AWARE Assessment Scenarios

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Abstract

This document defines the validation scenarios for assessing the Artificial Situational Awareness (ASA) system in the AWARE project. It outlines how validation scenarios are designed to simulate realistic ATC environments, varying in traffic complexity and ASA support levels, to evaluate system capability to adequately recognize controller intention, workload and situation awareness, to provide appropriate assistance to handle traffic in various modes of collaboration and to enhance operational safety.

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AWARE

Achieving Human-Machine Collaboration with Artificial Situational Awareness

AWARE

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Table of contents

List of figures

List of tables

1 Executive Summary

This document outlines the development and structure of the validation scenarios used to assess the Artificial Situational Awareness (ASA) system within the AWARE project. The primary aim is to explore how ASA supports Air Traffic Controllers (ATCOs) in various operational contexts, focusing on AI's recognition of ATCO intention, its understanding of task prioritization, ATCO situational awareness and workload, the modes of human-AI collaboration and its effects on ATCO workload, system performance, and safety/security impacts.

Overall, for the validation of the ASA system one training and for validation scenarios are developed that are derived from a structured set of exercise scenarios that simulate realistic en-route sector operations in Malmö ACC (sector ESMM23). The exercise scenarios were derived from another SESAR project. These scenarios reflect diverse and complex air traffic conditions, including a variety of traffic volumes, conflict geometries, restricted airspace activity, and dynamic pilot requests. The scenarios are designed to systematically evaluate various levels of ASA support, from no support to autonomous task execution, in regard to the ASA system's effectiveness, adaptability, and acceptability.

The scenario design is grounded in an ATCO task model and informed by cognitive and operational frameworks (e.g. Histon, Klein), allowing the exploration of controller strategies under time pressure, uncertainty, and goal conflict. Scenario specifications include detailed definitions of parameters such as meteorological conditions, flight dynamics, aircraft types, and traffic management plans, that match typical operational conditions at Malmö ACC sector ESMM23. The results of these simulations will contribute to understanding the capabilities and limits of the ASA system in enhancing controller performance and ensuring safe and resilient air traffic operations.

2 Introduction

This document outlines how the validation scenarios were designed for the AWARE project.

These scenarios serve to evaluate the Artificial Situational Awareness (ASA) system and its impact upon Air Traffic Controllers (ATCOs) in different operational settings. The scenarios are intended to represent real-world air traffic control situations that reflect the range, variability and scope of ATCOs 'work' i.e. the purposeful activity of the socio-technical system.

These scenarios need to encompass the scope of the operational environment and its intrinsic performance variability in terms, inter *alia* of traffic complexity and variability, i.e. diurnal variation, task demands, and adequacy of different support levels provided by the ASA system. The scenarios are designed to test the ASA system's impact upon ATCO performance, workload, and safety performance in air traffic management, in addition to service delivery, i.e. the effectiveness of the provision of an en-route air traffic service.

The scenarios in the human-in-the-loop simulations reflect operationally relevant situations and tasks associated with managing traffic and traffic flows within the target sector. While these are referred to as *validation scenarios* due to their operational focus, their development is informed by the structure and requirements of exercise scenarios. Exercise scenarios, which are derived from another SESAR project, are detailed blueprints that specify traffic samples, conflict configurations and event triggers used to construct the validation scenario. In this way, exercise considerations guide the creation of validation scenarios to ensure both research validity and operational realism.

The validation scenarios are also developed and designed to embrace a progression from low task load for familiarisation to increasingly complex tasks and traffic situations. This facilitates a structured assessment of ATCO performance and ASA system effectiveness in support of exploring the AWARE research questions.

Four validation scenarios are designed to evaluate different aspects of ATCO decision-making, workload management, service provision as well as interaction with the ASA system to ensure that the level of assistance and the overall system design support controllers effectively without increasing their cognitive workload.

The results will provide insights into the benefits, limitations, and acceptance of an adaptive design of Human-AI collaboration in air traffic control operations.

3 Needs Analysis of the Validation Scenarios

To develop the validation scenarios, first the ATCO tasks were systematically analysed to ensure that the ASA system may understand and provide prioritized and adequate support to ATCOs. The results are summarized in the AWARE ATCO task model. In a next step conceptual considerations for the design of exercise scenarios were considered. And finally, the research questions were reviewed to ensure all requirements for validation and empirical tests are met by the validation scenarios designed.

3.1 AWARE ATCO Task Model

An ATCO task model is essential for the technical system as it provides a structured framework for understanding, predicting, and supporting controller decision-making and workload management.

The ASA system relies on this model to classify and prioritise tasks based on traffic conditions, airspace constraints, and operational priorities, ensuring that AI assistance aligns with real-world ATCO workflows. By integrating data from eye tracking, HMI interactions, and traffic simulations, the model enables the system to recognise intent, suggest appropriate support actions, and even execute specific tasks autonomously when necessary (although still under the aegis and accountability of the ATCO). This structured approach enhances real-time decision-making, ensuring that the ASA system does not overwhelm controllers with unnecessary information but instead provides context-aware, task-specific assistance. Moreover, the task model allows for performance benchmarking, comparing AI-generated actions with ATCO best practices, ensuring that joint cognitive system support remains reliable, effective, and human-centred within complex ATM environments.

Outlined below is a representative derived task list for controllers that provides the means to support the framework of objectives and scope to be included in a scenario. Not all tasks are required in every scenario.

The tasks include:

1. Assume Aircraft: Pilots need to call the controller in the first initial call (receive aircraft calling sign). The ‘assume’ task also embraces the takeover control of the flight, which occurs at the transfer of control point. For that, the scenarios need to include aircraft which are not yet on the frequency of the sector.

2. Transfer/QSY: For this task, a controller needs to transfer a flight to the next sector.

3. Aircraft Requests: The controller needs to receive an aircraft request. This task is finished as soon as the controller answers the pilot’s request or when the aircraft leaves the sector. The task appears if there's a communication from the pilot to the ATCO. This requires that a pilot calls the controller.
4. Conflict Resolution: Vertical and horizontal conflicts need to occur in the sector. This should also include potential future conflicts which may evolve, with time for the duration that the flights are within the sector under the jurisdiction and control of the sector controller. That requires that at least two flights in the sector are in conflict.

5. Entry Conflicts: This task includes flights assumed that are still outside the sector boundaries and thus not under the control jurisdiction of the receiving sector. In this specific task, if there is a conflict that will lead to a loss of separation (separation will fall under 10 NM outside of the sector or close to the border). The task is necessary for the controller to manage those flights which are assumed but are still located outside of sector borders – if the ATCO wishes to issue a command (direct-to, heading/FL change), they need to communicate that with the neighbouring sector's ATCO. This requires that a scenario includes an entry conflict (meaning: assumed flights outside of sector borders).
6. Exit Conflicts: This task includes flights which will be transferred but are in conflict (separation will fall under 5 NM outside of the sector). The task includes situations when an exiting flight needs adjustments to its exit conditions (i.e. Exit Flight Level/XFL change) which will lead in a conflict. The controller must therefore contact the neighbouring sector (which will receive the aircraft) to inform them of the changes and agree on an acceptable alternative. This requires that a scenario includes flights exiting the sector and not all conditions are fulfilled.
7. Quality of Service (QoS): This task checks opportunities for the improvement of flight trajectory to have a more efficient flight path. QoS includes giving a direct routing or climbing a flight to a higher flight level. This task requires that a flight is not on the direct route and/or that the current flight level of a flight is not the same as the requested flight level.
   7.1. Restricted area: QoS is often combined with the activation/deactivation of restricted areas. A flight is not allowed to fly through a restricted area. As soon as this area is activated the flight needs to be managed around. As soon as the restricted area is deactivated, the flight can be sent directly again to the next way point. This requires that a scenario includes the activation and/or deactivation of a restricted area. An area can be restricted because of bad weather conditions or military activities.
8. Non-conformance Resolution: Non-conformance is that a pilot is not following/cleared to a command from the controller but still performs this command. This could be that a pilot is climbing/descending but is not cleared for this change. This task requires that a scenario includes a flight whose flight parameters (FL, speed, heading, etc.) don't match the one set in the flight plan or the one set by the controller.

3.2 Exercise Scenarios and Traffic Sample Selection

This chapter outlines the rationale, structure, and cognitive underpinnings used as a framework of general guidance for exercise design to appropriately design validation scenarios in the AWARE project, detailing how varying traffic complexity, ATCO task demands, and human-AI collaboration dynamics are designed to assess situational awareness, workload, decision-making, and system safety in realistic operational conditions.

The design of scenarios requires a structural foundation to allow systematic specifications for exercise scenarios including different scenarios with varying content, traffic flows and volume as well as complexity. This diversity is essential for the AWARE project to achieve this aim. Fundamentally, it

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allows for a comprehensive evaluation of the ASA system's impact across multiple operational conditions.

By designing scenarios that range from medium to high complexity, it is possible to systematically assess ATCO intent recognition by observing how the ASA system adapts to different levels of task demand and gaze patterns across different ATCOs and evaluate the appropriateness of its form of assistance.

To assess situational awareness and workload of ATCOs an exposure to diverse conditions is required. This will allow to measure how well the ASA system aligns with ATCOs' real-time decision-making under varying levels of task load and stress. ATCO support and joint cognitive system acceptance can only be effectively studied if controllers experience both routine and high-stakes situations, helping determine when and how joint cognitive systems are most beneficial. It will allow to explore how ATCOs make use of assistance and how the human-AI team copes with high task load and recovers from errors. To study ATCOs' expectations and experiences when working with a "collaborative algorithm" rather than using "just another tool" helps understanding and prevent situations where surprises arise when joint cognition in the sense of shared human-AI situation awareness is lost and intentions in approaching the challenges may divert.

