.g. Aerodrome of Departure).

  - ▪ DMA Type 2 is a volume of airspace of defined dimensions described as integral part of the Mission Trajectory and agreed upon a CDM process, satisfying the Airspace Users requirements.

- o Airspace Reservation (ARES Reservation): this allows users to create a specified volume of airspace temporarily reserved for exclusive or specific use by categories of users (e.g. military operations).

- o ATC Volumes Reservation: this allows airspace managers to define volumes of civil ATC airspace that are of high importance due to planned traffic load and/or complexity and in which ARES operations should not be planned.

- **Automation Axis** - considered as essential to support the performance of the Dynamic Airspace Configuration process. The automation will increase, amongst others, the range of possibilities in organising and managing the airspace, the efficiency of solutions by using optimisation algorithms, and the efficiency of the DAC decision-making process.

- **Human and Training Axis** - which conforms the last pillar of the DAC process and refers to the interdependency of training requirements as dynamicity in the airspace configuration increases; it also depends on the level of automation.
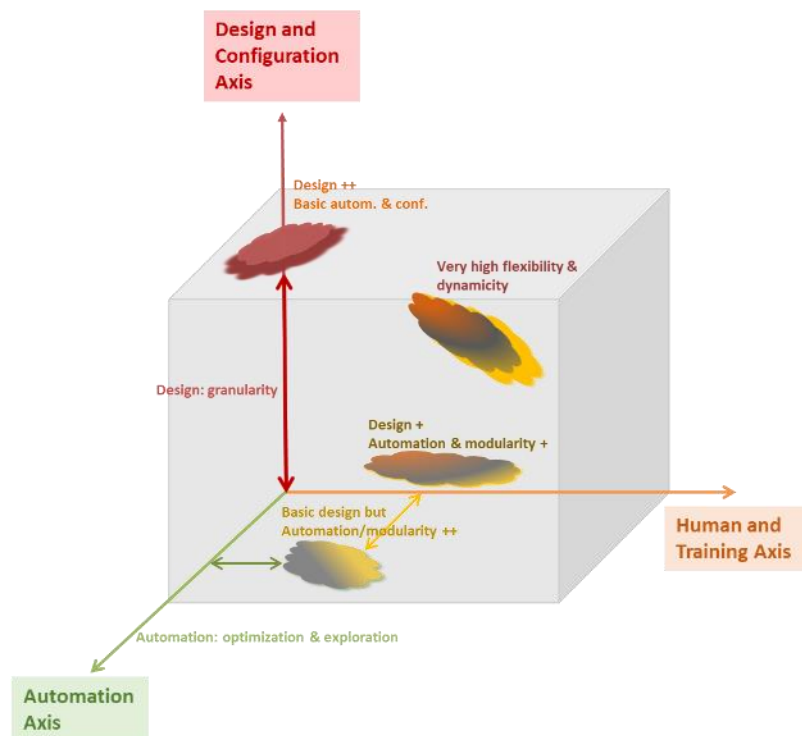
Figure 2. DAC Concept Axis

3.2.3 Flight Centric ATC Concept

In the Flight Centric ATC concept, ATCos are no longer responsible for managing the entire traffic within a given sector, but rather for managing a certain number of aircraft throughout their flight segment within a larger airspace or along flows of traffic. This means that aircraft may be under the responsibility of the same ATCo across two or more geographical sectors [7].

In terms of airspace, the FCA concept will dissolve the current sector boundaries for managing separation provision across several sectors, in order to enable larger sectors to be used (e.g. the new airspace distribution could be done at the level of Area Control Centres or Functional Airspace Blocks (FAB)).

The change to a flight-centric structure, without reference to geographical sectors, will open up the opportunity to better distribute the traffic and to avoid the loss of productivity in under-loaded sectors. Other benefits are also expected, such as reduced fuel consumption and emissions, enhanced predictability, improved operational and cost efficiency and maintained levels of safety.

In order to achieve the stated performance objectives, the introduction of a new role named "*allocator*" is required, as well as changes in the responsibilities of the current Executive and Planning Controllers.

- The allocator, supported by automated tools, is mainly responsible for the unequivocal allocation of the incoming traffic depending on several static or dynamic allocation criteria such as ATCo workload, complexity, flows, etc. The allocator is also responsible to allocate the responsibility to solve a conflict to a particular Executive controller, if needed, and to

balance, in coordination with the Flow Management actors, the demand and capacity in the Flight Centric Area.

- The Executive Controller is responsible for:

    o providing separation between controlled flights;
    o providing separation through coordination;
    o providing sequencing between controlled flights;
    o identifying conflict risks between aircraft and solve the conflict;
    o in case of conflict between aircraft under control of two different controllers coordinating who shall solve the conflict;
    o shared responsibility for conflict management;
    o monitoring flights regarding adherence to flight plan/RBT/RMT;
    o monitoring traffic not under control responsibility;
    o monitoring weather conditions;
    o may coordinate exit conditions directly;
    o if necessary, transferring the flight to another Flight Centric Executive Controller (for example for conflict resolution).

