SESAR Solution PJ.05-W2-97 TS/IRS for TRL4 - Part II Safety Assessment Report

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DIGITAL TOWER TECHNOLOGIES

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Abstract

This is a technical Safety Assessment Report for SESAR Solution PJ.05-W2-97 HMI Interaction modes for Airport Tower covering Solution PJ05-W2-97.1 and Solution PJ05-W2-97.2.

It provides Technical Safety Specification of the solutions addressing the Technical Specification Safety Requirements (TSSRs). These requirements specify the functionalities & performance characteristics derived from the operational uses envisaged for the technological solutions. It also addresses Technical Safety Requirements at Design level (TSRDs) as design characteristics of the technical system which ensure that the system operates as specified and is able to achieve the Design Safety Drivers of the solutions.

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1 Executive Summary

This document contains the technical Safety Assessment Report (SAR) for an application of the PJ.05-W2-97 HMI interaction modes for Airport Tower Technological Solution. The Safety Assessment Report (SAR) represents Part II of the TS/IRS document and presents the assurance that the Safety Requirements for the TRL2-TRL4 phases are complete, correct, and realistic, thereby providing all material to adequately inform the PJ.05-W2-97 Solution TS/IRS Part I.

The report describes safety assessment process applied to the following solutions:

Solution PJ.05-W2-97.1: Virtual Reality (VR) and Augmented Reality (AR) applications for tower that describes various technologies based on virtual and augmented reality incorporated into CWP for tower controller such as tracking labels, air gestures application and attention guidance cues applied to smart screens, or head-on displays.

Solution PJ.05-W2-97.2: ASR at the TWR CWP supported by AI and Machine Learning that describes the ASR application (enhanced by the use of Machine Learning) which enables the recognition and translation of spoken language into the system inputs to automatize certain tasks, which ATCO performs manually in today's systems / CWPs.

This safety report describes safety activities carried out for the following validation exercises:

- EXE-05.97.1-TRL4-TVALP-VAR-001 - A real-time simulation addressing the use of new interaction modes and attention guidance for controllers in the aerodrome control tower of Amsterdam Airport Schiphol.
- EXE-05.97.1-TRL4-TVALP-VAR-002 - A Real Time simulation addressing Virtual/Augmented Reality Tower Tools, Tracking Labels and Air Gesture Interaction at Bologna Airport.
- EXE-05.97.2-TRL4-TVALP-ASR-004 - A Real Time simulation addressing Automatic Speech Recognition at Budapest airport.
- EXE-05.97.1-TRL4-TVALP-VAR-005 - A shadow mode addressing Virtual and augmented reality + Tracking Label and Air Gestures at a Vitoria airport.
- EXE-05.97.2-TRL4-TVALP-ASR-006 - A Real Time Simulation addressing Speech Recognition at Braunschweig simulating multiple remote airport controller working position adapted from existing airports.
- EXE-05.97.2-TRL4-TVALP-ASR-007 - A Real Time simulation addressing Speech Recognition at in Rome simulating Sofia airport.

2 Introduction

The safety assessment is conducted in line with SESAR Safety Reference Material [2] to focusing on Guidance O mainly) and in accordance with [1].

2.1 Background

Both PJ.05-SOL97.1 and PJ.05-SOL97.2 address technologies validated within SESAR2020 PJ.16-04 Wave 1 project. SESAR 2020 Wave 1 PJ.16-04 project investigated new methods of controller interaction with the Human Machine Interface (HMI) at the Controller Working Position (CWP). The solution developed guidance and assessment methods regarding HMI, investigated new HMI needs and interaction modes in relation with SESAR solutions (including new user interface technologies such as speech recognition, multi-touch, and gaze detection). PJ16-04 main focus was En-Route and, Approach environments.

Furthermore, SOL97.1 considers the experience of the SESAR Exploratory Research project RETINA[1]. The RETINA project investigated the potential and applicability of Synthetic Vision (SV) tools and Virtual/Augmented Reality (V/AR) display techniques for the Air Traffic Control (ATC) service provision from the airport control tower. In the two-year project the concept was developed, implemented, and validated through human in the loop simulations where the external view is provided to the user in a semi-immersive virtual environment. The results showed that the RETINA concept provides quantified benefits in terms of mental workload, temporal workload, performance, effort, frustration, information accessibility, and head-down time. Moreover, the concept leads to the removal of some restrictions in low visibility conditions with positive effect on airport capacity and resiliency. Finally, it is contributing to safety improvement as it enhances situational awareness.