Additionally, testing under different complexities ensures a robust evaluation of system performance, verifying that ASA can function effectively in real-time while maintaining an acceptable accuracy rate across different scenarios. Finally, varying conditions help identify safety and security risks, ensuring that ASA support remains reliable in both medium and high-traffic environments.

The ATCO's operational work has a number of characteristics that the scenarios need to represent the characteristic varied nature of the task. Conceptually Vaughan (2021) summarises this in this way 'The human-technology interaction is not a neutral encounter but an interactive relationship: from devices, rules and procedures, tacit knowledge and material objects, controllers construct risk and safety. Controllers must negotiate the intersection of standardisation, cognition and information that appears in standardised forms but varies in behaviour'. From the framework of Joint Cognitive Systems and macro-cognition, the choreography of joint activity between machine artefacts, procedural and real time information and the interactions between aircraft and the operating environment is sensitive to temporal demands.

Time pressure is therefore a significant feature of controller workload. Task load that is high can influence the time with which a succession of elements of a tactical strategy can be enacted, or revised as new information becomes available or certitude grows. This can, in and of itself, lead to tactical adjustments being necessary to achieve goal states.

Uncertainty is one dimension of the embodiment of this. Controllers regulate their workload by varying operating methods through strategies that discriminate information elements that are constrained to salience and that are contextually germane (Sperandio, 1978). In this way, the controller manages the possibility of task saturation. Such regulation is a function of three dimensions, Sperandio (1978) argues. Regulation of workload is seen as an activity contingent upon feedback ATCO generated workload derived from the operational tactical strategies chosen that will achieve the desired goal states for individual aircraft as well as sector and network needs.

The ATCO conflict detection task is one that is influenced by certitude. In these instances, tactical strategies are based on judgements made by ATCOs on the future state of perceived interacting aircraft pairs or multiple interacting aircraft. Figure 1 presents the view of Bisseret (1981, pg. 83), in the case of the controller's detection task that four possible future states for a pair of aircraft can be found as a response to a stimulus that the ATCO attends to thereafter through processing particular variables. e.g, angle of convergence, position of the crossing point of closest point of approach etc.

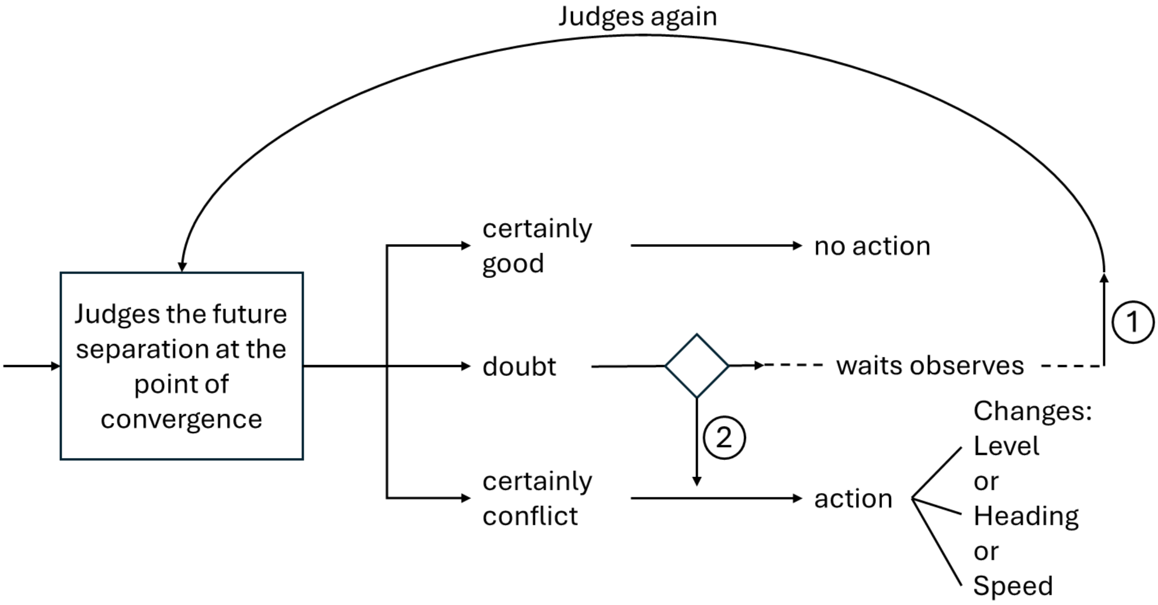

Figure 1: ATCO Judgement Heuristic (Bisseret, 1981)

The future state of aircraft represents one dimension of a goal state to be achieved. It can be the case that separation is one dimension of a goal state. This state can include coordination or transfer conditions such as spacing for sequencing.

These goal states and the path towards their achievement are framed through uncertainty. The closer traffic reaches the intended goal state, so certitude of achieving these builds. Each specific tactical strategy will have different degrees of certitude. Consequently, ATCOs make adjustments often continually to achieve goal states. In practice ATCO state this as having multiple plans in mind how to react to deal with uncertainty.

A feature of an ATCOs work is therefore that of goal conflicts where individual desired aircraft goal states influence others such that tactical strategies of differing aircraft can interact or influence achieving goal states. Thus, requiring changes to tactical strategies.

Histon (2003, pg. 118-12) identified four operating modes that ATCOs can be ascribed to cycle through:

- *Opportunity Mode*: a mode representing a state where the ATCO has cognitive resources sufficient to be able to support several degrees of freedom to act tactically. Such as offering optimal flight path adjustments e.g. changes to Top of Descent points that offer later descent profiles

- Route Structure Mode: Where the ATCO makes greater use of the airspace route structure which provides certitude and thus a different balance of cognitive resources by simplification through predictability of individual as well as multiple traffic flows
- Congestion Mode: Is deemed to be present when the traffic levels grow, and tactical strategies involve not just separation requirements but managing inter and intra traffic flows.
- System Shock Mode: Histon argues that this mode is infrequent but represents situations where, because of external conditions, plans and strategies need to be revised in the sense of wider contingencies. En-route holding because of an adjacent ATSU system disruption for example or slowing down traffic flows inbound airfields where traffic is perturbed

Figure 2 is a representation of Histon's view of the cognitive processes of an ATCO (Histon, 2008).

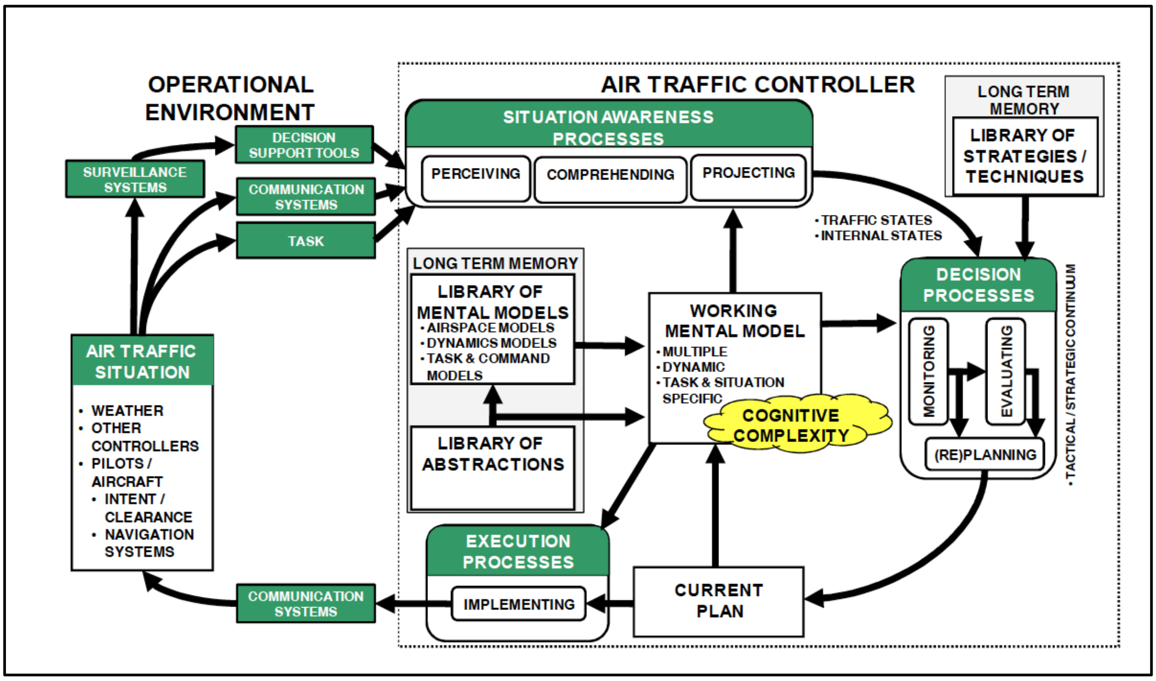

Figure 2: Histon's Cognitive Process Model

Of note is the notion of cognitive complexity. Especially how it affects the ATCO's mental model, which is constantly developing and adapting to changes in the airspace.

As a result, the degree of cooperation between humans and AI will have to adapt as availability of mental resources to monitor and evaluate AI assistance vary. This will add nuance to the joint system with diverse influences on the nature of its choreography and coordination demands.

This structured variation provides critical insights into the adaptability, reliability, and overall effectiveness of AI-assisted decision-making in air traffic control and how this enhances, or otherwise, controller performance.

3.2.1 The Nature of Human-Machine Collaboration

By systematically varying ASA support levels across scenarios, the project will determine the effectiveness, acceptability, and impact of the joint cognitive system on situational awareness, workload, and operational safety.

