1 Description of the use case

1.1 Name of the use case

ID	Application Domain(s)	Name of Use Case
UC1.ATM	Air Traffic Management	Airspace sectorisation assistant

1.2 Version management

Version Management			
Version No.	**Date**	**Name of Author(s)**	**Changes**
0.1	04.12.2023	Clark Borst (TUD)	Initial document
0.2	15.01.2024	Clark Borst (TUD)	Major revision
0.3	03.02.2024	Ricardo Bessa	Revision
0.4	26.02.2024	Cristina Félix	Revision

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 Air Traffic Management (ATM) system and hindering a smooth transition toward a sustainable future of ATM. Solutions to manage the workload of ATCOs can already be applied in pre-tactical phases, for example, by splitting a large Flight Information Region (FIR) into several smaller airspace sectors that each are under the control of a single ATCO. Generally, pre-tactical ATM Sector Management ensures optimal sector configurations are always used to split traffic (and workload) over more ATCOs during tactical operations. Sectorisation is primarily meant to better handle daily traffic fluctuations, making optimal use of the personnel available. Today, sectorisation is the sole responsibility of the ATC supervisor, who exclusively decides *when* and *how* to split and merge sectors best, warranted by situational demands and available ATCO personnel. Only scattered information is available on different platforms to aid supervisors in this task. Still, there is currently no traffic pre-analysis tool and/or integrated decision-support system to assist in, or even fully automate the sectorisation process.
Objective(s)	The system's objective is to partially and fully automate the sectorisation process to assist or replace the ATC supervisor in deciding when and how to split and merge sectors to balance the workload of tactical ATCOs.

1.4 Narrative of use case

Narrative of Use Case
Short description
At ATC centers, such as Santa Maria Oceanic Area Control Centre (OACC), as part of NAV Portugal ANSP, a staff manager (i.e. ATC supervisor), exclusively decides *when* and *how* to split best and merge sectors, warranted by situational demands and available ATCO personnel. The degrees of freedom in sectorization involve considering horizontal (2D geometry) and/or vertical (altitude) constraints and can thus result in split sectors horizontally and/or vertically. Typically, under nominal conditions, the supervisor can install several pre-fab sectorisation options. However, unexpected events, such as deteriorated weather conditions, flight emergencies (e.g., aircraft equipment failure), and unscheduled ATC personnel shortages (e.g., due to sickness) may require non-standard sectorisations to be installed. An AI-assistant, capable of operating under various levels of automation, will provide recommendations or even execute decisions on how to split the sector best horizontally, vertically, or both to balance ATCO workload while ensuring safety (i.e., adhere to horizontal and vertical separation criteria) and efficient traffic flows (i.e., reduce inefficiencies in flown track miles). The

AI-assistant will also act in a bidirectional way by allowing the human operator to nudge the AI-generated recommendations in directions that seem more favorable.

Complete description

Description of the sectorisation task: Sectorisation involves retrieving and integrating several data information sources that are often gathered from different (digital) platforms, such as:

- Expected traffic counts (available from EUROCONTROL CFMU)
- Air-ground and coordination message count
- Weather Information (METEO fore- and nowcasts)
- Airspace Reservations (e.g., military airspace, temporary 'no-fly' zones)
- Coordination Complexity (e.g., between area and arrival controllers)
- Terminal Area Complexity (e.g., weather-related airport capacity limitations)
- Equipment issues (e.g., comm issues between pilots and air traffic controllers)
- ATCO staff schedules (depending on traffic demands)

Based on the available ATCO personnel, including accounting for mandatory breaks after a 2.5-hour work cycle, the FIR is divided into several smaller airspace sectors, each under control by a single ATCO. How and when to best split and merge sectors horizontally and/or vertically depends on how well the traffic situation can be predicted over a specific time horizon. In general, the shorter the prediction horizon, the less uncertainty plays a role, but the more ad-hoc fluctuations in sectorisations can be expected with changing traffic loads. Therefore, a successful sectorisation should be predictable and robust over a sufficiently long time horizon.

At Santa Maria Oceanic Area Control Centre (OACC), as part of NAV Portugal ANSP, there are 3 pre-defined sectorisation plans to be used by the supervisor under nominal operational conditions:

1. **Unified Position**. Used in low traffic and/or complexity situations – one ATCO is responsible for working the full airspace.
2. **VHF sector and non-VHF sector**. Used medium/high traffic and/or complex situations. This sectorization is used mostly when there is much terminal traffic or high volume inside the VHF coverage area. If the situation justifies, there is the possibility to vertically split the non-VHF sector into several sectors to adjust the workload accordingly. The supervisor can also horizontally split the VHF sector into 3 different zones.
3. **North sector and South/Planning sector**. Used in medium/high traffic and/or complex situations. This sectorization is used mostly in low terminal traffic or low volume inside the VHF coverage area but high frequency of inbound coordination messages. If the situation justifies, there is the possibility to remove the VHF sector, creating 1 north sector, 1 south/planning sector, and 1 VHF coverage sector. In any of the examples above, the staff manager can split the South sector into several vertical sub-sectors.