SOL97.2 benefits from the experience in a number of projects on Automatic Speech Recognition in ATC. The first assistant based speech recognition system (ABSR) for an ATC approach area has been built in the project AcListant®[2] with laboratory speech data of ATCos and validated for aircraft radar label maintenance task in the project AcListant®-Strips. However, the development of this first ABSR system based on expert knowledge and adapting it to different environments manually would have been costly. Thus, the idea of the following SESAR Exploratory Research project MALORCA[3] for other ATC approach areas with ops room data from ATCos was to automatically learn the needed models, i.e., acoustic model, language model, command prediction model, etc. MALORCA project focused on the Automatic Speech Recognition, with the aim to significantly reduce controller's workload and increase ATM efficiency. The results demonstrated a command recognition rates between 90% and 95 between 90% and 95% (error rate between 2% and 5%) with assistant-based speech recognition (i.e. an AMAN dynamically generates context information to increase the recognition rate). Without context generation the recognition rate was only between 50% and 80%. Besides, the speech recognition was deemed as the more reliable input sensor, at least in the simulation setup.

[1] See also homepage http://www.retina-atm.eu/
[2] See also homepage https://www.malorca-project.de/wp/?page_id=348
[3] See also homepage https://www.malorca-project.de/wp/

The following, currently running, SESAR2020 Exploratory Research project HAAWAII[4] focusses also on the en-route area and additionally considers pilot utterances. HAAWAII aims to develop machine learning based applications for readback error detection and ATCo workload estimation. The German national funded ASR project STARFiSH concentrates on recognition of ATCo utterances on ground (not tower) and considers a specific airport layout. The currently running SESAR2020 Industrial Research project PJ.10-96-ASR aims to develop an ABSR system for an ATC approach area on TRL6. In the finished PJ.16-04-ASR project a command prediction module for the (multiple remote) tower domain has been developed. It must be clarified that EXE-240 performed in the frame of 16.04.02, only addressed the command prediction possibility in the tower environment without implementing a speech recognizer for the tower environment, while the task to validate if command prediction also improves recognition quality in the tower environment was recommended for Wave 2. During all those ASR projects an initial ontology for the annotation of ATC commands has been defined, later coordinated and agreed between major European ATM stakeholders and is still further enhanced.

Thus, there is no existing integrated ASR system based on machine learning for the tower environment. SOL97.2 benefits from experience with machine learning of models, displaying of ASR output and manipulation options for the ATCo, the defined ontology, and measurements of ASR and human performance in environments different from tower. These basics will be used to develop an ML-based ASR system for tower on TRL4.

The starting maturity level of SOL97 is TRL2 and it targets to reach TRL4 maturity at the end of Wave 2 activities.

Considering the previous development, solution PJ05-W2-97 starting maturity level is considered TRL 2. The targeted level is TRL 4 maturity at the end of Wave 2 activities.

2.2 General Approach to Safety Assessment

This safety assessment is conducted as per the SESAR Safety Reference Material (SRM) which allows the derivation of:

- Technical Specification Safety Requirements (TSSR) specifying the functionality of the technological system for the intended uses (the WHAT) – in terms of equipment, performance and integrity/reliability
- Technical Safety Requirement at Design level (TSRD) defining the design of the technological system (the HOW) in order to meet the TSSRs

Considering the safety impact of the solutions PJ05-W2-97 ‘HMI Interaction modes for Airport Tower, including 05-97.1 and 05-97.2, are considered as technological solutions.

The application of the technological solution safety strategy is motivated by the fact that the PJ.05-W2-97.1 and PJ.05-W2-97.2 solutions are exclusively concerning the system components offering new interaction modes with existing technologies, proving the same information to air traffic controllers.

The application of the technological solution safety strategy is motivated by the fact that the PJ.05-W2-97.1 and PJ.05-W2-97.2 sub-solutions are exclusively concerning the system components offering

[4] See also homepage https://www.haawaii.de/wp/

new interaction modes with existing technologies, proving the same information to air traffic controllers.

2.3 Scope of the Safety Assessment

The scope of technological safety assessment is equivalent to the scope of the PJ05-W2-97.1 and PJ05-W2-97.2 solution: therefore, it covers the operational environment conditions, OI steps/Enablers, Use Cases and Scenarios (in the Solution scope as per the TS/IRS) which will be covered by solution validation exercises.

Both solutions aim to achieve the TRL4 maturity. Following SESAR Safety Reference Materials, the safety assessment will deliver safe initial design (mainly by defining functionality, performance and integrity/reliability Technical Safety Requirements at initial design level (iTSRD) that will be documented as appropriate in the TS/IRS Part I).

Since the properties of the context in which the Technological Solution is to be used is crucial to the safety assessment, this assessment cannot be considered as generic but specific to the context of use defined in section 3.2 and consequently, the term ‘specimen’ safety assessment will be used.