The ASA system is envisaged to support the ATCO in their tasks, and it is also able to perform certain tasks autonomously. The tasks described above (Chapter 3.1) are represented in the exercise scenarios. A detailed description of the scenarios can be found in Appendix 5.1.

When researching the human in complex adaptive socio-technical systems, intrinsically the case in AWARE, there are a multiplicity of dimensions that influence the nature of the performance of the AWARE system and the human working with and within it. The research objective is not the human alone *per se*, but the design of the joint activity that the human and technical artefacts, as well as the philosophy of the concept and method of operation. Frameworks that explicate factors such as situational awareness, workload, stress are one dimension as is the usability of the interaction with artefacts that support the human actor in the purposeful activity of the system. Other frameworks are required to explicate the joint nature of human practitioners working with technical artefacts to fulfil the purposeful activity of the design of the work system.

One dimension of this is that of Macrocognitive work (Hoffman & Klein) and another is that of Joint Cognitive Systems (Hollangel and Woods, 2005, Woods and Hollnagel, 2006). AWARE introduces a different form of joint activity - ATCO-AI collaboration that yields different ways to achieve the purposeful activity. When studying and researching ATCO-AI collaboration these dimensions affect the choice of theoretical frameworks that can conceptualise the research object. Hollnagel & Dekker (2024, pg.8) argue that artefacts when introduced into designs of joint activity are 'not neutral in their effects and their introduction into a system only has intended and not unintended consequences'. It is acknowledged that humans will adapt to achieve goals, and will do so in joint activity systems such as AWARE.

Therefore, in AWARE, the nature of 'work' that is performed by the ATCO will change and a new expression of work emerges. Routine tasks and actions may be enacted differently when collaborating with an AI agent as well as, in some circumstances existing routines will continue. Coordination, in the sense of coordination between actors, will have a new dimension that of coordination with collaborative agents. The choreography of work thus changes. Non-nominal tasks and situations may require strategies to adopt new perspectives and goals to achieve the new choreography required.

Histon's view of the cognitive processes of an ATCO depicted in Figure 2 (Histon, 2008), is widely accepted within ATM research. It is proposed that this model be used as the basis for an argument that provides a way of assessing situational awareness. The model depicts the 'air traffic controller' as an element of the cognitive process model which includes recognisable facets drawn from other researchers' work. Situation awareness is a key element, but not the only focus of the model. Other psychological elements contribute to the mental workload model which in turn influences decision making and flowing to what is called an Execution Process.

For AWARE it is proposed that the 'projection' element of the ATCO model is one way of considering situational awareness as it correlates with the ATCO's developing of strategies that tactically manage the path of traffic through the sector. This will change as it is processed through, for example, the scanning patterns of controllers or stimuli that trigger review of the current traffic situation.

Working with the ASA system changes this. Assisted and autonomous task execution modes mean that the cognitive processes that form the framework of ATCO performance can be subject to change. For example, scanning patterns for controllers may differ. In the assisted mode, will the ATCO be required to monitor ASA as well as the sector-based systems that are available on the sector working position?

The changing nature of the ATCOs mental model of the traffic situation, projection and mental simulation of traffic situations leads to questions around the fidelity and salience of the model that ASA will have of the context. Will the support offered by the machine agent be consistent and coordinated with the situation as the ATCO perceives it as changes are integrated into the ATCOs mental model and situational awareness? Or will it require the ATCO to work to achieve common ground with the machine agent through extensive coordination?

This raises the question of which actor or agent is in control. This is a legitimate dimension of collaboration in human-AI agent work.

Histon's model of the ATCO depicts a flow of data and information within the cognitive process. It can be described as a constant control loop. ATCOs praxis is based on the continuous control loop that leads to minor strategic adjustment, such as changes in heading, speed or flight level, in response to the evolving system state, encompassing the current traffic situation, weather, airspace configurations, and other operational factors. This is reflected in the "Internal states'' and traffic states in Histon's cognitive process model. These changes are reflected in information to the next controller who is in the operations room.

Bieder and Bourrier (2013) best describe this in this view:

- 'Incidentally, we can mention that in aviation, although working together every day, pilots and controllers do not share the same philosophies and practices regarding procedures.
- Air traffic controllers have few procedures and checklists. Their philosophy is that a controller is trained and educated to work in a specific centre within a specific team. This is achieved through training and practices regarding procedures.

The character of decision making in the constant control loop is characterised by Klein as Recognition Primed Decision making, A theoretical framework that is fundamental when trying to unravel human work.

Thus, there are implications of this for the design of the exercise scenarios. The traffic situations that form the traffic samples need to reflect various nuances of the operating philosophy of the ATCO. In essence the philosophy of the way that an ATCO controls. This does not translate to tangible knowledge that is readily apparent or available to others.

It can be hypothesised, *a priori*, that the flow of tasks and work may be disturbed or enhanced in the various operating modes over a range of sector operating situations and variability e.g. traffic volume and density, diurnal variation of traffic flows ('first rotation bunching of traffic, percentage of aircraft requiring level changes etc. The nature of control is a fundamental facet of the exercise scenarios to explore the ATCO-AI collaboration and how the constant control model functions and is realised.

3.2.2 Scenario Specifications

This chapter describes the underlying systematic and variables considered in specifying the validation scenarios. The design of the validation scenarios must enable a systematic exploration of the AWARE project's research questions (AWARE, D2.2, 2024, p. 18), which are addressed through human-in-the-loop simulations. This section outlines the exercise scenarios that form the foundation for constructing the validation scenarios.

Detailed specifications for each exercise scenario are provided in Section 5.1. These exercise scenarios are scripted to include both specific operational situations and a baseline level of sector activity necessary to replicate realistic working conditions. The traffic samples used in the exercise scenarios are tailored to support each validation scenario and to simulate targeted system states and operational conditions, such as varying levels of demand and traffic complexity, that align with the objectives of the validation scenarios.

To achieve this, the scenario specification defines the key parameters of the simulation environment, ensuring consistency and realism in scenario development. These parameters are structured around categories of data that describe the air traffic operating context and are presented in Table 1:

Parameter	Description
Outline description	• Date, weekend/weekday • Traffic level • Complexity description • Monitor Value
Meteorological Conditions	• METARS for specified airfields that generate significant traffic flows: EKCH, ESSA, ESSB • Significant weather warnings: CBs, turbulence states • ACC specific Met forecasts
Type of Traffic	• # of general aviation flights • # of flights in restricted area • # of non-regular flights e.g. Business Aviation, State Flights • Others
Sector Traffic characteristics	• Peak Entry (10 minutes[3]) • Peak Occupancy (hour) • Peak Occupancy period (hour) • Peak Occupancy 10 minute 'jump' (hour)
Vertical Plane aircraft state	• % Aircraft in Cruise • % Aircraft Descent

[3] 10 minutes is the desired granularity

	• % Aircraft Climb
Aircraft Category	• % Heavy • % Medium • % Light
Network Operations/Traffic Management	• NO Pre-Tactical Plan 04.08.2025 • NO Tactical Plan 04.08.2025 • ESMM Tactical Traffic Management Interventions • Monitor Value planned against occupancy
Events and Episodes	• Event type and description • Event location

Table 1: ESMM23W parameters required to build scenarios

3.3 Mapping of Scenarios to the AWARE Research Questions

AWARE has established a set of research questions to evaluate the components of the ASA system and its impact for which the research design of the validation simulation needs to provide the means to explore. The AWARE Exploratory Research Plan categorises five areas of interest around human-AI collaboration (AWARE D2.2 ERP, 2024, pg, 18). All research questions for these five categories can be found in the Exploratory Research Plan (AWARE D2.2 ERP, 2024, pg, 18). Specific requirements can be derived from each of these categories, which must be taken into account when designing scenarios in order to achieve the objectives of the research design.

1. Intent

   Research questions about ATCO intent investigates whether the AI Assistant Application can accurately recognize ATCO intentions by combining gaze and HMI interaction data with a task model, how well these data sources can compensate for each other in case of reliability issues, and how much input is needed to effectively model cognitive processes for intention recognition (AWARE, D2.2, 2024, pg. 18).

   By designing scenarios that range from medium to high complexity, it will be possible to systematically assess ATCO intent recognition by observing how the ASA system adapts to different levels of task demand and gaze patterns.

2. Situational awareness and workload

   Research questions about situational awareness and workload (AWARE, D2.2, 2024, pg. 18) explore whether ATCO situational awareness can be assessed by comparing inferred intentions to priority tasks, and whether the AI Assistant Application can reliably detect increased or excessive mental workload in comparison to subjective and implicit performance measures.

   Situational awareness and workload assessment require exposure to diverse conditions to measure how well the ASA system aligns with ATCOs' real-time decision-making under varying stress levels. ATCO support and joint cognitive system acceptance can only be effectively studied if controllers experience both routine and high-stakes situations, helping determine when and how joint cognitive system is most beneficial. Additionally, testing under different complexities ensures a robust evaluation of system performance, verifying that ASA can function effectively in real time while maintaining an acceptable accuracy rate across different scenarios. Finally, varying conditions help identify safety and security risks, ensuring that ASA support remains reliable in both medium and high-traffic environments.

A requirement of different tasks to be simulated is that some need to be executed at the same time. To detect if the prioritisation is correct, several different tasks should be implemented concurrently in the scenarios, so that coordination and common ground can be allowed to adapt to the changing cognitive demands.

3. Supporting ATCOs

   Research questions about supporting ATCOs (AWARE, D2.2, 2024, pg. 18) examine the acceptability and impact of the application's support on ATCOs, including how they prefer to be supported, the suitability of higher automation in complex traffic situations, the effectiveness of design solutions in ensuring intuitive and low-effort support, and whether the provided information positively influences performance KPIs.