There might exist more unexplored sectorisation options, especially for novel/off-nominal operational conditions. In addition, the ATM community expects ATC staff shortages in the near future, requiring more flexibility in sector organisations. A hybrid AI system, based on supervised and unsupervised AI methods, could predict and provide sectorisation solutions for nominal and off-nominal situations by learning from historical data and exploring new sector structures based on synthetic data generation.

System description and role of the human operator: The sectorisation task is performed in a highly automated manner by an AI-based system. This system automatically observes the real-time data from all relevant ATM platforms, makes predictions on how and when to sectorise, and implements prediction results either as recommendations (to the human supervisor) or automatically installs the sectorisation plan and bypasses the human. The AI system can be considered a new tool supervised and evaluated by a human expert. The AI system communicates its decisions on an auxiliary display that, for example, visualises sector configurations on a map-like interface.

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

Steps involved in the use case. The following steps are performed in the ATM sectorisation use case:

1. **Definition and identification of the critical system parameters.** Here, the relevant ATM system and contextual data needed for the sectorisation task are gathered from (various) digital ATM platforms and integrated into a coherent, time-stamped "feature space" that drives sectorisation predictions. Training and validation of the AI system are based on historical and synthetic/artificial data.
2. **Sectorisation implementation**: Based on predicted traffic, environment, and staffing

conditions, a 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 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 automatically implements, and the human can only revise the system's decisions afterward.

3. **Triggering sectorisation revisions**: (Significant) changes in traffic loads, environment conditions, and staff availability can all trigger sectorisation revisions. Parameters and thresholds warranting revisions will need to be defined and should be configurable for operational scenario generation.
4. **Human review and adjustment**: Depending on the level of automation set for the AI system, the role of the human supervisor ranges from manually implementing a sectorisation plan to 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 are recorded, data will become available on 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 staff manager/supervisor: Staff manager/supervisor located at the operational control room, responsible for the sectorisation task.

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.

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

Stakeholders’ assets, values

ATC staff manager / supervisor

- Available personnel: low-quality AI predictions may yield infeasible sectorisation solutions (e.g., insufficient ATC personnel to handle all sectors)
- Reputation: low performance of the AI system can lead to a bad reputation of the supervisor in devising workable and acceptable sectorisations (e.g., adhere to the mandatory ATCO breaks and preserve stability of a sectorisation decision within a time window)

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 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

Accountability: who is responsible for the bad performance of the AI system

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 hurricane that requires closing off one 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 staff manager can either accept, revise of reject the AI-generated sectorisation. A good system would foster 100% acceptance.	Reflects the acceptance choice in the AI's system decision.
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.	Reflects the agreement degree of the AI system.
Trusthworthiness score	How much of the supervisor's 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 revised. 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., 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.
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 sectorization revisions.	Reflects the efficiency of the combined human-AI team performance.
AI prediction robustness	How accurately and robustly does the AI system predict a certain sectorisation over a certain time horizon.	Reflects the AI system performance.
ATCO workload	The experienced workload of an ATCO working in a sector that was either split or merged by the AI system.	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 sectorisation 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 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 sectorisation task 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 AI sectorisation system responds to predicted traffic fluctuations under nominal operational conditions. Variations in traffic loads over a typical day (24-hours) will be used as inputs.	Fluctuations in traffic load over 24 hours, including periods of inbound and outbound of Santa Maria FIR.	Nominal ATCO staffing capacity	System proposes and/or executes acceptable sectorisation results and presents results on an auxiliary interface for the human supervisor to evaluate.
2	Environment perturbations	This scenario deals with sudden changes in airspace availability due to adverse weather conditions of different magnitudes/scales, impacting sectorisation results.	Over a 24-hour period, various durations and scales of weather-related perturbations (e.g., off-nominal wind conditions due to storms) may require off-standard sectorisations.	Nominal ATCO staffing capacity	System proposes and/or executes off-standard sectorisation results and presents results on an auxiliary interface for the human supervisor to

					evaluate.
3	ATCO staff shortage	This scenario deals off-nominal ATCO staffing capacities, impacting sectorisation results.	Over a 24-hour period, various perturbations in ATCO staffing capacities (e.g., due to sickness) will require off-standard, yet acceptable sectorisations. These events may be used in conjunction with environmental perturbations, simulating edge-case situations.	Off-nominal ATCO staffing capacity	System proposes and/or executes off-standard sectorisation results 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 considers 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 behaviour 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 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). Commonly, a FIR is divided into multiple sectors.