- The Planner Controller is responsible for:

    o coordinating entry conditions;
    o changing exit conditions on request by Flight Centric Executive Controller;
    o providing early conflict detection and resolution (depending on the conflict detection and resolution tools horizon, mainly supported by the Planner Controller Aid) for conflicts before entering the Flight Centric Area;
    o providing early conflict detection and resolution proposal to Executive Controllers for conflicts inside the Flight Centric Area in a medium term horizon.
    o input tactical trajectory changes into the Flight Data Processing System if requested by a Flight Centric Executive Controller;
    o assisting in Executive Controller tasks on request;
    o re-assigning responsibility for specific aircraft from one Flight Centric Executive Controller to another Flight Centric Executive Controller due to operational procedures and/or on request;
    o the Planner Controller could also apply level capping and rerouting of individual flights internally in the Flight Centric Area to offload certain areas depending on the time horizon and the DCB needs.

With regards to the three layers of Conflict Management, the FCA concept addresses all of them as follows:

- Strategic Conflict Management: the nature of the concept allows a better integration of this process through the distribution of conflicts by means of advanced allocation techniques and use of predefined resolution strategies within the Flight Centric Area.

- Separation Provision: the Executive and Planner controllers are still responsible for separation provision. Nevertheless, the Planner Controller is not only responsible for conflict resolution before the flight enters the Flight Centric Area but also inside it, providing

resolution proposals to the Executive Controller. In addition, the conflicting traffic may be under the control of different Executive Controllers.

- Collision Avoidance: supported by the safety nets, the Executive Controller is responsible for collision avoidance.

4 TAPAS Operational Use Cases Description

In this section, the Operational Use Cases to be addressed by TAPAS are described both textually and logically.

4.1 ATFCM Use Case

4.1.1 Definitions

In order to ease the reading of the ATFCM Use Case, a set of concepts and definitions are provided below [12][13].

- **Hourly Entry Counts (HEC):** number of flights entering a Traffic Volume within a one-hour time period.

- **Occupancy Counts (OCC):** number of flights that are inside a defined location at a precise time and that correspond to the flights that are (or will be) worked by ATC at that time.

  o **Duration**: Time Interval reference defined for a specific traffic volume. The interval is used to evaluate and compare the load against the Occupancy Traffic Monitoring Values (Peak and Sustained).

  o **Peak**: Occupancy Traffic Monitoring Value defined for a specific duration interval. If the load value in the traffic volume for the pre-defined duration exceeds the peak value an alarm is triggered.

  o **Sustained**: Occupancy Traffic Monitoring Value defined for a specific duration interval. This value indicates the maximum sustained value manageable.

  o **Step**: Time rolling interval for which a duration period is 'moved' to evaluate the load.

  o **Elapse**: Time interval that defines the 'evaluating' period of sustained value.

  o **Occurrence**: Number of times that the load is above the sustained value defined.

- **Hotspot:** 4D volume (defined in time and space) representing a potential DCB, identified by ANSP(s) and potentially the Network Manager.

- **Optispot:** 4D volume (defined in time and space) representing a traffic situation where opportunity for optimisation has been identified by ANSP(s). An ATFCM situation yet to be optimised represents a nominal, safe and planned event.

- **Mandatory Cherry Picking regulation:** DCB measure used to solve short peaks (e.g. 1h or 1h 30min) of limited number of flights in congested areas. It consists of selecting flights creating complexity and applying ATFCM measures only to those flights.

4.1.2 Scope

The scope of this use case is limited to the detection, declaration and resolution of imbalances during the Pre-Tactical Phase, and particularly, focused on D-1 (day before operations). This includes not only imbalances induced by existing differences between demand and capacity, but also induced by the opportunity to improve performance levels.

4.1.3 Actors

4.1.3.1 Primary Actors

The primary actor is the Local Traffic Manager (LTM).

4.1.3.2 Supporting Actors

The supporting actors are the Air Traffic Service Unit Supervisor and the Network Manager.

4.1.4 Preconditions

Traffic demand from D-7 (seven days before operation) to D-1 (day before operations), that is Pre-Tactical Phase, is available, allowing the Imbalance Monitoring and Prediction Service to calculate all the imbalance methodologies outputs (mainly Hourly Entry Counts and Occupancy Counts).

Capacity figures, expressed for each possible configuration are also available, expressed in terms of entry count capacities and Occupancy Traffic Monitoring Values (OTMV) counts, including both maximum simultaneous occupancy and maximum sustained occupancy figures.

4.1.5 Post conditions

Once an imbalance is detected, the appropriate kind of spot is declared, and the required DCB measures taken (both capacity and demand measures) at the Pre-Tactical Phase (up to D-1), the Local Traffic Manager shall monitor the spot resolution status.

4.1.6 Success end state

The imbalance is detected, the appropriate spot is declared (hotspot or optispot, depending on the nature of the imbalance), and the required DCB measures that solve the imbalance are taken.

4.1.7 Failure end state

The imbalance is not detected due to uncertain information, missing information or information corrupted. Therefore, the spot is not declared nor solved, which can lead to an overload situation in the Tactical Phase.

4.1.8 Trigger

The imbalance detection and resolution may be triggered by:

- an alert on the Traffic Volume capacity threshold violation;

- an alert on the Occupancy Traffic Monitoring Values violation;

4.1.9 Use Case Flow

4.1.9.1 Main flow

- For each Traffic Volume under the Area of Responsibility of the LTM, the Traffic Counts (Hourly Entry Counts, HEC and Occupancy Counts, OCC), are displayed to the LTM for their continuous monitoring.

- For each Traffic Volume, the LTM analyses the information provided by the Imbalance Prediction and Monitoring Service (i.e. HEC and OCC).

- If some of the local monitoring values established for a particular Traffic Volume are violated (capacity, occupancy or performance), an alert is displayed to the LTM.

