1 Description of the use case

1.1 Name of the use case

ID	Application Domain(s)	Name of Use Case
UC2.ATM	Air Traffic Management	Flow & Airspace management assistant

1.2 Version management

Version Management			
Version No.	Date	Name of Author(s)	Changes
0.1	15.01.2024	Clark Borst (TUD)	Initial document
0.2	19.01.2024	Joaquim Geraldes (NAVP) Cristina Félix (NAVP) Hélio Sales (NAVP)	Major revision
0.3	03.02.2024	Ricardo Bessa	Revision
0.4	05.02.2024	Joaquim Geraldes (NAVP) Cristina Félix (NAVP) Hélio Sales (NAVP)	Second major revision
0.5	13.02.2024	Giulia Leto (TUD) Clark Borst (TUD)	Revision and polishing
0.5.1	26.02.2024	Cristina Félix	Minor editorial change
1.0	15.04.2024	Cristina Félix	Final revision with new KPI's and ATM workshop feedback update
1.1	18.04.2024	Giulia Leto	Scenario updates with ATM workshop feedback
1.2	13.05.2024	Clark Borst	Update scenario details with steps
1.3	14.06.2024	Clark Borst	Update
1.4	19.06.2024	Cristina Félix Joaquim Geraldes Hélio Sales	Final Revision
1.5	08.07.2024	Ricardo Bessa	Final version

1.3 Scope and objectives of use case

Scope and Objectives of Use Case	
Scope	Air traffic density in European airspaces is steadily increasing. At the same time, pressing economic and environmental concerns force a fundamental shift towards time- and trajectory-based air traffic operations. Taken together, increased traffic loads and operational complexities may eventually drive the workload peaks of the tactical air traffic controller (ATCO) beyond acceptable thresholds, threatening the overall safety of the ATM system and hindering a smooth transition towards a sustainable future of ATM. For instance, in the Lisbon Flight Information Region (FIR), serviced by NAV Portugal, operational complexities arise from the activation of military areas, which can significantly restrict the usage of the upper airspace for General Air Traffic (GAT), requiring traffic to deviate horizontally, especially when in combination with unexpected events (e.g. deteriorated weather conditions, flight emergencies). Routing of flight around military areas is proposed and implemented in pre-tactical phases. As of today, there is no pre-analysis tool and/or integrated decision-support system for assisting in, or even fully automating, the structuring of sectors with trajectory-efficient (e.g., flight time and fuel burn) routes and sectorisations to keep the

	workload of the tactical ATCOs within acceptable thresholds, i.e. without exceeding sector capacity limits.
Objective(s)	The system's objective is related to the flight execution phase when a military area is activated and the ATC has to issue deviations to avoid the activated area. The goal is to provide advice to ATCO about deviations with better sector capacity adherence and performance measured by an indicator of environmental area - *en-route flight inefficiency of the actual trajectory* (KEA). The use case will consider, as well, the need to review the sectorisation plan due to the military areas activation and required trajectory efficient deviations.

1.4 Narrative of use case

Narrative of Use Case

Short description

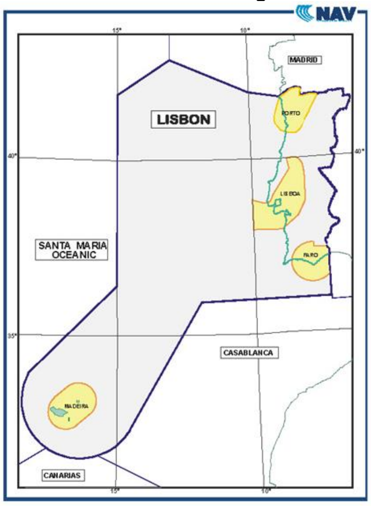
The Lisbon FIR includes an upper airspace area, four lower-airspace Terminal Maneuvering Areas (TMAs) and several military permanent and temporarily restricted areas. Because the upper Lisbon airspace is a so-called Free Route Airspace (FRA), flights can take any preferred route from entry to exit points, but preferably the most efficient (short) route.