   It should be tested if ATCOs accept different levels of autonomy with the joint cognitive system in complex as well as other traffic scenarios. Differing task load and demands emanate from combinations of low traffic demand and high complexity, high traffic demand and low complexity and the transitions between system states.

   Having different scenarios with varying content, traffic amounts, and complexity is essential as it allows for a comprehensive evaluation of the ASA system's impact across multiple operational conditions. By designing scenarios that range from medium to high complexity, it is possible to systematically assess ATCO intent recognition by observing how the ASA system adapts to different levels of task demand and gaze patterns.

4. System performance

   Research questions about system performance (AWARE, D2.2, 2024, pg. 18) investigate whether the developed AISA system can operate fast enough for real-time integration with ATM systems, whether all monitoring tasks from the AISA ConOps can be automated, and whether the achieved accuracy is sufficient across those tasks.

   The requirements for the validation scenarios emphasise that traffic samples need to include some flights under the control of the active sector that provoke sufficient opportunity for monitoring by the ATCO.

   Given that ASA will classically adopt some monitoring tasks the significance of coordination and choreography within the joint system and being able to assess this through a framework for effective coordination: Inter-Predictability (including common ground) and directability. The latter provides an indication of resilient performance.

5. Safety and security

Research questions about safety and security (AWARE, D2.2, 2024, pg. 19) explores the safety and cyber-security implications of integrating the AI Assistant Application, including potential hazards, the system's ability to enhance safety by supporting ATCO situational awareness, the effectiveness of mitigation measures in meeting safety requirements, and how artificial situational awareness can model human awareness and address cyber-security risks.

The scenarios should incorporate safety-critical tasks like conflict detection, coordination with adjacent sectors, and handling unexpected events (e.g., nonconformances). Moreover, ATCOs must be assigned a workload that challenges their ability to maintain situational awareness, requiring simultaneous monitoring, prioritization of tasks, and adaptive behaviour, thereby enabling assessment of how well the AI system supports them without introducing new operational hazards.

Table 2 provides a concise overview that links each project objective to its relevant research questions, ensuring that each objective's scope and goals align with the questions driving the research and validation activities. This forms the basis for mapping the exercise scenarios to both research questions and the AWARE validation scenarios.

Exercise Scenario Nr.	Exercise Scenario Description	Validation scenario	Research Question Category
1	Managing workload around conflict detection tasks	1, 2, 3, 4	Intent; Situational awareness & workload; Supporting ATCOs
2	Conflict detection and resolution at a single crossing point where there are a multiplicity of intersecting and interacting trajectories	1, 2	Intent; Situational awareness & workload
3	Managing a multiplicity of different points at which tracks cross the boundaries of adjacent sectors of ACCs	4	Intent; Situational awareness & workload; Supporting ATCOs
4	ATCOs deal with traffic levels at or above declared sector capacity or monitor value.	3, 4	Intent; Situational awareness & workload; Supporting ATCOs
5	ATCOs are managing traffic flows that interact at or close to a sector boundary	1, 2, 3, 4	Intent; Situational awareness & workload; Supporting ATCOs
6	Uncertainty around aircraft entering the sector and its associated entry point at the boundary with adjacent ACCs on transfer to the sector.	NA	Intent; Situational awareness & workload
7	ATCOs managing vertical flight-path management of traffic	1, 2, 3, 4	Intent; Situational awareness & workload; Supporting ATCOs

8	Managing traffic streams inbound to specific airports.	1, 2, 3, 4	Intent; Situational awareness & workload; Supporting ATCOs
9	Goal conflicts, tactical strategies, uncertainty and ATCOs prediction of future traffic situation.	1, 2, 3, 4	Intent; Situational awareness & workload
10	Prediction of aircraft performance in tactical strategies chosen by ATCOs and the fulfilment of goals and other conditions.	NA	Supporting ATCOs
11	Sources of performance variability in sector operations and management, and adaptation through meteorological challenges.	NA	Intent; Situational awareness & workload
12	Time pressure, uncertainty, incomplete and partial information in controlling traffic and managing sector operation.	2, 3, 4	Intent; Situational awareness & workload

Table 2: Mapping of validation and exercise scenarios with AWARE research questions

3.4 Complexity Factors

Complexity is accepted as an ever-present feature of ATM operations. The nature of complexity and the way it manifests itself is complex in and of itself. A high occupancy of the sector, at or close to its monitor value, may not lead to complex situations per se if aircraft are at their cruising levels and there are few level changes, and the aircraft are all transiting the ATC sector in the same direction. A lower occupancy rate with aircraft transiting in opposite directions may yield complex interactions within and between flows of traffic.

Appendix 5.1 provides the means to ascertain and explicate specific operational facets to explore the research questions. The twelve exercise scenarios were elicited to capture examples of complex situations from the operational perspective. There are two levels of description for each. One being the operational dimension i.e. the controlling facets that make a situation complex in terms of conflict geometries. Some of these influences the second dimension, like the degrees of freedom that an ATCO may have in the scope of strategies to achieve goals. The presence of restricted airspace for example, or the imposition of conditions for transfer of aircraft to the next ATSU.

The second dimension is best described as the mental (or cognitive processes) that ensue and arise as a function of task load, workload and the strategies that a controller derives. There are fundamental characteristics of the operational environment that ATCOs work in and with. These are inherently associated with the reality of never having ‘perfect knowledge’ or ‘perfect information’.

Table 3 provides several generic complexity factors and Table 4 indicates where the exercise scenarios provide a correlation.

Complexity Factor	Description	Correlation with Exercise Scenarios
Airspace Design - Conflict point juxtaposed close to sector boundary	A conflict point that is juxtaposed close to a sector boundary Inside or just beyond) Including merging of traffic flows at the conflict point	Exercise Scenario 5
Airspace Design - Restricted Airspace	Military and other airspace areas that are established and require different routes through a sector than the standard or nominal routes	Exercise Scenario 3
Airspace Design - Interaction between standard flows	Interaction between flows of traffic within standard route structure e.g. inbound and outbound flows, merging points, crossing points	Exercise Scenarios 1, 2, 3, 6, 8
Goal Conflicts	Specific goals defined for traffic that are to be achieved e.g. before transfer of control a transfer level for which the achievement of can be influenced by other goals for traffic	Exercise Scenario 1, 3, 6, 7, 8, 9
Conflict Detection - Free Route/Direct route related Uncertainty	ATCO strategies that manage uncertainty around the exit point of a sector	Exercise Scenario 1
Conflict Detection - Multiplicity of tracks that cross boundaries of adjacent sectors	Instantaneous increase of controller workload and cognitive complexity generated by uncertainty and coordination demands.	Exercise Scenario 4, 10
Letters of Agreement - Achieving LOA conditions in complex traffic situations	Resolving and achieving conflict free transfer to adjacent ATSUs where LOAs are in place and the coordination conditions cannot be met	Exercise Scenario 9, 10
Non-Standard Flights	The presence and management of non-standard flights within a sector e.g. Radar and NAVAID calibration flights, non-deviating status military flights	Not included
Managing Aircraft's vertical flight paths	Vertical Flight path management of aircraft to achieve optimal opportunities for aircraft, e.g. continuous climb or descent. May involve changes to coordination sequences or LOA level allocation. Tactical strategies to manage flows of traffic inbound to airfields can involve interventions in flight path management	Exercise Scenario 7, 8,9, 10
Managing traffic flows into and outbound airfields	Flights arriving and departing airfield served by the particular sector involve managing at both the individual as well as the level of traffic flows. The activity can involve merging of traffic flows into one traffic flow as,	Exercise Scenario 7, 8, 9 & 10

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	sequencing flows of traffic to achieve a defined spacing before transfer	
Workload transition	The tempo of sector operations can change rapidly in both nominal as well as non-nominal system states. This change of tempo places pressure on the ATCO through time pressure as well cognitive complexity. Strategies to manage such situations may lead to sector reconfigurations if resources are available	Exercise Scenario 4, 10, 2
Workload at or above sector capacity	Traffic Management can lead to traffic volumes at or above planned levels. A range of strategies are used to manage such instances. Buffers in available capacity can absorb some of the instantaneous peaks, leaving the operation brittle. There is the risk of traffic levels exceeding capacity.	Exercise Scenario 4
Meteorological conditions	Sector operations are subject o the panoply of meteorological conditions. Specific meteorological conditions are subject to Significant Weather Warnings e.g. Moderate and Severe turbulence, Cumulonimbus activity, wind-shear, that require ATCOs to take appropriate consideration of. Some meteorological conditions can disrupt sector operations significantly or require a need for managing traffic flows differently e.g. Low visibility procedures. Consequently, these conditions can influence cognitive complexity	Exercise Scenario 10,12

Table 3: Correlation between complexity and exercise scenarios

However, what constitutes context is dependent and specific to the unique operational environment of Malmö ACC. Therefore, these generic complexity factors need to be enhanced with those factors unique to Malmö ACC.

Complexity Factor	Description	Exercise scenarios
Departures from ESGG Southbound via NORBY e.g. ESGG-LDSP	Departures conflict at the Division Flight Level	7, 8, 10
Arrivals into ESGG from the south for runway 21	Different descent profiles for each runway in use introduces different patterns of interactions and conflicts	7, 8, 10
Merging of traffic flows inbound to EKCH	The merge point for EKCH, to the South-West of the sector a includes a flow that navigates along the western sector boundary that interacts with other flows with adjacent sectors	7, 8, 10
Managing and Sequencing of traffic flows inbound ESSA via NILUG	ESSM23 serves a number of traffic flows inbound to ESSA	5, 7, 8, 9, 10

Managing traffic flows inbound ESSA and ESSB	ESSM23 is required to manage two intersecting flight paths for the Stockholm TMA - ESSA and ESSB. These have different exit flight levels, but the sector needs to manage these traffic flows to achieve the required exit goal state.	5, 7, 8, 9, 10
Managing Inbound and Outbound flows of traffic to ESMS	ESSM23 manages traffic flows from and to ESMS.	5, 7, 8, 9, 10

Table 4: Correlation of complexity factors with exercise scenarios

4 Description of Validation Scenarios

The validation design concept is described in the ERP (AWARE D2.2, 2024), which is important for the validation scenario design.