- The LTM analyses the alert issued by the system and decides, based on the nature of the imbalance, the declaration of the appropriate spot.

  o If the spot is safety-critical, the LTM declares a hotspot and publishes it into the Network Operations Plan (NOP).

  o If the spot is not safety-critical, that is, the spot is related to performance optimisation, the LTM declares an optispot and publishes it into the NOP.

  In general, and just as reference, the following predefined conditions might be applied to distinguish between safety-critical and non safety-critical cases, based on Hourly Entry Counts and Occupancy Counts criteria:

  o *Hourly Entry Counts:* the situation is considered safety-critical if there is an overload (HEC over 110% of capacity threshold) or there is more than one count bar of HEC above the capacity threshold.
  o *Occupancy Counts:* the situation is considered safety-critical if there is an overload (Occupancy Peak threshold violated) or if the occupancy counts are between the peak and sustained thresholds more than the occurrence established for the elapse time defined.

- For the spot declared, the LTM analyses the nature and root causes of the spot complexity based on the violation of the Traffic Counts (HEC, OCC) thresholds.

- Depending on the nature and severity of the spot, the LTM analyses if capacity measures are appropriate for the spot resolution.

  o The LTM evaluates the sectorisation plan and identifies if the change required to solve the imbalance is a minor or major change:

    ▪ If the spot is to be resolved with a minor change, the LTM selects the sectorisation, then selects an airspace element, remove the element from the current sector and adds the appropriate element to an operational sector. In addition, the DCB indicators are calculated and presented for the proposed configuration.

- If the spot is to be resolved by means of a major change, the LTM selects the operational sector/area of interest, runs the sectorisation optimiser (system that may be based on Artificial Intelligence algorithms or logical rules), and assess the proposed configuration based on the DCB indicators calculated and presented.

  o Once the new sectorisation plan is decided, the LTM analyses its local DCB impact:

  - If the local impact is positive, the LTM implements the new sector configuration plan and publishes it into the NOP.

  - If the local impact is negative, the LTM reassesses the sector configuration plan and/or initiates the preparation of demand measures.

- If capacity measures are not adequate to resolve the spot, demand measures or a combination of capacity and demand measures are to be evaluated.

  o **Elaboration of demand measures - ATFCM Scenarios**

  - Depending on the nature and severity of the hotspot declared, the LTM selects the most appropriate type of ATFCM scenario (e.g. Level-Capping, Horizontal Re-Routing). These are typically based on pre-defined ATFCM scenarios provided by the Network Manager (NM), but customised solutions may also be considered.

  - The LTM, supported by the What-If tool, performs a local impact assessment of the scenario selected and the candidate impacted flights in terms of a set of indicators (e.g. HEC, OCC, Additional Distance or Time, Additional Fuel Burnt, etc.)

  - If the scenario causes impact outside the AoR of the LTM, then a Network Impact Assessment will be requested and evaluated.

  - If the local impact assessment and Network Impact Assessment (when applicable) are both positive and the spot could be resolved with the selected scenario, then the LTM implements the scenario and publish it into the NOP. If not, other types of demand measures should be assessed via What-If support.

  o **Elaboration of demand measures - Trajectory Measures**

  - Depending on the nature and severity the declared spot, the LTM selects the most appropriate type of Trajectory Measure or combination of Trajectory Measures to be applied (e.g. Level-Capping, Horizontal Re-Routing, Mandatory Cherry Picking).

  - The LTM selects the candidate flights or flows impacted by the trajectory measure or combination of measures selected.

  - The LTM, supported by the What-If tool, performs a local impact assessment of the trajectory measure proposed and candidate flights selected in terms

of the set of indicators. These indicators may vary depending on the type of measure selected (e.g. HEC, OCC, Complexity, Delay, Additional Time, Additional Distance, etc.). The assessment of the local impact includes the assessment of the impact of the measure in adjacent sectors belonging to the AoR of the LTM.

- If the measure or combination of measures selected has any kind of impact outside the AoR of the LTM, then a Network Impact assessment will be requested and evaluated.

- If the local impact assessment and Network Impact Assessment (when applicable) are both positive and the spot could be resolved with the selected measure or combination of demand measures, then the LTM implements the measure and publish it into the NOP. If not, other the LTM should launch the implementation of an ATFCM Regulation.

   o **Elaboration of demand measures – ATFCM Regulation**

- The LTM, supported by the What-If tool, performs a local and network impact assessment for the appropriate Regulation Period, Regulation Width and Regulation Rate, and analyses the most appropriate parameters based on indicators such OCC, HEC, total delay, average delay per flight, etc.

- The LTM request NM to implement the Regulation according to the What-If results.

- Once the selected measures have been implemented, the LTM monitors the spot resolution status, and if deviations are detected, the LTM assesses the need for corrective actions.

4.1.10 Failure flows

If the failure end state occurs, and there is a remaining imbalance that may lead to a safety issue, then the spot shall be resolved by the LTM/EAP or Planner and Executive controller taking actions on the impacted flights during the Tactical Phase.

4.1.11 Technological Context

Within European Airspace, the ATFCM activities have been performed by the LTM role using a Collaboration Human Machine Interface (CHMI) provided by EUROCONTROL to have remote access to the functionalities existing in the NM (Regional ATFCM system), constituting the FMP on the ATC centre. This CHMI system interfaces the NM system through standardised B2B Web Services in order to have access to the relevant NM functionalities.