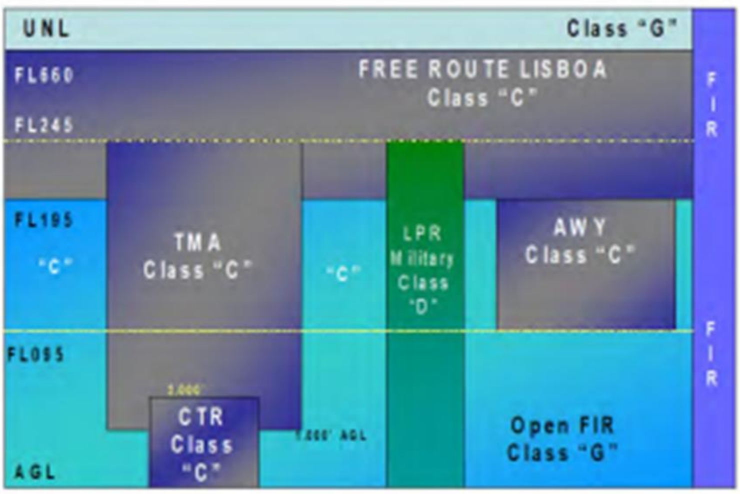
The activation/deactivation of military airspace in the Lisbon FRA can induce deviations from the flight plan routes. In this sense, to optimize the lateral deviation of the flights due to avoidance of an eventual temporary military activated area, the AI assistant will analyze and suggest a decision in sectorisation and routing of the main flows in Lisbon FIR (e.g., flight from London to Lisbon via either North or East entry coordination points of the Lisbon FIR).

Human operators, more specifically the ATC and FMP supervisors, will be supported by an AI-assistant in how to best configure airspace sectors and optimize the routes for traffic flows at the enroute sectors of the Lisbon FIR in order to balance achievement of a better KEA (*Key performance Environment indicator based on Actual trajectory*, measuring the average en-route additional distance with respect to the great circle distance) and adherence to sector capacity limitations. The AI assistant will also act in a bidirectional way by allowing the human operator to nudge the AI-generated recommendations in more favorable/acceptable directions. The airspace sectorisation and flow structures, as devised by the AI and nudged by the operators in the pre-tactical phase, will be used by Tactical Air Traffic Controllers to manage traffic around the military activated areas.