2.4 Layout of the Document

This safety report consists of the following sections

- Section 1 - presenting the Executive summary.
- Section 2 - presenting the Scope and approach to safety assessment from safety perspective.
- Section 3 - describing the. Scene of the Safety Assessment
- Section 4 - describing the Technical Safety Specifications
- Section 5 - describing Safe Design of the Technical System.
- Section 6 - demonstration of achievability of the Technical System Safety Specification
- Section 7 - presenting Acronyms
- Section 8 - presenting References and applicable documents

3 Setting the Scene of the Safety Assessment

3.1 Concept overview and scope of the change

3.1.1 PJ.05-W2-97.1: Virtual Reality (VR) and Augmented Reality (AR) applications for tower

PJ.05-W2-97.1 - Virtual and augmented reality applications for tower describes various technologies based on virtual and augmented reality incorporated into CWP for tower controller such as tracking labels, air gestures technologies and attention guidance cues applied to smart screens, or head-on displays. The aim of the applications is to support tower ATCOs to conduct safe operations under any meteorological conditions while maintaining a high taxiway and runway throughput.

Virtual/Augmented Reality in ATC Tower environment supports the ATCO by blending real world images with computer-generated data in real-time, so that visual information can be enhanced to improve identification and tracking of aircraft (or vehicles) on the airport surface (tracking labels, additional airport layers, weather information) auxiliary information is merged with the out of the window view.

Virtual and Augmented reality devices do not change as such the ATCO's task neither task allocation between Human and HMI, however are expected to support monitoring task of CWP HMI by the provision of information superimposed by the V/A-R interface onto the real out of the window view.

Output devices (CWP-HMI) are expected to be complemented: V/A-R head-up interface will provide information currently only available in the head down devices CWP-HMI e.g. tracking labels, wind conditions. V/A-R is expected to also provide airport overlays to support LVC operations and provide controllers with synthetic view support to conduct air traffic control with equivalent-to-good visibility conditions (e.g. airport layout, vehicles and aircraft movements).

Air gesture recognition technology in V/AR in tower environment enables the user to interact with tracking labels when performing not time critical tasks. Air gesture recognition is expected to partially replace physical interactions with CWP to navigate in the head-up interface displayed information and to provide GND controller clearances of push-back and start-up. Input devices (mouse, keyboard/digital pen) are expected to be complemented: air gesture to interact with A/V-R head-up interface will support controllers in the navigation of visualization interface and in the provision of GND clearances of start-up and push-back.

Attention control cues incorporated in V/AR in tower environment enables to guide and monitor controller's attention to priority/critical tasks. Attention guidance is expected to reduce the visual scan of head-down CWP HMI by providing head-up alert and indications of ATC critical situations and auditory cues. No significant changes are expected in terms of allocation of tasks (human & System) even if Attention guidance to ATC critical situation is expected to reduce ATCO CWP-HMI scan in head-down.

Also here, output devices (CWP-HMI) are expected to be complemented: V/A R Attention Guidance head-up interface will provide alerts and safety warnings currently only available in the head down devices CWP-HMI. Attention guidance will also track and monitor controller's attention to guide the gaze to the ATC safety critical situation when controller is looking elsewhere.

3.1.2 PJ.05-W2-97.2: ASR at the TWR CWP supported by AI and Machine Learning

An Automatic Speech Recognition (ASR) system gets an audio signal from the controller working position (CWP) as input and transforms it into a sequence of words, i.e. “speech-to-text” following the recognition process. The sequence of words is transcribed into a sequence of air traffic control (ATC) concepts (“text-to-concepts”). For example, the word sequence “bonjour Air France two four eight six line up and wait runway two seven left” is transformed into “AFR2486 LINEUP RW27L”.

The ASR system may benefit from surveillance data, flight plans, meteorological data, routing information etc. - a so called **Assistant Based Speech Recognition (ABSR) system**. The ABSR derives command hypotheses from the contextual knowledge to support the speech recognition engine in choosing the right recognition hypotheses. This increases the command recognition rate and minimizes the command recognition error rate.

The **Artificial Intelligence/Machine Learning (AI/ML) applied to ASR function**, supports the “Command Hypotheses Predictor” that periodically receives contextual information updates such as surveillance data, flight plan data, route information, clearance information, weather information etc. This information is used to predict possible future controller commands based on a machine learned command prediction model on historic surveillance and speech data.

The ASR function consists of the following **major capabilities**:

- **Word Sequence Extraction** - The recorded verbal utterance from the controller pilot communication is an input into the automatic speech recognition engine, which outputs a list of recognized words (transcription).