The traffic samples represent typical traffic flows for the time of day and are representative of what Swedish ATCOs would expect. Fluctuations in traffic volumes would therefore fit in with this, as these fluctuations are a facet of the diurnal fluctuations in traffic volumes over the course of a day. The traffic of sector ESMM23 FL290 and above from 04.08.2024 is used for all four validation scenarios plus the training. This specific day was selected as the basis for deriving the scenarios because it is representative of typical traffic flows within ESMM23 and thereby provides a foundation for adding nuance to the traffic sample to enhance the validation traffic scenarios and support the specific research goals and maintain fidelity to sector operations. The max capacity of sector ESMM23 is 40 aircraft per hour with a max occupancy of 17 aircraft on frequency at the same time.

NEST data was utilised to generate comprehensive traffic samples, which were subsequently implemented in the Orion Creator software ([Simulator & Training Systems - Orion Suite | Tern Systems]). To ensure route accuracy, Flightradar24 was used to identify and define appropriate flight paths. While the NEST dataset included full flight trajectories, a subset of flights was carefully selected and adapted to align with the specific operational and research requirements of the validation scenarios.

Figure 3 shows a screenshot of the Orion Creator software, which was used to design the validation scenarios. It includes the sector ESMM23 with two restricted areas (1 and 2).

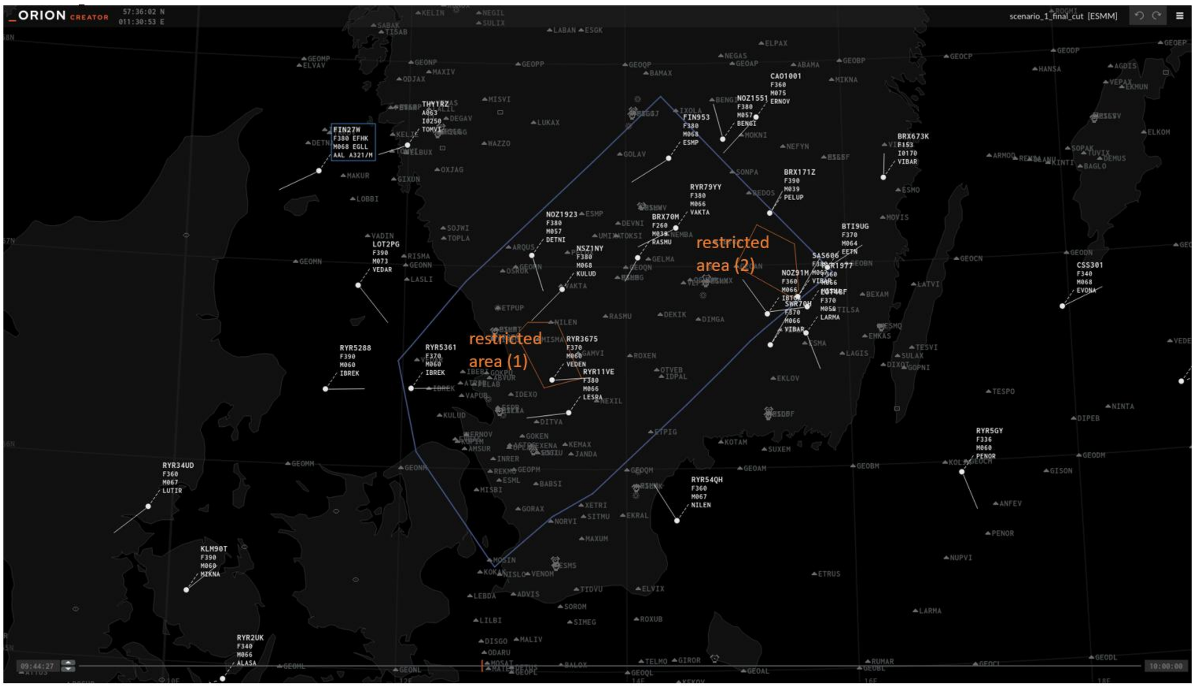

Figure 3: Swedish airspace in Orion

Figure 4 illustrates the diurnal distribution of traffic occupancy for the selected day (04.08.25). This day was a Sunday and therefore a weekend sample. Additionally, time windows for the training and all four scenarios are highlighted. From this 2-3h time window, a final validation duration of 20-25 minutes is used to reduce traffic variability between different ATCOs.

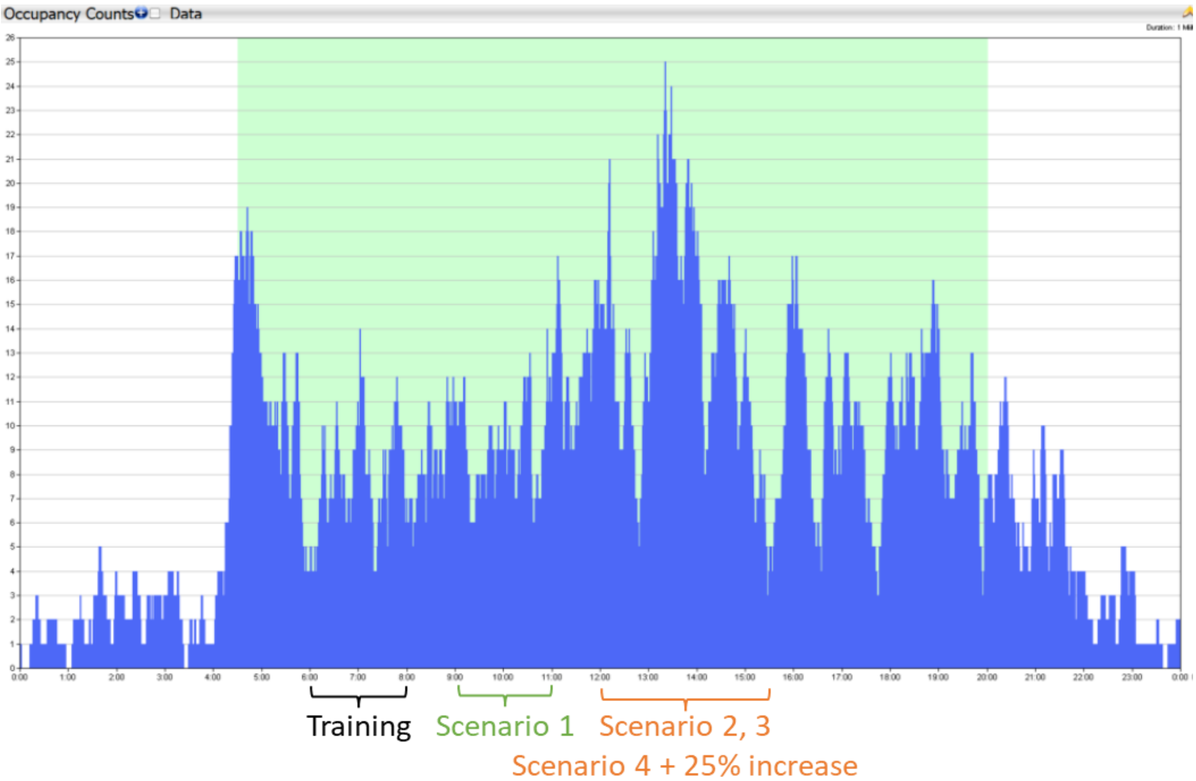

Figure 4: ESMM23 Occupancy on 04.08.2024

The characteristics of the validation scenarios are presented in Table 5, mapped with ASA modes of operation. The level of ASA support depends on the group the ATCOs' were assigned to.

Table 6 provides an overview of key traffic events, airspace restrictions, and conflict situations across training and four validation scenarios. The time of conflict mentioned in Table 6 is measured at the minimum distance between the aircraft. Each scenario includes:

- Airspace configuration: Whether restricted areas are active or inactive during the scenario.
- Conflict events: Specific times and flight levels where aircraft conflicts (entry, exit, or potential) occur, requiring ATCO intervention.
- Pilot & adjacent sector requests: Requests from pilots or adjacent sectors (e.g. FL change) that may introduce conflicts.
- Non-conformance events: Situations where aircraft deviate from expected behaviour, such as flight level busts or speed violations, to challenge ATCO monitoring and resolution strategies.

Scenario	Traffic level	Complexity	Time	Duration [min]	ASA Support	
					Assisted	Autonomous task execution
Training	Medium	Medium	06:40 - 07:40	60	No	No
Scenario 1	Medium	Medium	09:35 - 10:00	25	No	No
Scenario 2	High	High	12:02 - 12:22	20	For some groups not all[4]	For some groups not all[4]
Scenario 3	High	High	13:18 - 13:38	20	For some groups not all[4]	For some groups not all[4]
Scenario 4	High + 25% (futuristic)	> High	14:20 - 14:40	20	For some groups not all	For some groups not all

Table 5: Structural properties of the validation scenarios

[4] The level of ASA support depends on the group the ATCOs' were assigned to.

