1 Description of the use case

1.1 Name of the use case

ID	Application Domain(s)	Name of Use Case
UC.ATM.2	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

1.3 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 assist in, or even fully automate, 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 & required trajectory efficient deviations.

1.4 Narrative of use case

Narrative of Use Case
Short description

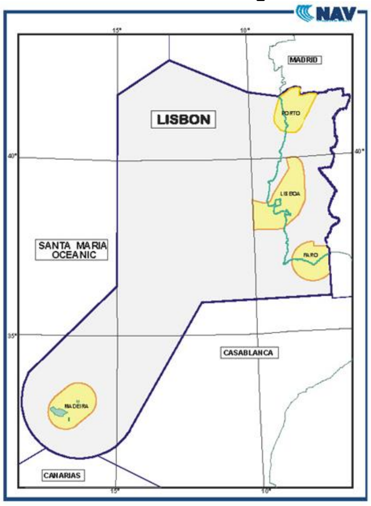
The Lisbon FIR includes an upper airspace area, four lower-airspace Terminal Maneuvering Areas (TMAs) and several military permanent and temporarily restricted areas. Because the upper Lisbon airspace is a so-called Free Route Airspace (FRA), flights can take any preferred route from entry to exit points,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

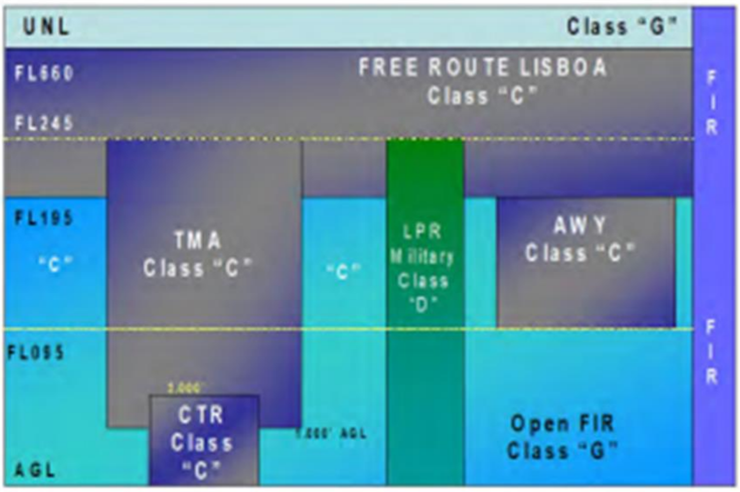
The activation/deactivation of military airspace in the Lisbon FRA can induce deviations from the flight plan routes. In this sense, to optimise the lateral deviation of the flights, due to avoidance of an eventual temporary military activated area, AI assistant will analyse and suggest a decision in 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.