- **Concept Extraction** – The above-described extracted word sequence is the input for the extraction of concepts, i.e. the extraction of ATC commands following the defined ontology (annotation).

- **Post Evaluation** - The extracted controller commands constitute a hypothesis, which needs to be checked against any relevant contextual information. Hence, there should be a check against the currently predicted controller command hypotheses and against mouse or keyboards inputs if available. The finally checked controller commands, i.e. the most reasonable hypotheses due to the ABSR functionality chain, can then be used for further ASR applications such as presenting the recognized commands on a human machine interface (HMI).

Additional Capability, belonging to a specific technical implementation:

- **Command Prediction** - The “Command Hypotheses Predictor” periodically receives contextual information updates such as surveillance data, flight plan data, route information, clearance information, weather information etc. This information is used to predict possible future controller commands based on a machine learned command prediction model on historic surveillance and speech data.

ASR support will automatically highlight flights that have been contacted and automatically recognize clearances issued by the ATCO via R/T communications to the flight under control. The manual input of the clearance by mouse/digital pen/keyboard will be replaced by the automation support of the ASR

technology and thus the physical action will be replaced by controlling and monitoring tasks and correction actions in case of need.

ASR tool will change input and output of ATCO devices: Automatic recognition of clearance will be displayed in the HMI and Automatic highlight of flight to be informed/cleared in the HMI will be provided. Voice communication instead of hardware (mouse/keyboard/digital pen) will be main change in terms of input device.

3.2 Stakeholders' expected benefits with potential Safety impact

The improvements will impact ATCos directly (workload, situational awareness) and consequently ANSPs expect to improve safety, ATCO's productivity (CEF2; cost-effectiveness) and resilience by using these enablers.

ANSPs are interested in exploiting the full capabilities of new interaction modes in specific operational cases for runway and ground controllers.

3.2.1 Virtual/Augmented reality

The Virtual/Augmented Reality in tower environment aims at supporting tower ATCOs to conduct safe operations under any meteorological conditions. By means of this solution, the controllers will no longer be limited by what the human eye can physically see out of the tower windows. This is expected to lead to an increased ATCO situational awareness, reduction of workload and a reduction in reaction times leading to increase of controller's productivity.

Virtual and augmented reality along with tracking labels and air gestures by presenting **digital data and overlays superimposed onto the out of the tower view** give the controller the possibility of an increased head-up time of the airport traffic. Therefore, V/AR is expected to decrease cognitive workload as the expected decrease in head-down time reduces the cognitive load needed to switch from head-down 2D visualization to head-up perspective view and by that to reduce controllers' workload, increase situational awareness and improve task efficiency and safety.

V/AR is also expected to provide ATCos with information regarding the status of the aircraft and aerodrome obstacles in **low visibility conditions**. This will generate that, in some airports, LVC procedures can remove some restrictions currently in place, minimizing the capacity loss in LVC. The updated information provided by V/AR will improve situational awareness in LVC producing an improvement in the resilience and safety of airports.

Furthermore, even in good visibility conditions, some of the limitations regarding the display of information (e.g. planning times and warnings) that might be missed due to increased focus on the outside view, can be mitigated. A more **intuitive display of safety nets and attention guidance** supporting ATCOs in spotting critical situations quickly is expected to decrease human error and workload and increase situational awareness as the access to information will be easier and less effort from controller will be required to process it, therefore improve human performance and safety.

3.2.2 Automatic Speech Recognition

Automatic speech recognition (ASR) supported with AI/ML techniques, which enables the recognition and translation of spoken language into the system reducing their workload and improving safety.

Automatic speech recognition (ASR) supported with AI/ML techniques in the tower environment enables the recognition and translation of spoken language (both from controllers' and pilots' utterances) into the system leading to the reduction of controllers' workload and increase of situational awareness. This is expected to have a positive impact on controller's productivity (cost efficiency), human performance and safety.

Automatic Speech Recognition is expected to reduce controller's workload with the automatic update of the clearances in the HMI, but also to decrease head-down time and therefore increase situational awareness. The recognition and highlighting of the callsign on the Visual Panorama from pilot's utterance also contribute to the increased situational awareness. At the same time, it is expected that the human error would also be reduced if the system recognizes well that the ATCO made a mistake with the callsign (and even notifies the user).