Scenario	Restricted area	Conflicts	Pilot Requests	Adjacent Sector Requests	Non-Conformance
Training	• 06:40: activate restricted area (1) until 06:55 • 06:50 activate restricted area (2) until end of scenario	• FL370: 06:50, WZZ19XS & RYR2482 • FL390: 07:00, FIN8CX & SAS95T • FL360: 07:06, SAS2677 & NOZ1051 • FL340: 07:28, THY82L & AFR55SU	• 06:46, SAS2645 request FL380 due to turbulence • 06:49, EWG7KM request M0.78	07:06, next sector requests LOT4EB at FL380	NA
Scenario 1	• Activate restricted area (1) whole time • Restricted area (2) deactivated whole time	• FL380: 09:39, BRX171Z & NOZ1551 & LOT48F (potential depends on ATCO input for BRX171Z FL change) • FL370: 09:42, LOT48F & BTI9UG (exit conflict) • FL380: 09:41, RYR79YY & NOZ1551 (entry conflict) • FL390: 09:50, LOT2PG & RYR5288 • FL380: 09:53, RYR11VE & NSZ1NY (exit conflict) • FL360: 09:57, RYR1977 & CAO1001 (potential conflict)	RYR11VE to FL400	09:49, RYR79YY request FL400 due to turbulence	NA
Scenario 2	Nothing active	• FL360: 12:07, RYR284V & NOZ87XV • FL380: 12:08, KLM60A & NOZ8UD & CAO1007 (exit conflict) • FL360: 12:13, SAS2903 & NOZ87XV • FL340: 12:18, GPX5HA & NBT092 & CKK205	WZZ78ZL requesting FL360 during initial call à conflict with SAS2903	12:12, next sector requests NOZ1871 direct to LUNIP	GPX5HA has MA077 is faster than NBT092: ATCO should solve this and pseudo pilot does not adhere.
Scenario 3	Activate both restricted areas (1) & (2) whole time	• FL360: 13:23, AFR55SU & RYR3AP (entry conflict) • FL360: 13:30, RYR3AP & SAS1811 (exit conflict) • FL370: 13:37, RYR37VN & SAS2648	13:30: THY9 requesting FL320 (currently FL300) à conflict with NSZ578R	• 13:20, next sector request DLH8CR at FL330 • 13:32, next sector requests	13:23: FL Bust: NSZ534R gets the FL340 in initial call. Then NSZ534R & NSZ578R (both on FL320) climb to FL340, but

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				SAS2112 direct to NILUG	NSZ578R was not cleared to FL340.
Scenario 4	• Activate restricted area (1) • Deactivate restricted area (2) whole time	• FL380: 14:25, THY69W & SAS1809 • FL340: 14:25, FIN7WK & CCA937 (entry conflict) • FL340: 14:26, WZZ7063 & CES709 • FL380: 14:32, VKG1587 & FIN3EF • FL380: 14:37, FIN82Y & DLH6DP (exit conflict)	QTR50U request FL380 during initial call	• 14:32, next sector requests EWG1AR direct to NILUG • 14:34, next sector request SAS1803 5° to the right	14:35: Speed bust: FIN4AY is too fast, gets a request to decrease speed but does not adhere to it (impacting FIN83Y)

Table 6: Validation scenario description

Table 7 describes the occupancy rate for each scenario every 5 minutes. Only aircraft within the sector are counted. Aircraft on the sector border and 15NM away from the border are counted as well since they should already be on the frequency.

	Start	+5 min	+10 min	+15 min	+20 min	+25 min	mean	SD
Scenario 1	7	10	13	14	9	7	10.0	3.0
Scenario 2	12	16	17	9	8	NA	12.4	4.0
Scenario 3	11	13	18	15	14	NA	14.2	2.6
Scenario 4	10	16	20	19	13	NA	15.6	4.2

Table 7: Occupancy every 5 minutes

Table 8 describes the proportion of climbing & descending flights in respect to the total amount of flights. Additionally, it shows the proportion of how many flights could get a direct-to and therefore, improve the QoS.

	Total amount of flights	Climbing & descending [%]	QoS [%]
Scenario 1	23	21.74	26.1
Scenario 2	31	16.7	43.3
Scenario 3	30	17.2	24.1
Scenario 4	28	20.7	20.7

Table 8: Proportion of climbing, descending flights and flights for QoS

Table 9 describes how many aircraft would fly through an activated restricted area when the trajectory is not adapted.

	# aircraft in restricted area (1) [-]	# aircraft in restricted area (2) [-]
Scenario 1	9	NA
Scenario 2	NA	NA
Scenario 3	5	2
Scenario 4	11	5

Table 9: Number of aircraft in restricted area

More details about the exact flights in each scenario (incl. departure, route, destination, aircraft type, speed, cleared FL and departure time) can be found in Appendix 5.1.

5 Appendices

5.1 Exercise Scenario Descriptions

The body of knowledge that these specific exercise scenarios have been drawn from, stems from previous research exploring the resilient performance of ACC sectors in Barcelona, Madrid and Malmö ACC's (FARO, 2015). The sections below describe exercise scenarios, which will be used as a basis for the creation of the validation scenarios.

Exercise Scenario 1

This scenario involves managing workload around conflict detection tasks.

ATCOs manage their workload so as to create a margin for the increased uncertainty where direct routes, outside FRA, as a pilot request or for a change in RFL or some change from the nominal path

Tactical strategies employed:

- Delay in response to pilot's requests,
- increased use of tactical radar headings to provide certainty in tactical situations,
- Increased use of vertical separation to resolve conflicts (as opposed to lateral solutions)

Exercise Scenario 2

Scenario specifically associated with conflict detection and resolution at a single crossing point where there are a multiplicity of intersecting and interacting trajectories (tracks).

In some cases, interactions may involve aircraft tracks at the same level.

Strategies: Use radar headings, or direct routes to create 'margins' around conflict points which alter conflict geometries.

Strategy to reduce the number of interactions at a particular area/fix/crossing point by reducing the potential for interactions between the flow of traffic in the specific area. The aim is to spread out the interactions avoiding convergence at exit points.

Exercise Scenario 3

Managing a multiplicity of different points at which tracks cross the boundaries of adjacent sectors of ACCs. Potential reasons for this include airspace utilisation in adjacent centres e.g., military reserved airspace, CB activity downstream, ad hoc, cross boundary direct routes outside LOA entry and exit points. The effect is an increase in instantaneous workload as a result of the increased uncertainty around the coordination of the aircraft with the next ACC/sector.

Strategies:

- Increased communication with pilot to clarify the route the aircraft have been cleared to,

- use of tactical radar headings to manage the uncertainty of both route and coordination status of the ac,
- last minute coordination close to the boundary, changes of the next sector in the coordination sequence.

Exercise Scenario 4

A Scenario where ATCOs deal with traffic levels at or above declared sector capacity or monitor value. Traffic management measures are used for managing demand versus capacity.

Strategies:

- The ATCO will intervene more, sector split/reconfiguring the airspace, ATFCM regulations, or tactical measures such as managing vertical profiles, rerouting and changing of entry and exit conditions into and out the sector.
- The strategy is to optimise sector capacity and sustain operations by creating contingencies (buffers) within the system

Exercise Scenario 5

Scenarios where the ATCO is managing traffic flows that interact at or close to a sector boundary. Potentially managing traffic flows inbound and outbound from a major airfield, or diurnal traffic flows e.g. first rotation or subsequent rotation flows. Or Variability in terms of different patterns as a function of CDRs.

These patterns can be different conflict geometries as well as in the vertical plane

- Same direction
- Opposite direction
- Crossing/tracks

Exercise Scenario 6

The uncertainty around aircraft entering the sector and its associated entry point at the boundary with adjacent ACCs on transfer to the sector. Scenario to address the limitation of the Ground-based system (i.e. flight data processing, radar data processing) to support flexible route across ACC sector boundaries. Controllers predict a fix that the aircraft may route to, which provides an initial routing into the sector which is then updated once the aircraft comes on frequency.

Strategies used by sector team:

- to build a picture of the route of the aircraft about to enter the sector.
- Change to routings or headings once the aircraft has established 2-way communication with the receiving sector, change of heading

Exercise Scenario 7

ATCOs managing vertical flight-path management ATCOs delay descending traffic by not following level restrictions, leaving aircraft to continuous descent or left at cruising level for longer thus more efficient flight path management. This is a function of stratified vertical sectorisation and descending traffic earlier (i.e. before an FMS TOD point) to position the aircraft into a lower sector and thus deconflicting flows of traffic

Exercise Scenario 8

One facet of the en-route controllers' function is that of managing traffic streams inbound to specific airports. The nature of this function can be complicated where managing the arrival flow involves merging flows from different entry points to exit and transfer through a common fix.

In some circumstances, this task may involve spacing traffic flows into an ordered stream of traffic where the spacing is maintained using speed control. Strategies to achieve this may involve management of aircraft speed using speed control.

Exercise Scenario 9

In the typical work of ATCOs controlling traffic, create strategies to manage aircraft to achieve a number of goals and goals states. For example, achieving the Exit Flight Level (XFL) or coordinated out Flight Level, speed, heading or navigation fix.

The strategies that are derived involve a prediction of the future state of the aircraft. These predictions that ground the strategies are neither trivial, simple or deterministic. These strategies can include elements of tactical strategies that involve satisfying multiple goals and situations involving interactions between aircraft under the executive control of the sector team, as well as those that are not. Embedded within the strategies will be philosophies of controlling and managing traffic.

Much of the knowledge that is drawn upon is tacit. For example, knowledge of how particular aircraft operators operate 'their aircraft'. This can vary considerably. Tactical strategies will use the predicted future state of aircraft. However, circumstances can change such that 'plan A' may need adapting to the new system state such that new prediction of the future system state leads to changes in the tactical strategies.