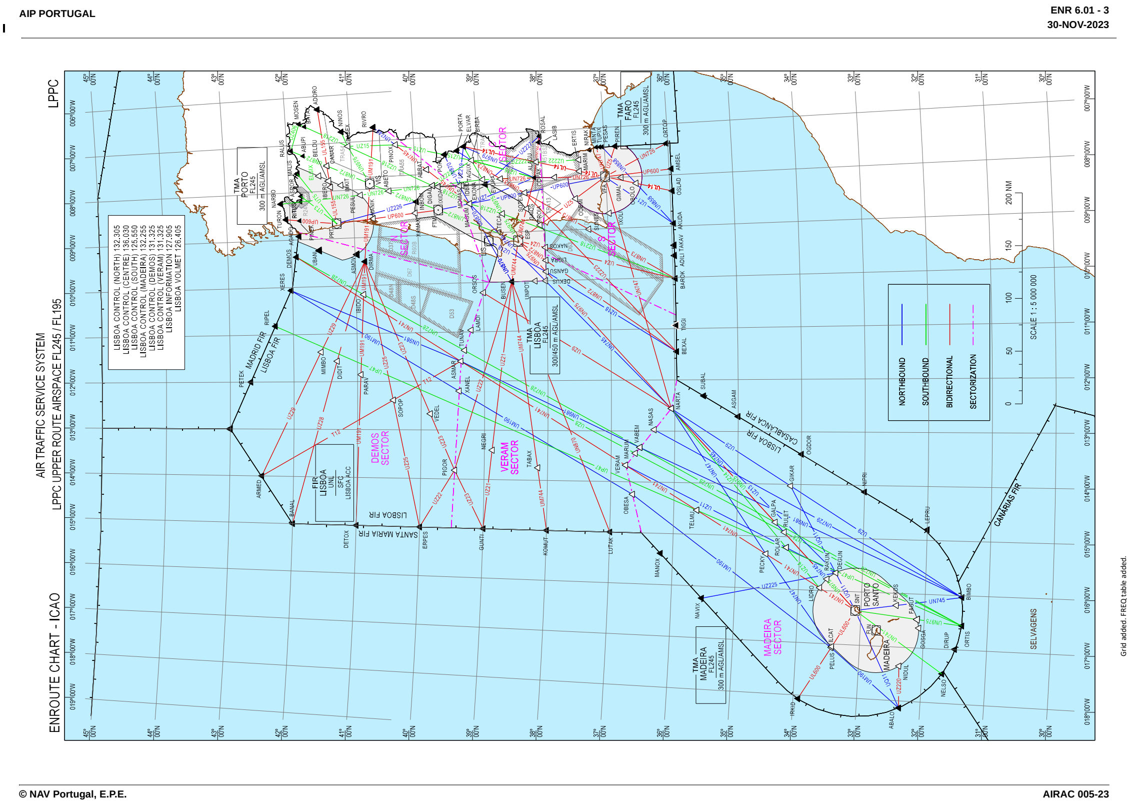
Complete description

Description of the current Lisbon FIR situation: The Lisbon FIR includes four TMA's (marked in yellow in the figure below). Within the Lisbon FIR, the airspace is classified "C", "D", and "G", with the airspace classification "D" being associated with military restricted areas. Under the Flexible Use of space (FUA) concept, the military-restricted areas may be released for management by the ANSP in order to allow for General Air Traffic (GAT) operations. When the military areas are released to the ANSP, the airspace classification of the delegated areas changes from "D" to "C".





Above FL 245, the concept of Free Route Airspace in the Lisbon FIR (FRAL) is implemented since May 2009. Under the FRAL concept, all upper airspace of the FIR is available by default for civil aircraft planning purposes. Within the upper airspace, the activation/deactivation of military areas (highlighted with grey contours in the figure below) and its impact on civil planned flights is handled in the pre-tactical time horizon, as the activation of military areas can be planned from several weeks to one day in advance. Transitions from the upper Lisbon airspace to the TMAs in the lower Lisbon airspaces occur at fixed coordination points.



Currently, en-route flight inefficiency of the flown trajectories is monitored and targeted through a *Horizontal En-route Flight Efficiency* KPI, the *Key performance Environment indicator based on Actual trajectory* (KEA). Routings deviating from those in nominal conditions, caused by military activations, changes in weather conditions or deviating airline decisions may lead to worse KEA values. As the Lisbon FIR above FL 245 is free of pre-defined routes, flexibility for routing outside of the restricted areas is available to account for major deviations of the KEA. However, re-routing too many flights through the same airspace may exceed the sector capacity limit, requiring vertical and/or horizontal splits (i.e., sectorisations) to balance ATCO workload.

Therefore, given certain environmental and operational conditions, FRA structures and routings might exist that balance *flexibility* against *predictability* targets in optimized ways. Here, “optimized” is defined in terms of flight trajectory efficiency (e.g., flight time and fuel burn) and reduced operational complexity (e.g., crossing and merging points) that impact ATCO workload, leading in the worst case to exceed the sector capacity limits. A hybrid AI system, based on supervised and unsupervised AI methods, could analyse and provide routing and airspace configuration solutions for various operational scenarios in which the Lisbon FRA is restricted (due to activated military areas, weather conditions, etc.), predicting the KEA penalty and suggesting new routings and sectorisations that minimize the KEA while respecting sector capacity limits. Training scenarios can be selected from historical data and, for highly perturbed scenarios, can be based on synthetic data generation.

System description and role of the human operator: The airspace design for capacity and flow management for operational scenarios in which the Lisbon FRA is restricted is performed in a highly automated manner by an AI-based system. This system automatically observes data from all relevant ATM platforms and makes predictions on how to organize the airspace in terms of routings and sectorisation, and implements results as recommendations to the human operator (e.g., ATC and FMP supervisors).

The AI system can be considered as a new tool that is supervised and evaluated by a human expert. The AI system communicates its decisions on an auxiliary display that, for example, visualizes airspace configurations on a map-like interface.

The role of the human operator (here, the ATC and FMP supervisors) is to evaluate the AI-based recommendations by requesting additional information and explanations, accept or reject advisories, and nudge AI decisions in a different direction by manual interventions. All decisions and interactions will be logged, allowing the AI system to continuously learn from human preferences.

Steps involved in the use case. The following steps are performed in the ATM Flow & Airspace management use case:

1. **Definition and identification of the critical system parameters.** Here, the relevant ATM system and contextual data needed for the airspace structuring (i.e., routing and sectorisation) task are gathered from (various) digital ATM platforms and integrated into a coherent, time-stamped "feature space" that drives airspace structuring predictions. Training and validation of the AI system are based on historical and synthetic/artificial data.
2. **Airspace structuring implementation**: Based on predicted traffic, airspace military activations, environment, and staffing conditions, a minimum KEA routing plan and consequential sectorisation plan are predicted. The solution is presented to the human supervisor as a recommendation on an auxiliary interface. When the AI system acts at a lower level of automation, the human supervisor manually implements the routes and sector plans. At higher levels of automation, the AI recommendations are executed based on "management by consent" (= AI implements only when the human accepts) or "management by exception" (= AI implements unless the human vetoes). At the highest level of automation, the AI system is automatically implemented, and humans can only revise the system's decisions afterward.
3. **Triggering airspace structuring revisions**: (Significant) changes, namely on military airspace activations & deactivations, as well as traffic loads, environment conditions, and staff availability, can all trigger routing and sectorisation revisions. Parameters and thresholds warranting revisions will need to be defined and should be configurable for operational scenario generation.
4. **Tactical deviations implementation**: Based on the operational conditions that lead to steps 2&3 above, the Tactical Air Traffic Controller will reroute the traffic around the military-activated areas to balance the better KEA and sector capacity adherence.
5. **Human review and adjustment**: Depending on the level of automation set for the AI system, the role of the human operator ranges from manually implementing a routing and sectorisation plan to revising AI-implemented plans (see step 2). Humans can consult additional information and explanations underpinning AI's decisions on demand, which is expected to foster trust in and acceptance of the AI system. As all human interactions will be recorded, data will become available for the type of explanation used most frequently and how certain explanations impact the acceptance of AI decisions. Such data can be used to improve the combined human-AI team performance.

Stakeholders

ATC supervisor
The air traffic control supervisor, who is located in the operational control room, is responsible for the airspace-structuring task.

FMP supervisor
Local Flow Management Position supervisor is responsible for sector capacity management.

ANSPs responsible for the FIR
e.g., NAV Portugal, the Portuguese Air Navigation Service Provider (ANSP), responsible for the Santa Maria Flight Information Region (FIR) and the Lisbon FIR.

Other ANSPs
Neighboring ANSPs are connected to the NAV FIRs (e.g., ONDA (Morocco) and ENAIRE (Spain)).

Tactical Air Traffic Controller
A single human ATCO is responsible for maintaining safe, efficient, and expeditious flows of air traffic within a single airspace sector.

National Air Force
Example: the aerial military force of Portugal (Força Aérea Portuguesa (FAP)), responsible for the Air Search and Rescue Service, air policing service and Flight Information Service (FIS).

Airlines and pilots
Airlines for adhering to planned operations; flight crew responsible for the safe and efficient execution of a planned flight.

Society and the general public
Operational efficiency and safety pay dividends in terms of fuel burn, CO2 emissions, and punctuality.

Stakeholders' assets, values

ATC or FMP supervisor • Available personnel: low-quality AI predictions may yield infeasible airspace structuring solutions (e.g., insufficient ATC personnel to handle all sectors). • Tactical activations with short notice may affect the scenery (e.g., route efficiency decreases due to flight deviations, and the capacity of the sectors dedicated to GAT exceeded). **ANSPs (incl. NAV and neighboring ANSPs)** • Reputation: the ability to maintain efficient airspace usage and ability to coordinate traffic flows with neighboring FIRs. • Safety: AI system recommendations should avoid creating traffic hotspots. **Tactical Air Traffic Controller (ATCO)** • (Mental) workload and Situation awareness: AI-recommended airspace structuring (routings of flights and sectorisation) should balance traffic loads in ways that adhere to acceptable workload limits and enable ATCOs to maintain situation awareness. **Airlines and pilots** • Reputation: adhering to planned flights while reducing inefficiencies in flown track miles, possibly leading to delays.
System's threats and vulnerabilities
Unexpected events: Air traffic operations can be affected by events related to unexpected weather (e.g., local adverse weather cells, off-nominal wind conditions), flight emergencies (e.g., aircraft equipment failure), and unscheduled ATC personnel shortages (e.g., due to sickness). The scale of such events could lead to invalid or no solutions at all, for example, in the event of a volcano eruption or hurricanes that require closing off an entire airspace. **Quality of data exchange infrastructure:** To ensure optimal decision-making, access to high-quality, real-time data will be required. Currently, information is scattered over various ATM systems, requiring a sufficiently robust IT infrastructure that can distribute data over the network to and from various Air Traffic Service (ATS) units. Delayed and uncertain information could negatively impact the quality of decisions.