Nevertheless, as part of SESAR programme activities (both during the original SESAR programme and during the Wave 1 & 2), some further evolutions for the FMP have been considered, and different industrial partners have started to develop new products with the aim of supporting Sub-Regional and Local ATFCM activities, maintaining:

- The B2B Web Services used by the CHMI, so the interface and interoperability with the Regional ATFCM product is guaranteed (both to receive flight information, and to coordinate the spots and the resolution measures)

- New interfaces with the local FDP systems, in order to improve the tactical phase information of the planned flights.

Concerning the state-of-the-art functionalities for the detection of imbalances, those products are designed to :

- Count the predicted HEC and OCC on configurable airspace volumes, and compare the figures with the declared capacity for such airspace volumes (both the sustain capacity and the peak capacity)

- Similarly, count also the expected traffic following a certain route or crossing a certain fixpoint.

- Compute complexity figures, based on complex algorithms taking into account not only the total number of flights, but also an assessment on how complex will be to manage each flight taking into account flight-specific profile and other local characteristics.

- Compare those complexity figures with equivalent sustain and peak thresholds.

- Provide this information to the LTM through a user friendly interface, where the LTM can have both a summary and a detailed view on all the imbalances detected, and where it can declare OptiSpots or Hotspots.

On top of the functionalities to detect imbalances, current systems also include some functionality to design and coordinate solutions to the declared spots. Those functionalities include:

- Supporting the LTM to perform those minimum adjustments on the sector boundaries and shapes in order to solve an imbalance with the minimum impact to the sectorisation plan.

- The automatic identification of sectors configurations which would optimise the Demand and Capacity Balance for a given number of available ATCOs, supporting DAC concept. The idea is to propose a certain number of CSs that can be set in order to efficiently manage the existing traffic load scenario, maintaining a balanced workload among the different ATCOs.

- The design of tentative measures in order to reduce the demand, including :

  o Predefined measures. These are preconfigured measures for the most common imbalances where certain known flows of traffic are involved, and for which a standardised solution is defined (such as re-routing or level capping those flows).

  o Ad-hoc trajectory measures, where the LTM can manually select (cherry-picking) flights where certain trajectory measures are to be applied. These measures are used for non-conventional imbalances, which are demanding some creative measures to solve them.

  o ATFCM regulations, constituting the strongest measure, where the LTM can select those flights to be delayed/impacted.

Concerning the demand measures, the current systems support the definition of what-if scenarios where the impact of all the designed measures is displayed to the controller, in order to summarise:

- The foreseen resulting imbalances, if any, and

- The impact that each measure has on each flight, including the total delay and the predicted extra fuel compared to the original scenario.

Once the LTM has designed a measure and has properly analysed its impact, the measure can be coordinated with the NM and also internally (in case the measure solves any imbalance on the tactical phase). The current industrial products support this coordination through the standardised B2B Web Services.

It must be noted that the current automation level on those products is different if we compare the capacity measures with the demand measures :

- Concerning the capacity measures, the existing products are already able to proactively propose to the LTM the optimal sector plan taking into account some KPIs requested. This way, the LTM only needs afterwards to agree and apply the proposed measure.

- Concerning the demand measures, no proactive solutions are proposed by the system. It just enables the LTM to design the measure and evaluate its impact.
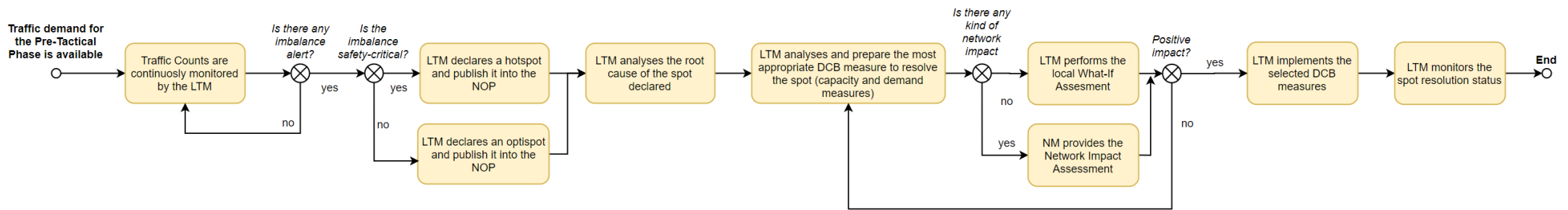
Figure 3. ATFCM Use Case Diagram

4.2 CDR Use Case (Planning Separation Assurance)

4.2.1 Scope

The scope of this use case concerns the conflict detection and resolution process in the planner controller timeframe, as part of the planning separation assurance process.

4.2.2 Actors

4.2.2.1 Primary Actors

The primary actor is the Planner Controller.

4.2.2.2 Supporting Actors

The supporting actor is the Executive Controller.

4.2.3 Preconditions

Planning and Tactical separation standards for the Area of Interest are provided. These may be dynamic according to the scenario being evaluated.

4.2.4 Post conditions

Once planning conflict detection and resolution is completed, tactical conflict detection and resolution is applied.

4.2.5 Success end state

The planning conflict detection and resolution process identifies any potential conflict at the entry, exit, and executive controller Area of Responsibility, agreeing on the flight entry and exit coordination conditions.

4.2.6 Failure end state

The planning conflict detection and resolution process fails to identify the potential conflicts at the entry, exit and executive controller Area of Responsibility; or the flight coordination conditions are not agreed resulting in the flight being rejected.

4.2.7 Trigger

There is incoming traffic in the planning control Area of Interest.