For example, a strategy for working with two aircraft inbound to the sector from adjacent ACCs through different entry points that are predicted to conflict can lead to a particular series of interventions to ensure separation. As such interactions are frequent, the custom and practice of adjacent sectors when transferring their traffic may lead to a resolution being instigated as, for example, the transferring sector requests a direct route for the aircraft that removes the need for intervention in the controller's tactical strategy.

This scenario has elements of routine task and workload as well as non-nominal. The tempo of the need for adaptation can lead to a change of prioritisation of the sequencing of tasks and actions.

Exercise Scenario 10

A particular facet of tacit knowledge that is fundamental for an ATCO is knowledge of aircraft performance. The tactical strategies derived at the moment that an ATCO becomes aware of traffic

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offered to the sector or before often leads to the development of a controller's prediction of the aircraft's trajectory through the sector. The context will shape the nuance of this

The future state of the aircraft is in essence 'known' on the basis of numerous repetitions experienced each and every day of an aircraft's performance amidst a panoply of varying meteorological conditions. For example, high temperatures during summer days can lead to a degradation of aircraft climb performance especially for traffic operating long sector lengths as the aircraft weight is high.

Differences in aircraft performance can manifest for a variety of reasons. These differences have consequences as they change the basis for predicting the future state of the aircraft. This may necessitate adapting tactical strategies, which can lead to new separation geometries requiring resolution. This, in turn, can result in changes to exit coordination conditions if the aircraft are unable to achieve the planned outcome.

Exercise Scenario 11

There are numerous sources of variation that can be experienced within en-route ATC operations. One manifestation that is ever present is that of meteorological conditions. The degree that meteorological conditions can lead to the needs to adapt tactical strategies or disrupt sector operations is wide.

For example, where severe turbulence is forecast and experienced, potentially Reduced Vertical Separation (RVSM) may not be able to be sustained, necessitating a reversion to 2000' separation above FL290.

Wind shear is a meteorological phenomenon which impacts aircraft performance in the climb and descent and can lead to variations in speeds that are flown and thus disrupt tactical strategies that involve tactical strategies for sequencing flows of traffic inbound to aerodromes - potentially leading to increased spacing between successive aircraft.

Exercise Scenario 12

This scenario emphasises a number of characteristics of ATCO work - time pressure, uncertainty, partial and incomplete information as well as goal conflicts and changing goals that the sector has to fulfil.

5.2 Flight Routes in Validation Scenarios

This chapter provides more details about the exact flights in each scenario (incl. departure, route, destination, aircraft type, speed, cleared FL and departure time). It only lists the aircraft in the sector ESMM23.

Scenario 1:

Scenario	Callsign	AC Type	DEP	Dep. time	DES	Speed	Planned Level	Route
1	BRX171Z	A320	ESMS	09:11:37	ESSA	M039	F390	GEOQM-PELUP-NILUP
1	BRX70M	A320	ESSA	08:51:30	ESMS	M039	F390	PETEV-ELPAX-RASMU
1	BTI9UG	BCS3	EHAM	08:26:49	EETN	M064	F370	ALASA
1	CAO1001	B744	ZUUU	00:22:17	EHAM	M075	F360	SP-BABAP-TRS-ERNOV-KOPIM
1	DLH3FR	A20N	EDDF	09:00:00	ESSA	M066	F370	GITER-VEDAR-ARS-ELTOK
1	FIN953	E190	EFHK	08:48:00	EKCH	M068	F380	ESMP-ERNOV
1	KLM90T	B738	EHAM	08:58:19	ESSA	M060	F390	DOSUR-MIKNA-NILUG
1	LOT2PG	B789	KLAX	22:17:34	EPWA	M073	F390	VEDAR-ERNOV-GOSOT
1	LOT48F	E195	ENGM	08:55:16	EPWA	M059	F370	OKSAT-GETPA-DETSO-LARMA
1	NOZ1551	B738	LHBP	07:48:25	ENGM	M057	F380	LARMA-SONPA-BENGI-LUNIP
1	NOZ1923	B738	ENGM	09:07:55	LDDU	M057	F380	DETNI
1	NOZ91M	B738	LDSP	07:38:24	ENGM	M066	F360	GORPI-TEMLI-IBTOX-IXOLA-LUNIP
1	NSZ1NY	B38M	ESKN	09:16:25	LEMG	M068	F380	KOXIM-ELPAX-IXOLA-TOKSI-KULUD-ATTUS
1	RYR11VE	B738	EYKA	08:44:22	EGGP	M066	F380	VEDEN-LESRA
1	RYR1977	B738	EVRA	09:01:07	EIDW	M066	F360	MISMA-LESRA
1	RYR3675	B738	EIDW	07:42:27	EYPA	M063	F370	GOREV-IBREK-VEDEN
1	RYR5288	B738	EIDW	07:54:11	EYPA	M060	F390	GOREV-IBREK-VEDEN
1	RYR5361	B738	EIDW	07:49:45	EYPA	M060	F370	GOREV-IBREK-VEDEN
1	RYR54QH	B38M	EPKK	08:43:25	ESGG	M067	F360	NILEN
1	RYR79YY	B738	EFHK	08:43:33	EBCI	M066	F380	LUPET-BEDOS-VAKTA-AMSUR-RAXLU
1	SAS606	A20N	LSZH	08:07:50	ESSA	M067	F380	BAKLI-VIBAR-NILUG
1	SWR70H	BCS3	LSZH	08:08:59	ESSA	M066	F370	BAKLI-VIBAR-NILUG
1	THY1RZ	A321	ESGG	09:40:50	LTFM	M068	F350	TOMVI-ARQUS-MISMA-NORVI-ELVIX-KOLOB

Scenario 2:

Scenario	Callsign	AC Type	DEP	Dep. time	DES	Speed	Planned Level	Route
2	BLX698	B38M	LGSA	08:50:04	ESGG	M069	F350	LUSID-NEXIL-NILEN-ARQUS
2	CAO1007	A332	ESSA	11:35:12	LFPG	M069	F380	PETEV-TIPIX-ELPAX-VEDAR
2	CCA848	A359	EGKK	10:51:26	ZSPD	M074	F370	DOSUR-KOTAM-EVONA
2	CES203	B77W	EGKK	10:34:34	ZSPD	M074	F310	DOSUR-GEONM-NEXIL-GEOBN-GEOCN
2	CKK205	B77L	ZSPD	02:08:16	EHAM	M075	F340	NISIX-ERNOV-KOPIM-ALS
2	DIWAW	BE20	EDDG	11:05:37	EFRO	M037	F280	GEONM
2	DLH3MA	A320	ESGG	11:55:00	EDDM	M065	F380	TOPLA-ERNOV-NIKDA
2	DLH803	A20N	ESSA	11:52:14	EDDF	M066	F360	NOSLI-ABAMA-BEDOS-RASMU-NORVI
2	FIN1CW	E190	LEAL	08:47:37	EFHK	M067	F370	RAXLU-NILEN
2	FIN7Z	E190	EDDL	10:59:46	EFHK	M067	F390	MEGAR-GORAX
2	GPX5HA	A319	BKPR	10:19:45	ENGM	M077	F340	NORVI-NILEN-LAV-LUNIP
2	KLM46M	B738	ESSA	11:59:00	EHAM	M068	F380	PETEV-TOKSI-DOSUR
2	KLM60A	B738	EFHK	11:02:54	EHAM	M068	F380	TOKSI-DOSUR
2	LOT6	B788	EPWA	11:24:00	KJFK	M073	F360	GEOCL-XETRI-VEDAR
2	NBT092	B789	VTBS	01:30:19	ENGM	M075	F340	LUSID-NEXIL-NILEN-LAV-SABAK-XENTA-LUNIP
2	NOZ1871	B738	LIRF	09:51:31	ENGM	M067	F370	KEKOV-ESGK-LUNIP
2	NOZ87XV	B738	LGAV	09:04:22	ENGM	M067	F360	GOSOT-SABAK-LUNIP
2	NOZ8UD	B738	LGSA	08:39:39	ENGM	M068	F380	GOSOT-NILEN-ARQUS-SABAK-LUNIP
2	NSZ3199	B738	ESSA	11:40:55	EKCH	M066	F380	PETEV-IXOLA-RASMU-ERNOV
2	RYR284V	B739	EYPA	11:27:50	EIDW	M066	F360	DITVA-LESRA
2	RYR3FG	B739	LEAL	08:39:42	ESSA	M066	F370	ATTUS-HANSA-NILUG
2	RYR835	B739	ESSA	12:06:40	LIPZ	M067	F380	NOSLI-ABAMA-UNGAV
2	SAS1911	A20N	ESSA	11:25:54	LEMG	M067	F360	PETEV-ELPAX-PELOX
2	SAS2903	A20N	ESSA	11:37:49	LPPT	M067	F360	PETEV-ELPAX-PELOX-KESUR
2	SAS7654	A20N	LGRP	07:54:22	ESGG	M056	F340	POKEN-GEOQM-ARQUS-GIXUN
2	SAS9250	E195	ESSA	11:30:00	EKCH	M069	F370	BENGI-IDEXO-ERNOV
2	SWR98X	BCS3	ESSA	11:34:22	LSZH	M066	F380	LUFAK-KOKAK
2	THA955	A59	ENGM	11:51:49	VTBS	M067	F350	OKSAT-GETPA-NEGIL-ANFEV
2	WZZ3MP	A321	EPWA	11:30:00	ENTO	M067	F340	LARMA-LALIL-REPKU
2	WZZ77ZL	A21N	ENHD	11:30:00	EPGD	M066	F350	KULUD
2	WZZ78ZL	A21N	ENHD	11:30:00	EPGD	M066	F350	LASLI

Scenario 3:

Scenario	Callsign	AC Type	DEP	Dep. time	DES	Speed	Planned Level	Route
3	AFR55SU	BCS3	ESSA	12:44:45	LFPG	M066	F360	PETEV-ELPAX-KESUR
3	AIC157	B788	VIDP	06:13:02	EKCH	M075	F360	DEREX-TOKSI-ERNOV
3	CES554	B77W	LFPG	11:57:05	ZSPD	M074	F310	DOSUR-TOMBU
3	CSC9603	A333	EFHK	12:39:24	EBBR	M068	F350	KOSKA-KOPIM
3	CSN451	B77L	ZSPD	03:35:08	EHAM	M076	F340	LUPET-DEMIR
3	DLH8CR	A321	EDDF	12:07:59	ESSA	M067	F350	GITER-IXOLA-GIMLO-NILUG
3	FEG3016	B738	ENGM	13:06:26	HESH	M067	F310	OKSAT-LATKU-NEGIL-ESGJ-NEMBA-TEMLI-RUMAR
3	FIN7RX	A321	EKCH	13:07:02	EFHK	M068	F390	KEMAX-ROXEN
3	GPX4AH	A319	ESMT	13:15:34	BKPR	M068	F370	VAKTA-KEMAX-ELVIX-POKEN
3	KLM1245	E75L	EHAM	12:11:39	ESSL	M063	F370	DOSUR-VAKTA-MIKNA
3	KLM69H	B739	EHAM	12:16:06	EFHK	M068	F370	DOSUR-GEONM-GOKPU-IBTOX
3	LOT2E	B789	EPWA	12:41:13	KLAX	M073	F320	LARMA-TILSA-NEMBA
3	NSZ2CP	B738	LEMG	10:02:21	ESSA	M068	F390	BAGOS-MOSIN-NEXIL-NEMBA-VIBAR-NILUG
3	NSZ4507	B738	ESSA	12:44:42	EDDB	M067	F380	NOSIL-ABAMA-BIKRU
3	NSZ4927	B738	ESSA	12:48:02	EDDB	M067	F360	NOSIL-ABAMA-BIKRU
3	NSZ534R	A320	ESSA	13:03:19	LPPT	M068	F320	PETEV-ELPAX-ALS
3	NSZ578R	A320	ESSA	12:56:35	LPPT	M068	F320	PETEV-EPLAX-ALS
3	QTR50U	B788	ENGM	13:01:00	OTHH	M066	F310	OKSAT-KELIN-OSRUK-ETPIG-AMROR
3	RYR37VN	B738	ESSA	13:00:55	LIMF	M066	F370	NOSLI-ABAMA-MAKEL
3	RYR3AP	B738	ENTO	12:56:30	EPPO	M067	F360	BIKRU
3	RYR8CV	B738	EPGD	13:08:53	ENTO	M065	F360	PENOR-SABAK-REPKU
3	SAS1811	A320	ESSA	12:48:38	LEBL	M067	F360	NOSLI-ABAMA-MAKEL
3	SAS2112	A320	ESMS	13:12:38	ESSA	M040	F340	JANDA-PELUP-NILUG
3	SAS2648	CRJ9	EDDH	12:57:50	ESSA	M067	F370	MEGAR-LEBDA-MOSIN-KEMAX-ROXEN-MIKNA-PELUP-NILUG
3	SAS4637	A20N	ENGM	12:58:16	LGAV	M068	F390	GEOPL
3	SAS4804	A319	LDSP	11:20:10	ENGM	M067	F380	GOSTO-SABAK-LUNIP
3	SAS6437	A20N	LGRP	10:04:03	ENBR	M068	F360	GOSOT
3	SAS7400	A20N	LGRP	09:59:20	ENBR	M068	F380	GOSOT
3	SAS7416	A20N	LGRP	10:05:42	ENGM	M068	F380	NUPVI-LUNIP
3	THY9	B77W	LTFM	11:03:14	KLAX	M075	F300	AMROR

Scenario 4:

Scenario	Callsign	AC Type	DEP	Dep. time	DES	Speed	Planned Level	Route
4	AFR87HG	BCS3	EFHK	13:40:08	LFPG	M066	F380	NISIX-RAXLU
4	AIC157	B788	VIDP	07:17:39	EKCH	M075	F360	DEREX-TOKSI-ERNOV
4	CCA937	B77W	ZBAA	05:39:37	EGLL	M076	F340	DEREX-GEOAM-BABSI-ALASA
4	CES709	B77W	ZSPD	04:29:35	LEMD	M076	F340	BEDOS
4	CES771	B77W	ZSPD	04:18:24	EHAM	M075	F380	GEOBN-RASMU-IEBI-DEMIR
4	DLH1PL	A20N	ESSA	13:58:01	EDDM	M067	F380	NOSLI-ABAMA-ETPIG-SALLO
4	DLH6DP	A20N	ESSA	13:59:01	EDDM	M067	F380	NOSLI-ABAMA-ETPIG-SALLO
4	EWG1AR	A320	EDDH	13:54:20	ESSA	M065	F350	MEGAR-LEBDA-KEMAX-BEDOS-PELUP-NILUG
4	FIN1PM	A321	EFHK	13:19:49	EKCH	M067	F360	TOKSI-ERNOV
4	FIN3EF	A320	EFHK	13:25:46	LFPG	M067	F380	NISIX-DEMIR
4	FIN4AY	E190	EFHK	13:42:55	EDDL	M074	F380	KOSKA-GIMRU
4	FIN5G	A359	EFHK	13:18:57	EHAM	M074	F410	TOKSI-DOSUR
4	FIN7WK	A320	LFPG	12:55:26	EFHK	M067	F340	GITER-ETPIG-EKLOV-NEBSI
4	FIN82Y	E190	EFHK	13:34:19	EDDL	M068	F380	KOSKA-GIMRU
4	FIN83Y	E190	EFHK	13:36:53	EDDL	M068	F380	KOSKA-GIMRU
4	KLM1246	E75L	ESSL	14:26:28	EHAM	M064	F360	ELPAX-IXOLA-TOKSI-DOSUR
4	PGT44CF	A21N	ENGM	14:05:43	LTFJ	M066	F310	OKSAT-LATKU-NEGIL-KOTAM
4	RYR15XF	B738	ENTO	14:10:12	EPKK	M067	F370	BOMGU-SABAK-TOPLA-POKEN
4	RYR6748	B738	LHBP	12:49:26	ESGG	M056	F320	KOLOB-NILEN-ARQUS
4	SAS1424	A20N	EKCH	14:14:23	ESSA	M067	F330	KERMAX-MOKNI-PELUP-NILUG
4	SAS1571	A20N	ESSA	13:59:30	LEAL	M068	F370	PETEV-ELPAX-PELOX-IBREK-DEMIR
4	SAS1803	A20N	ESSA	13:54:06	LEMG	M067	F390	PETEV-ELPAX-PELOX
4	SAS1809	A20N	ESSA	13:46:59	LEPA	M065	F380	NOSLI-ABAMA-BAGOS
4	SAS410	E195	EKCH	14:10:00	ESSA	M065	F330	KEMAX-ROXEN-BEDOS-MIKNA-NILUG
4	SAS6728	A20N	ESSA	14:00:43	LEAL	M068	F350	PETEV-ELPAX-IXOLA-NILEN-GEONM-DEMIR
4	THY69W	A359	LTFM	11:51:32	KIAD	M074	F380	AMROR-NILEN-ARQUS-SABAK-REPKU
4	VKG1587	A339	LGRP	11:14:12	ENGM	M071	F380	GOSOT-SABAK-LUNIP
4	WZZ7063	A321	ENTO	13:57:14	EPWA	M068	F340	BOMGU-LATKU-NEGIL-LARMA

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5.3 Correlation Matrix

This correlation matrix in Table 10 provides the correlation of validation scenarios with exercise scenarios, mapping them to the AWARE research goals as declared in the AWARE Experimental Research plan. Through this mapping, specific research questions can be aligned with specific validation scenarios and exercises that provide salient operational episodes to explore each of the scientific objects of interest in the research question.

	Traffic Level	Complexity	Ex. Scenario 1	Ex. Scenario 2	Ex. Scenario 3	Ex. Scenario 4	Ex. Scenario 5	Ex. Scenario 6	Ex. Scenario 7	Ex. Scenario 8	Ex. Scenario 9	Ex. Scenario 10	Ex. Scenario 11	Ex. Scenario 12
Training	Medium	Medium	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Validation Scenario 1	Medium	Low - Medium	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1, 2 & 3 STO3: 4	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2 & 3 ST01: 2 &3 ST02:1 & 3
Validation Scenario 2	High	High	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3

Validation Scenario 3	High	High	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3
Validation Scenario 4	High (+25%)	> High	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1,2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3	GO 1, 2 SO1: 1 & 2 SO2: 2&3 ST01: 2 &3 ST02:1, 2 & 3

Table 10: Correlation matrix

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5.4 Extract from the Swedish IAIP

(https://aro.lfv.se/Editorial/View/13884/ES_ENR_6_3-1_en)

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7 List of Acronyms

Acronym	Description
ACC	Area Control Centre
AISA	Artificial Intelligence Situational Awareness
ASA	Artificial Situation Awareness
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CDRs	Coded Departure Route
EKCH	ICAO Location Indicator for Copenhagen
ESGG	ICAO Location Indicator for Goteborg
ESMS	ICAO Location Indicator for Malmo-Stirrup
ESSA	ICAO Location Indicator for Stockholm-Arlanda
ESSB	ICAO Location Indicator for Stockholm-Bromma
ESMM 23	Malmö ACC Sector 2 and 3 combined traffic volume
FL	Flight Level
NM	Nautical Mile
QoS	Quality of Service
QSY	Q Code for Transfer of an aircraft to a new frequency

Table 11: List of acronyms