1.5 Key performance indicators (KPI)

Name	*Description*	*Reference to the mentioned use case objectives*
Acceptance score	Measure of acceptance degree of the generated AI solution for human operators	Reflects the acceptance choice of the AI's system decision. (0% - 100%). Measured directly from yes/no/revision input, translated into % across the operator's multiple interactions with AI-generated solutions.
Agreement score	How much the supervisor agrees with the AI-generated sectorisation. Note: agreement and acceptance are not the same. One can accept a solution but not necessarily agree with it. A good system fosters a high-level agreement	This reflects the degree of agreement on the AI system proposal. (Likert, 7-points scale)
Trust in AI solutions score	How much of the operator's confidence in the AI-generated solution, with and without the need for additional explanations.	This reflects trust in the AI system's decision. (Likert, 7-points scale)
Decision Support satisfaction	System effectiveness in supporting the efficient decision-making by airspace managers	Reflects the effectiveness of the AI system. (Likert, 7-points scale)
Efficiency score	How many times an AI-generated solution was revised. A good system would minimize the number of human interventions.	Reflects the efficiency of the combined human-AI team performance. (0% - 100%). Measured directly from user input (was the solution modified? Yes/no), translated into % across the

		operator's multiple interactions with AI-generated solutions
Significance of human revisions	The extent of human revisions compared to the AI decision. Here, small, localized revisions (e.g., merging two small adjacent sectors in the northeast corner of the FIR) would be rated differently from larger or multiple revisions across various areas in the FIR.	Reflects the AI system performance. (LOW, MED, HIGH interaction %). Measured directly from user input (of the modified solutions, how much interaction was measured? LOW number and extent of changes, MEDIUM number, and extent of changes HIGH number and extent of changes), translated into % across the operator's multiple interactions with AI-generated solutions
System Reliability	System trustworthiness - operation as expected under several conditions without major failures.	Reflects the efficiency of the combined human-AI team performance. (0%-100%). Measured directly from how many times the AI-generated solutions are sound or lead to failures
AI prediction robustness	How accurately and robustly does the AI system predict a certain sectorisation over a certain time horizon. Does re-evaluation of the sector structure in a shorter time horizon lead to different solutions? It is undesirable if small variations in capacity lead to significant differences in the sector structures/routings.	Reflects the efficiency of the combined human-AI team performance. Measured directly from the AI generated solutions. How big a variation in capacity has to be to cause the AI to revise its previous solutions.
Prompt demand rate	Assess how many times the ATCO prompts additional explanations from the AI generated solutions.	Reflects the AI system performance. (LOW, MED, HIGH interaction %) Measured directly from user input (how much interaction with explanations occurred and how the generated scenario is rated using the 'dynamic density index', measuring complexity), translated into % across the operator's multiple interactions with AI-generated solutions
AI co-learning capability	Does the ATCO feel that by the end of the trial runs, the AI has learned his preferences?	Links to the desired output of the AI system. (Likert, 7-points scale).
Human Response Time	Needed response time to react to AI advisory/information.	(LOW, MED, HIGH response time %). Measured directly from user input (dismiss a window when they feel satisfied after evaluating a scenario, LOW less than 5 min, MEDIUM 5-10 min, HIGH more than 15 minutes), translated into % across the operator's multiple interactions with AI-generated solutions.
Reduction in Delays	Percentual reduction of flight delays due to AI implementation in airspace and air traffic management.	0% - 100%
Workload perception	Assess ATCOs perception of the system impact on their workload (either positive or negative).	Likert, 7-points scale1 (Huge Increase in workload) to 7 (Huge decrease of workload)

1.6 Features of use case

Task(s)	Planning, prediction, optimization, interactivity, recommendation.
Method(s)	Supervised Learning (e.g., ensemble decision trees) and Reinforcement learning.
Platform	BlueSky digital environment.

1.7 Standardization opportunities and requirements

Classification Information
Relation to existing standards
ISO/IEC 23894:2023, Information technology — Artificial intelligence — Guidance on risk management. Autonomous management and optimization of sectorisation in pre-tactical ATM operations are high-stake tasks, and therefore, risk management specifically related to AI is fundamental. **ISO/IEC 38507:2022**, Information technology — Governance of IT — Governance implications of the use of artificial intelligence by organizations. Autonomous AI requires an analysis of governance implications and also a redefinition of the organization structure. **ISO/IEC 24029-2:2023**, Artificial intelligence (AI) — Assessment of the robustness of neural networks — Part 2: Methodology for using formal methods. Since artificial neural networks can be a component of the autonomous AI system, formal methods to assess the robustness properties of neural networks are fundamental to certify and monitor autonomous systems. **ICAO DOC 4444** – Standards and Recommended Practices in Air Traffic Management **ERNIP Part 3** – EUROCONTROL Procedures for Airspace Management, Airspace Management Handbook for the Application of the Concept of the Flexible Use of Airspace. https://www.sesarju.eu/masterplan2020 - European ATM Master Plan
Standardization requirements
Establish a standard set of KPIs for measuring the performance of AI-based airspace structuring systems, and how the AI performance compares to heuristic methods in prediction and planning systems.