4.2.8 Use Case Flow

4.2.8.1 Main flow

- For each one of the new incoming flights in the sector planning area of interest (AoI), the planner controller (PC) assesses the offered entry coordination conditions of the upstream

sector and flight desired profile in order to determine the existence of any planning problems at the offered entry conditions.

- If conflicts are identified with the offered entry conditions, the PC will assess if the conflict may be resolve by the executive controller (EC).
  - o If the resolution of the entry conflict by the EC is appropriate, then the PC will refer to the EC, who will assess the conflict nature.
    - If the entry conditions are accepted by the executive controller, then the PC will agree the entry coordination conditions and determine safe potential exit coordination conditions.
      - The PC will assess the flight trajectory profile through the Area of Responsibility (AoR) for executive controller suitability.
      - If the sector profile and exit coordination conditions are suitable, then the PC makes the coordination offer to the downstream sector.
        - o If the answer from the downstream sector planner controller is positive with regards to the exit coordination conditions, the flight is accepted.
        - o If the answer from the downstream sector planner controller is negative, then the exit coordination conditions are due to review by the PC to offer a counterproposal or the flight is rejected as the last resort.
      - If the sector profile or exit coordination conditions are not suitable, then the PC will re-assess the flight plan trajectory to change the exit coordination conditions or the flight path within the AoR.
    - If the entry conditions are not accepted by the executive controller, then the PC will revise the sector entry coordination conditions with the upstream sector, making a counterproposal.
      - If the revised entry coordination conditions are agreed, then the PC will continue with the assessment of exit coordination conditions and trajectory profile suitability through the AoR.
      - If the revised entry coordination conditions are not agreed, then the PC will reject the flight.
  - o If the resolution of the entry conflict by the EC is not appropriate, then the PC will revise the sector entry coordination conditions with the upstream sector, making a counterproposal.
    - If the revised entry coordination conditions are agreed, then the PC will continue with the assessment of exit coordination conditions and trajectory profile suitability through the AoR.

- ▪ If the revised entry coordination conditions are not agreed, then the PC will reject the flight.

- • If there are no conflicts identified with the offered entry conditions:

    - o The PC agrees the entry coordination conditions and determines safe potential exit coordination conditions.

    - o The PC also assesses the flight trajectory profile through the Area of Responsibility (AoR) for executive controller suitability.

        - ▪ If the sector profile and exit coordination conditions are suitable, then the PC makes the coordination offer to the downstream sector.

            - • If the answer from the downstream sector planner controller is positive with regards to the exit coordination conditions, the flight is accepted.

            - • If the answer from the downstream sector planner controller is negative, then the exit coordination conditions are due to review by the PC to offer a counterproposal or the flight is rejected as the last resort.

        - ▪ If the sector profile or exit coordination conditions are not suitable, then the PC will re-assess the flight plan trajectory to change the exit coordination conditions or the flight path within the AoR.

4.2.9 Failure flows

The failure end state occurs:

- • If the entry coordination conditions are not agreed, then the flight shall be diverted to a different sector.

- • If the planning conflict detection and resolution process fails to identify conflicts at the entry coordination conditions or throughout the executive controller AoR, then the executive controller will be the one dealing with the all potential conflicts during the tactical conflict detection and resolution phase.

4.2.10 Technological Context

The first CDR tools were initially designed in parallel to the first trajectory based ATC systems and FDPs, assuming that the uncertainties around flight trajectory prediction would be low, and so the predicted conflicts would be reliable.

Nevertheless, and following operational usage, it was concluded that the accuracy of ATC Planned Trajectories is limited by the lack of information about airspace user's preferences or meteorological data. This limited accuracy implies an uncertainty on future aircraft position, which grows for longer look-ahead horizons, and limits the confidence of the planner controller on the mid-term predicted aircraft position. As the density/complexity of airspace increases, it was considered impossible to

design, in a mid-term look-ahead horizon, a conflict free ground plan. Tactical intervention was then needed to solve a significant number of conflicts, further contributing to the overall mid-term uncertainty.

One of the key limitations of this trajectory prediction process is the limited quality of the performance model of the aircraft, together with the lack of knowledge on FMS known vertical restrictions and the crew-specific piloting preferences. All the previous combined results into a significant uncertainty around the vertical speed that can/will be navigated.

In order to improve the CDR tools, two main approaches have been followed along the SESAR programme.

4.2.10.1   First approach: to create CDR tools properly managing this uncertainty

During the original SESAR programme, some new tools were designed to manage existing uncertainty around the predicted planned trajectory. This way, and aligned with the need to assess the entry conditions, exit conditions and trajectory profile through the EC AoR, the following ideas were validated:

- Firstly, entry risks are computed, where the most likely flight trajectories are evaluated in the vicinity of the entry boundary, and around the predicted/coordinated entry level, in order to detect other flights that could be in conflict with this entry one (either being other entry flights, or exit flights).

- Similarly, to compute exit risks, where the most likely flight trajectories are evaluated in the vicinity of the exit boundary, and around the predicted/coordinated exit level, in order to detect other flights that could be in conflict with this entry one.

- Finally, to detect the risks along the sector AoR, considering the entry and exit levels coordinated levels, and also other intermediate levels expected to be used along the sector crossing (such as, potentially, the En-Route Cruise Level on that sector).