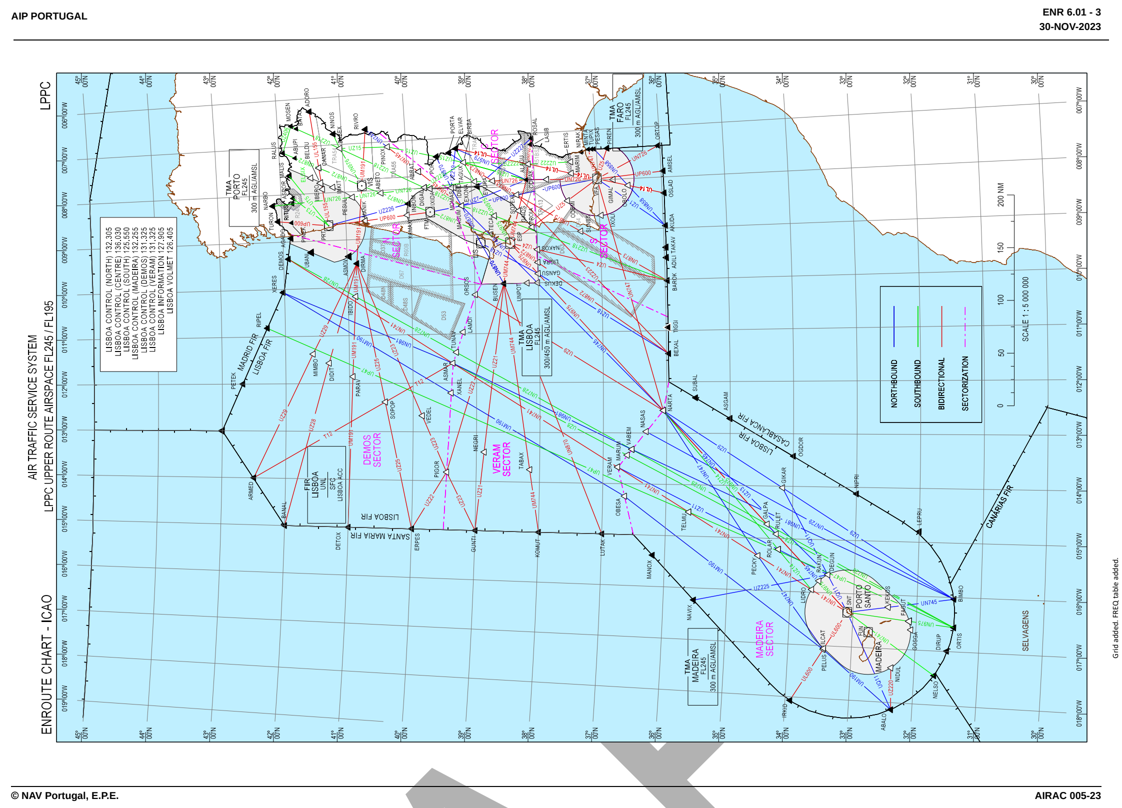
Complete description

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 Airspace (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, there might exist FRA structures and routings that balance *flexibility* against *predictability* targets in optimised ways. Here, “optimised” 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 organise 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 drive airspace structuring predictions. Training and validation of the AI system is 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 is 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 on the basis of "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 automatically implements, and the human can only revise system decision afterwards.
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 the steps 2&3 above, the Tactical Air Traffic Controller will reroute the traffic around the military activated areas, in order 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 towards revising AI-implemented plans (see step 2). The human can consult additional information and explanations underpinning the 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 what type of explanation is 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
Air Traffic Control supervisor located at the operational control room, responsible for the airspace structuring task.

FMP supervisor
Local Flow Management Position supervisor responsible for the 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, connected to the NAV FIRs (e.g. ONDA (Morocco) and ENAIRE (Spain)).

Tactical Air Traffic Controller
A single human ATCO 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 a safe and efficient execution of a planned flight.

Society and general public
Operational efficiency and safety, pay dividends in terms of fuel burn, CO_2 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 (eg., route efficiency decrease due to flight deviations, capacity of the sectors dedicated to GAT exceeded).

ANSPs (incl. NAV and neighboring ANSPs)

- Reputation: 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 requires 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	A human operator can either accept, revise of reject the AI-generated airspace structuring advice. A good system would foster 100% acceptance.	Reflects the acceptance choice related to the AI's system decision.
Agreement score	How much the human operator agrees with the AI-generated airspace structuring advice. **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.	Reflects the agreement degree of the AI system.
Trustworthiness score	How much the human operator has confidence in the AI-generated solution, with and without the need for additional explanations.	Reflects the trust in the AI's system decision.
Efficiency score	How many times an AI-generated solution was manually revised by human operator. A good system would minimise the number of human interventions.	Reflects the efficiency of the combined human-AI team performance.
Significance of human revisions	The extent of human revisions compared to the AI decision. Here, small, localized revisions (e.g., merge 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.
Human response time	How much time is needed by the human supervisor to evaluate an AI decision, with and without the need for consulting additional explanations.	Reflects the efficiency of the combined human-AI team performance.

AI response time	How much time is needed by the AI system in responding to operational and/or contextual changes warranting airspace structure revisions.	Reflects the efficiency of the combined human-AI team performance.
AI prediction robustness	How accurately and robustly the AI system predicts a certain sectorisation over a certain time horizon or routing minimizing the KEA indicator for each affected flight.	Reflects the AI system performance.
ATCO workload	The experienced workload of an ATCO working with the airspace structure generated by advice of the AI system, possibly in sector that was either split or merged.	Links to the desired output of the AI system.

1.6 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 optimisation 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 organisations. 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.

1.7 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 optimise 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 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.	System proposes and/or executes efficient flight routes and sectorisation and presents results on an auxiliary interface for the human supervisor to evaluate. This results are then used as baseline for comparison with scenarios with restricted airspace availability.
2	Small perturbation	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 with minimising the KEA, while adhering to sector capacity limits, which may require off-standard sectorisations.	Activation of one or two military areas.	Nominal traffic load over 24 hours. Nominal ATCO staffing capacity. Normal weather conditions.	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	Medium perturbation	This scenario deals with highly 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, to	Activation of more two military areas in conjunction with challenging weather conditions.	Nominal traffic load over 24 hours. Nominal ATCO staffing capacity.	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.

		evaluate robustness of the solutions.			
4	Large perturbation	This scenario deals with the future increase in traffic feed, in combination with highly 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 two military areas in conjunction with challenging weather conditions, with an increased traffic feed (e.g., 125% of present-day traffic).	Nominal ATCO staffing capacity.	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 Requirements

Requirements		
Categories ID	**Category name for requirements**	**Category description**
Ro	Robustness	Encompasses both its technical robustness (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 unintentional harm can occur. *Source: EU-U.S. Terminology and Taxonomy for Artificial Intelligence. First Edition*
E	Efficiency	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., 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	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 minimising system failures or errors.
E-1	Capability to optimise resources and operations	System shall maximise airspace and ATCO staffing utilisation.
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	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 responsible for directing air traffic through a volume of airspace in safe (i.e., maintain separation standards) and an efficient manner (i.e., expedite to flow of traffic, reducing delays and avoid inefficiencies in flow track miles).
Air Navigation Service Provider (ANSP)	Organisation that provides the service of managing the aircraft in flight or on 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 under control of usually a single authority (ANSP). Sometimes one or more FIRs have a combined upper area control and/or FIRs are split vertically into lower and upper sections.
Airspace sector	A three-dimensional geographical area within a FIR 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 management