1.8 Societal concerns

Societal concerns
Description
Increased air traffic density in Europe: The challenge of maintaining safe and efficient air traffic management under increased traffic loads while adhering to the workload capacity limits of tactical ATCOs. **Privacy and data protection**: The use of AI in ATM airspace structuring (routing and sectorisation) involves the collection and analysis of large volumes of data, including potentially sensitive information. There is a concern about how data is stored, processed, and protected, especially in compliance with data protection regulations like GDPR. **Transparency and accountability**: There is a societal demand for transparency in how AI systems make decisions, especially in high-stake transportation systems like ATM. The public might be concerned about the lack of understanding of AI decision-making processes and the accountability mechanisms in place in case of failures or errors. **Employment and skill shift**: The full automation of the airspace structuring (routing and sectorisation) tasks might lead to concerns about job displacement and the need for reskilling of ATC staff. While AI can optimize operations, it also changes the nature of work, requiring a shift in skills for human operators who now need to oversee and interact with advanced AI systems. **Public trust and acceptance**: For the successful implementation of AI in air transportation, gaining and maintaining public trust is crucial. There may be apprehensions and resistance from the public regarding the shift to AI-driven systems, especially among those accustomed to traditional methods.
Sustainable Development Goals (SGD) to be achieved
SGD9. Industry, innovation and infrastructure / SGD11. Sustainable cities and communities / SGD13. Climate action

2 Environment characteristics

Data characteristics	
Observation space	Partially observable. Data update is near real-time with a certain look-ahead time (minutes up to hours). Domain: defined on a continuous space. Size: > 2000 flights per day, with > 10 observable states per flight, > 8 sectors with > 20 coordination points (entry and exit points) per sector

	Noise: The observation can be noisy due to unsynchronized update frequencies and data quality of various data platforms (e.g., weather updates).
Action space	Mixed action space: sectorisation decisions are discrete (e.g., 'split' and 'merge'), but sector geometry can vary on a continuous space depending on the algorithmic approach. Routing decisions are continuously characterized by waypoint locations. The action space of a human ATCO (for routing advisories) is three-dimensional (altitude, heading, speed). Size: The action space of the human ATC staff manager is limited to the number of sectors to choose from and depends on ATCo staff availability, the number of flights, and the weather conditions (determining geographic restrictions). The action space of the human ATCO is three-dimensional (altitude, heading, and speed) and depends on the number of flights in the sector. Time horizon: sectorisation and routing actions range typically from a few minutes to a couple of hours (= pre-tactical operations)
Type of task	Human staff managers and AI assistants act in a sequential environment: the previous decisions can affect all future decisions. The next action of these agents depends on what action they have taken previously and what action they are supposed to take in the future.
Sources of uncertainty	Stochastic (weather forecasts, variability in traffic load, unpredicted ATCo staff shortage, variability in opening and closing MIL areas)
Environment model availability	Yes (aircraft performance models, ISA standard atmosphere)
Human-AI interaction	Co-learning between the human and AI: AI assistant proposes a sectorization and routing plan, the human staff manager and planner ATCO evaluates the plan, and human agents accept or revise the plan (= feedback to AI assistant).

3 Technical details

3.1 Actors

Actor Name	***Actor Description***
FMP supervisor	The human FMP supervisor is responsible for implementing a sectorisation plan and routing structure on a pre-tactical time scale. The FMP supervisor needs to evaluate the outputs of an AI assistant that aims to support the supervisor in generating sectorisation and routing suggestions.
AI assistant	The AI assistant provides sectorisation plan and routing suggestions to the FMP supervisor. It takes predicted information about the environment from various systems (e.g., weather forecasts from METEO services, traffic loads from Central Flow Management Unit, ATCo staff schedule, etc.) and historical data. In the training phase, it can act on the environment to evaluate its recommendations. In the evaluation/testing phase, the actions on the environment should be performed by the human only.
Environment	The FMP supervisor interacts with the BlueSky digital environment and with the AI assistant through a secondary interface. The AI assistant can also portray its sectorisation and routing recommendations directly in the BlueSky environment (top-down Earth map).