Due to the uncertainty of the trajectory prediction, the tools include big uncertainty margins around any vertical manoeuvre expected to be executed within the concerned sector: both in terms of the exact position where the manoeuvre will start, and also related with the vertical speed that is likely to be navigated by the aircraft. As a result, in high-density and complexity airspaces, these tools detect a significant amount of risks, where the objective for the planner is:

- To assess if the risks for the existing coordinated entry/exit levels, together with the planned route are manageable by the EC;

- To analyse if any different entry or exit level, or any alternative routing within the sector AoR would minimise the number of risks, in order to facilitate subsequent EC tasks.

Currently existing tools also allow to create what-if scenarios for modifications of both the entry/exit levels as well as modifications of the route, in order to evaluate their associated risks.

Additionally, and during SESAR 2020, some new approaches to manage the uncertainty will be explored. In particular, some partners will explore the possibility to use AI/ML in order to anticipate the most likely aircraft trajectory across the AoR. This process will learn from flights history in order to anticipate the trajectory in three dimensions:

- The Flight Intent, where the most likely ATCo future tactical clearances will be anticipated, including both level clearances but also directs to or re-routings.

- The Aircraft Intent, where the most likely piloting manoeuvres in response to ATCo clearances will be anticipated, also based on previous behaviour.

- The performance model, where the experience from previous profiles will be used in order to better anticipate the aircraft performances, and so the trajectory.

All the previous will contribute into a probabilistic approach to the trajectory. This approach will feed some conflict detection algorithms to find the most likely conflicts that could exist for the flight across the AoR, increasing the planner controller situational awareness.

4.2.10.2　Second approach: To minimise the uncertainty of the trajectory

Aligned with the TBO concept, SESAR is exploring the options to minimise the uncertainty of the planned trajectory, through the following approach:

- To use ADS-C EPP & Speed Schedule reports in order to have more accurate information on the aircraft performance and airspace user preferences, integrating this information in the planned trajectory computation algorithm to improve the accuracy of the trajectory.

- To use a detailed meteorological model, improved thanks to the usage of the aircraft as additional sensors (getting information from Mode-S), implementing a nowcasting process for more precise short-term weather forecast, and integrating also this information in the planned trajectory computation algorithm to improve the accuracy of the trajectory.

- To perform an automated 3D consistency check system between the FMS flight plan and the FDP flight plan, in order to detect discrepancies on the route and on any level or speed restriction.

- To design and uplink complex clearances, allowing to clear mid-term horizon manoeuvres (including speed clearances), and reduce the tactical short-term interventions, and enabling their usage from the ATC system.

All the previous improvements, when combined all together, will minimise the uncertainty around the planned trajectory, reducing the amount of false-positives and missed conflicts even in high density/complexity airspaces.
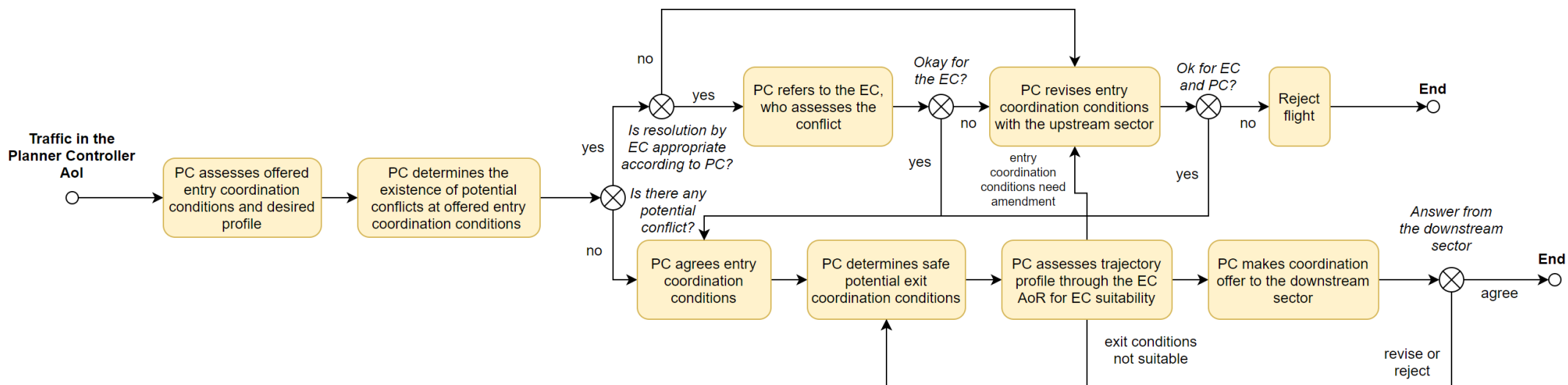
Figure 4. CDR Use Case Diagram (Planning Separation)

4.3 CDR Use Case (Tactical Separation Assurance)

4.3.1 Scope

The scope of this use case concerns the conflict detection and resolution process in the executive controller timeframe, as part of the tactical separation assurance process.

4.3.2 Actors

4.3.2.1 Primary Actors

The primary actor is the Executive Controller.

4.3.2.2 Supporting Actors

The supporting actors are the executive controllers of the upstream and downstream sector.

4.3.3 Preconditions

Conflict detection and resolution during the planner timeframe for action has been performed.

Separation requirements are provided for the Area of Interest. These may be dynamic depending on the region being analysed.

4.3.4 Post conditions

Flights are able to traverse the regions and are handed-over to the downstream sector free of conflicts.

4.3.5 Success end state

Conflict detection and resolution during the tactical separation assurance process is performed and all the potential tactical conflicts are identified and resolved.