4 Step-by-step analysis of use case

4.1 Overview of scenarios

Scenario conditions					
No.	**Scenario name**	**Scenario description**	**Triggering event**	**Pre-condition**	**Post-condition**
1	Nominal operational conditions	The condition is used as a baseline, allowing the comparison of minimum KEA routings devised by the AI system under nominal operational conditions with routings devised in restricted airspace availability conditions. Traffic loads over a typical day (24 hours) will be used as inputs.	Nominal traffic load over 24 hours, including periods of inbound and outbound of Lisbon FIR.	Nominal ATCO staffing capacity. Normal weather conditions.	The system proposes and/or executes efficient flight routes and sectorisation plans and presents results on an auxiliary interface for the human supervisor to evaluate. These results are then used as a baseline for comparison with scenarios with restricted airspace availability.
2	Military restrictions	This scenario deals with decreased airspace availability due to the activation of one or two military areas. Traffic should be routed around the military-restricted airspace while minimizing the KEA and adhering to sector capacity limits, which may require off-standard sectorisation.	Activation of one or two military areas.	Nominal traffic load over 24 hours. Nominal ATCO staffing capacity. Normal weather conditions.	The system proposes and/or executes efficient flight routes and off-standard sectorisation and presents results on an auxiliary interface for the human supervisor to evaluate.
3	Environmental disturbances	This scenario deals with highly decreased airspace availability due to challenging weather conditions, reducing the availability of airspace on a short time horizon.	Challenging weather conditions.	Nominal traffic load over 24 hours. Nominal ATCO staffing capacity. No active military areas.	The system proposes and/or executes efficient flight routes and off-standard sectorisation and presents results on an auxiliary interface for the human supervisor to evaluate.
4	Large perturbation	This scenario deals with decreased airspace availability due to the activation of more than two military areas, in conjunction with challenging weather conditions, further reducing on a short time horizon the availability of the airspace. This case simulates an edge-case situation.	Activation of more than two military areas in conjunction with challenging weather conditions.	Nominal ATCO staffing capacity.	The system proposes and/or executes efficient flight routes and off-standard sectorisation and presents results on an auxiliary interface for the human supervisor to evaluate.

4.2 Steps for all scenarios

For each scenario the number of steps are the same and in-line with current practices in capacity flow & management and sectorisation on medium- to long-term time scales.

Step no.	Event	Name of process/ activity	Description of process/ activity Service	Information producer (actor)	Information receiver (actor)	Information Exchanged
1	Start	The FMP supervisor prepares his/her shift	FMP supervisor selects a maximum time horizon for a sector plan and enters that information into the system. The shift is prepared taking into account the forecasted traffic, the airspace restrictions, and the available ATCOs	FMP supervisor	AI assistant	SET
2	Initialise plan	AI assistant generates an initial plan	The FMP supervisor requests an initial sectorisation and routing structure from the AI assistant. This includes portraying a horizontal and vertical sector layout on a map and/or secondary interface, a network of KEA efficient routings, a timeline showing ATCo staff and traffic occupancy per sector, and a time slider enabling the FMP supervisor to preview changes in sectorisation and routings on a map. The predicted state of the system in terms of traffic movements and weather condition (e.g., wind) is also displayed and responsive to the time slider.	AI assistant	FMP supervisor	SRPLAN
3	Plan evaluation	The FMP supervisor evaluates the plan	The AI assistant may propose several alternative sector plans and routing structures, each with a different probability values (based on historical data), KEA efficiency scores, and robustness scores depending on ATCO and traffic capacity, fluctuations in predicted traffic load, and uncertainty in weather forecasts. Using the time slider, the FMP supervisor can evaluate the probability, efficiency, and robustness scores for different times within the maximum look-ahead time horizon.	AI assistant	FMP supervisor	STATE
4	Human interacts	The FMP supervisor interacts with the plan	The FMP supervisor interacts with the suggested sector plan and routings in one of the following ways: 1) accept the top-rated AI suggestion and implement it; 2) nudge the AI suggestions by making small changes (e.g., one sector merge or split and adjust one or two traffic streams); 3) revise large sections of the plan (e.g., revise multiple sectorisation	Staff manager	AI assistant	DEC

			events across various time horizons and revise several traffic streams).			
5	Re-schedule	Trigger an alert to re-schedule	The AI assistant monitors changes in predicted system and environmental states. When updated information deviates from the information and data that was used for the implemented sector plan and routing structure, the AI assistant issues an alert, triggering the FMP supervisor to go back to Step 2.	AI assistant	FMP supervisor	AL

5 Information exchanged

Information exchanged (ID)	Name of information	Description of information exchanged
SET	Inputs and settings for AI assistant	FMP supervisor sets maximum time horizon for the AI assistant
SRPLAN	Sector plan	AI assistant suggestions for sectorization and routings.
STATE	Predicted system state	Predicted system state over a certain time period, including traffic load, weather conditions, ATCo capacity, sector and routing topology, probability, efficiency, and robustness scores.
DEC	Human decision / interaction with the AI assistant operator	FMP supervisor's choice in terms of accepting, nudging, and revising.
AL	AI assistant alert	AI assistant issuing an alert, signaling to the FMP supervisor that data used for predictions have changed significantly, warranting re-scheduling.

6 Requirements

Requirements		
Categories ID	**Category name for requirements**	**Category description**
Ro	Robustness	It encompasses both its technical robustness (the ability of a system to maintain its level of performance under a variety of circumstances) as well as its robustness from a social perspective (ensuring that the AI system duly takes into account the context and environment in which the system operates). This is crucial to ensure that, even with good intentions, no harm can occur unintentionally. *Source: EU-U.S. Terminology and Taxonomy for Artificial Intelligence. First Edition*
E	Efficiency	The ability of an AI system to achieve its goals or perform its tasks with optimal use of resources, including time, computational power, and data.
I	Interpretability	Make the behavior and predictions of AI systems understandable to humans, i.e., the degree to which a human can understand the cause of a decision. *Source: Molnar, Christoph. Interpretable machine learning. Lulu. com, 2020.*
Re	Regulatory and legal	The AI system's capacity to meet its objectives while complying with relevant laws, regulations, and ethical standards.
O	Other	Other non-function requirements related to environmental concerns and maintenance
Requirement R-ID	**Requirement name**	**Requirement description**
Ro-1	System resilience to unexpected events	The AI system should work correctly under a variety of conditions and withstand operational disruptions. This includes resilience to unexpected events like adverse weather and sudden changes in the ATCO staff availability.
Ro-2	Cyber and data security	Focuses on protecting the system against unauthorized access, cyber threats, and data breaches. This ensures the integrity and confidentiality of sensitive operational data and safeguards the system from malicious attacks.
Ro-3	The system's reliable operation and decisions	Shall show the capacity to perform its required functions under stated conditions for a specified

		period. This includes maintaining consistent performance and minimizing system failures or errors.
E-1	Capability to optimize resources and operations	The system shall maximize airspace and ATCO staffing utilization.
E-2	Scalability	Concerns the system's ability to handle growth in traffic loads, such as increased air traffic or airspace expansion, without performance degradation. This ensures the system remains effective as the scale of ATM operations increases.
I-1	Provide clear, understandable explanations for its decisions	It is crucial for human operators to validate and trust the AI's decisions, especially in restricted airspace conditions with complex sectorisation scenarios.
I-2	Usability of the system from the human and other stakeholders perspective	It should include intuitive interfaces, ease of use, and effective communication of information.
Re-1	Compliance with legal standards and regulations	Adherence to data protection laws, safety regulations, and ethical guidelines governing AI systems in public transportation and the EU AI Act.
O-1	Maintainability	Involves the ease with which the system can be maintained and updated. This includes the ability to diagnose and fix issues, update software, and adapt to changing operational requirements.
O-2	Environmental Sustainability	Addresses the system's impact on the environment. This includes considerations such as energy efficiency of the AI algorithms and the broader ecological footprint of the system's implementation and operation.

4 Common Terms and Definitions

Common Terms and Definitions	
Term	**Definition**
Air Traffic Controller (ATCO)	Human operator is responsible for directing air traffic through a volume of airspace in a safe (i.e., maintaining separation standards) and efficient manner (i.e., expediting the flow of traffic, reducing delays, and avoiding inefficiencies in flow track miles).
Air Navigation Service Provider (ANSP)	An organization that provides the service of managing the aircraft in flight or in the maneuvering area of an airport and which is the legitimate holder of that responsibility. In this use case, NAV Portugal is the considered ANSP.
Flight Information Region (FIR)	A three-dimensional area in which aircraft are usually under the control of a single authority (ANSP). Sometimes, one or more FIRs have a combined upper area control, and/or FIRs are vertically split into lower and upper sections.
Airspace sector	A three-dimensional geographical area within an FIR is under control by a single ATCO or multiple ATCOs (e.g., planner and executive controller). A FIR is commonly divided into multiple sectors.
General Air Traffic (GAT)	All aviation traffic conducted in adherence to the International Civil Aviation Organisation (ICAO) regulations.
Flow Management Position (FMP)	ANSP Unit responsible for sector capacity and traffic flow management