4.3.6 Failure end state

Conflict detection and resolution during the tactical separation assurance process fails to identify all the potential tactical conflicts, which may lead to potential minima separation violation between flights.

4.3.7 Trigger

The incoming aircraft is assumed by the executive controller.

4.3.8   Use Case Flow

4.3.8.1   Main flow

- Once the flight is assumed by the executive controller, the EC will assess the planned and desired trajectory profile in order to identify any potential conflict.

  - If no conflicts are identified, the EC will assess the planned profile constraints and agreed coordinations, if any.

    - If there are not any planned profile constraint or agreed coordination conditions, then the EC will select the appropriate clearance to achieve the desired profile.

    - If there are planned profile constraints or agreed coordination conditions, then the EC will select the adequate clearance to respect the agreed constraints or coordinations.

    - Once the appropriate clearance is selected, the executive controller will issue the clearance to the pilot, who will assess the ATC given clearance.

      - If the clearance is agreed, then the pilot will execute the clearance and the executive controller will monitor clearance implementation and check conformance to the planned constraints. If there is not conformance to the planned constraints and clearance given, the executive controller will assess the new conflicts induced by the non-conformance, if any.

      - If the clearance is not agreed, then the pilot will inform the executive controller of the non-agreed clearance and the executive controller will re-assess the situation.

  - If conflicts are identified, and those conflicts are located within the EC AoR, then the EC will take action to establish the necessary separation and then continue with the assessment of the planned profile constraints and agreed coordinations.

  - If conflicts are identified, and those conflicts are located within the AoR of a different executive controller then, depending on the need to coordinate the conflict resolution, the EC will agree coordination actions or will continue with the assessment of the planned profile constraints and agreed coordinations.

4.3.9   Failure flows

If the failure end state occurs, the minima separation betweeen flight may be potentially violated, leading to aircraft airborne collision avoidance system intervention.

4.3.10 Technological Context

The first generation of trajectory based ATC systems focused on the computation of what was called afterwards the "planned trajectory". This trajectory, together with its related CDR tools were designed to be used by both planner and executive controllers on their tasks. Nevertheless, due to the same lack of accuracy explained in 4.2.10**¡Error! No se encuentra el origen de la referencia.**, it was quite difficult to fully rely on those tools, in high density and complexity scenarios.

4.3.10.1   SESAR 1 improvement: tactical tools

During SESAR 1 programme, within projects P04.07.02 and its technical counterparts (P10.02.01, P10.04.01 and P10.04.02), tactical tools were designed in order to match the specific needs from executive controllers.

Those tactical tools included the computation of a new type of trajectory: the tactical trajectory, whose main characteristics are:

- The time horizon of this trajectory is short: around 10 to 15 minutes maximum (on the other hand, the planner one covers the whole AoI of the ATC centre);

- This trajectory only follows the current clearances, without evolving to level or speed constraints which have not been cleared yet. This implies that the trajectory will first evolve and then maintain "forever" (during its whole time horizon) any open clearance such as a Heading or a Cleared Flight Level/Altitude;

- It is constantly updated, on each and every correlated radar track (on the other hand, the planner one is just updated when there is any significant update);

- Concerning vertical evolutions, the approach is more to extrapolate current tendencies than to guess a different one from complex mathematical models (of course, in case any specific vertical speed was cleared, this clearance is respected by the tactical trajectory).

SESAR 1 projects also defined CDR tools relying on those trajectories. In particular:

- Each and every tactical trajectory is compared against all other ones in order to search for potential lose of separation between them, on each radar track update;

- In order to facilitate the selection of conflict-free clearances, SESAR 1 projects defined a tool based on a quick computation of "What-Else" trajectories, together with their potential conflicts.

  - o The idea is that, when the executive ATCo opens any clearance menu in the CWP, some speculative trajectories are computed for all the default options shown in that menu, and all their potential conflicts with existing tactical trajectories are also computed.

  - o Thanks to that, all those default options of such CWP menu are shown in different colours depending on the conflicts that have been found on them, and this provides a very nice support to the executive ATCo to select conflict-free clearances.

- o This way, this tool is not exactly "proposing" clearances, but at least informs in a very useful manner on which are the conflict free options.

- o Those speculative trajectories are also updated at each and every radar track, as long as the CWP menu is still open.

The previous approach for the tactical tools has one interesting characteristic: the number of tactical trajectories (nominal ones plus speculative ones) which are computed is significantly higher than the planned trajectories. Full-load scenarios consider the need to compute more than 100.000 tactical/speculative trajectories and millions of conflict detection algorithm executions per second. In order to reach such demanding performance requirements, algorithms have been defined to be as simple and quick as possible.

Additionally, the Conformance Monitoring tools were redesigned. While the original approach to conformance was to check if the track was following the planned profile, the new conformance monitoring tools significantly modified this behaviour specially in the vertical profile. It is now considered that, as long as no particular vertical speed is cleared, the aircraft is free to evolve to the new cleared flight level at their preferred rate. So, any evolution towards the cleared flight level is considered conformant with the clearance, while contradictory manoeuvres are detected and a warning is shown to the ATCo.

4.3.10.2   SESAR 2020 approach: conflict resolution and accuracy improvements.

SESAR 2020 is currently exploring how to use the ADS-C downlinked reports (in particular, the EPP) in order to improve the mid-term accuracy of the tactical trajectory. In particular, the EPP can help to detect any likely change of the current aircraft tendency, and can also constitute a reference on how the aircraft could evolve in a scenario where a non-conformance with the current clearance has been detected.

Additionally, SESAR is also planning the development of new algorithms intended to provide Conflict Resolution Advisories for the tactical conflicts detected. In particular, different approaches will be followed:

- One based on AI/ML, where the idea is to see if an Artificial Intelligence can learn the typical actions an ATCo takes when finding a new conflict, in order to deconflict the traffic, and this way propose this action in future conflicts.

- One based on deterministic approaches, where the what-else functionality will not only provide which are the conflict-free solutions, but also will rank them depending on their impact on the flight efficiency and expected controller workload, so as to propose the best one for the ATCo.
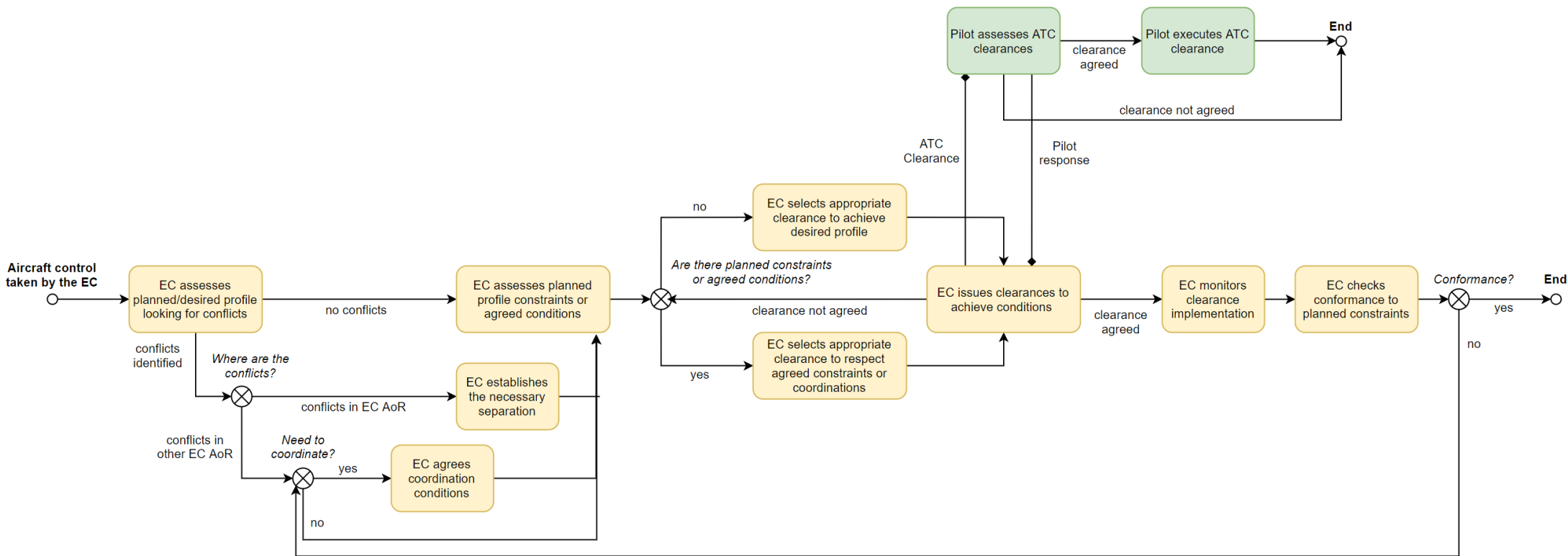
Figure 5. CDR Use Case Diagram (Tactical Separation)

5 Next steps

This section provides the next steps within the TAPAS project once the operational use cases have been described along this document.

- The first immediate step is to identify the functions / tasks per use case that will be used to build the TAPAS Functional Roadmap of allocation of tasks between the human and the machine for each one of the operational use cases and automation levels. This work will be carried out by WP2 and reported into D2.2 Consolidated Requirements and Functional Roadmap.

- Secondly, WP2 input will feed WP3 workflow in order to build the transparency requirements to be considered when developing the AI/ML models within WP4 for each one of the operational use cases described.

6 References

[1] SESAR 2020 Concept Of Operations Edition 2019 Edition 01.00.00.

[2] PJ06-D2_1_030 V3 SPR INTEROP OSED Final Version - Part I Edition 00.03.02, 2019.

[3] SESAR Solution 08.01 SPR-INTEROP-OSED for V2 - Part I Edition 02.00.03, 2019.

[4] SESAR JU (https://www.sesarju.eu/sesar-solutions/trajectory-based-operations).

[5] 18-02A SPR-INTEROP/OSED Trajectory Management for V1 - Part I, Edition 00.01.00, 2019.

[6] SESAR JU (https://www.sesarju.eu/sesar-solutions/flight-centric-air-traffic-control).

[7] SESAR Solution PJ.10-01b (Flight Centric ATC) FINAL SPR-INTEROP/OSED for V2 - Part I, Edition 00.04.00, 2019.

[8] European ATM Portal (https://www.eatmportal.eu).

[9] PJ18-W2 4D Skyways Grant Agreement No. 87232.

[10] ICAO Doc. 4444 Procedures for Air Navigation Services.

[11] ICAO Annex 11 Air Navigation Services.

[12] ATFCM Operations Manual – Network Manager. EUROCONTROL. Edition 24.0.

[13] SESAR PJ09 OSED-SPR-INTEROP – Part I. Edition 00.02.00.