3.3 Intended Operational use of the Technological Concept

3.3.1 Intended use identified from SESAR Operational Solutions

3.3.1.1 Virtual/Augmented reality

Currently, there is no SESAR operational solution for which the Virtual/Augmented Reality technology, as covered by the PJ05-97.1 Technological solution, is an enabler. Therefore, its intended use within SESAR is limited to the use cases identified in the scope of the solution:

Name	Description
UC-97-TRL4-TS-101	Guiding ATCO's attention via perceptual cues in case of potentially critical ATC situation *In case of a potentially critical ATC situation, the ATCO's attention will be raised via visual and optionally also via auditory cues on the augmented reality interface.*
UC-97-TRL4-TS-102	Guiding ATCO's attention via perceptual cues in case of potentially missed command actions *Several situations are possible:* *a) In case the ATCO acknowledges an attention cue but then disregards the area of attention and the situation persists, new cues will appear on the interface to raise the controller's attention to a higher level.* *b) The same will occur when the controller acknowledges the attention cue, keeps focussing on the area of attention and the seriousness (depending e.g. on different alerting levels for a conflict) of the situation increases.* *c) The same will also occur when the controller does not acknowledge the cue within a given time period.*

Name	Description
UC-97-TRL4-TS-103	Retrieve of information by means of V/AR *Use V/AR (including tracking labels) to retrieve all relevant positioning, identification, flight status, weather information needed for the specific RWY and GND tasks in the specific condition.*
UC-97-TRL4-TS-104	Tracking labels in Augmented Reality for landing/departing aircrafts *Use tracking labels in AR device so that a clear distinction between different aircraft lined up for landing can be made*
UC-97-TRL4-TS-105	Tracking labels for conflict detection alerts *Use tracking labels inside an AR device to present safety warnings such as conflict detection alerts, runway incursions, and conflicting clearances that give a clear indication to the controller that a situation requires some attention while looking outside in a mainly head-up situation.* *In case of a critical ATC situation, the ATCO's attention will be more easily associated with the concerned aircraft via visually associated call sign data tagging.*
UC-97-TRL4-TS-106	Clearance issue by means of Air Gestures *Use tracking labels air gesture interaction to issue clearances for not-time-critical tasks (start-up, push-back)*

Table 1 Virtual/Augmented Reality Use Cases

More information on each of the above listed Use Cases can be found in the section 3.1.1.1.2 of the TS/IRS document Part I.

3.3.1.2 Automatic Speech Recognition

Besides its application in the Tower environment, the application of the Automatic Speech Recognition in the en-route environment is also addressed within the scope of the SESAR Technological solution PJ10-W2-96. Furthermore, potential usage of the ASR commands to trigger visualisation of sectorisation is envisaged within the operational solution PJ.09-W2-44 'Dynamic Airspace Configuration (DAC). Namely, the ASR would recognize voice commands related to an upcoming sectorization change and flights that would be affected by this change and highlight these changes in the CWP. Further to this, it would support the navigating of the 3D visualization of the air space in the CWP through voice commands recognition.

The main use of the ASR is described in the Use cases identified within the solution PJ05-97.2 listed in the table below (more details on each of the Use Cases can be found in in the section 3.2.1.1.2 of the TS/IRS Part I):

Name	Description
UC-97-TRL4-TS-201	Highlighting of recognized callsign *The ASR recognizes a callsign from the verbal controller pilot communication and highlights it in the controllers' HMI for the relevant time duration. This helps the controller to check further information extracted from the complete utterance displayed in the HMI later on.*
UC-97-TRL4-TS-202	Showing full recognized utterance/command in HMI *The ASR system recognizes the complete utterance/command issued by the controller on the frequency and shows it on the controllers' HMI in a compact format. This includes recognition of the callsign, command types, command values, units, qualifiers and conditions if applicable (e.g., DLH123 PUSHBACK, DLH123 TAXI VIA A B, DLH123 LINEUP RW23R).*
UC-97-TRL4-TS-203	Manual manipulation of an ASR output *If the controller decides that the output of the ASR system is not correct, he/she has to correct the recognized command types and/or the recognized values or even the recognized callsign.*
UC-97-TRL4-TS-204	Automatic Acceptance of ASR output *When a command is recognized by the ASR system, it is then shown to the controller. If the controller does not reject the command within an (adjustable) time frame (e.g. 10 seconds), the recognition result is automatically accepted.*

Table 2 Automatic Speech Recognition Use Cases

3.3.2 Other intended use outside SESAR

- Virtual/Augmented Reality

Nowadays many different industries are readily experimenting with virtual/augmented reality technology in order to streamline their operations, improve safety and efficiency, and train staff in a enhanced manner. In aviation industry,

NASA's Ames Research Center is investigating into the usage of V/AR technologies for uncrewed vehicle air traffic management[5]. Visualizing complex data through augmented reality makes it easier

[5] See also homepage https://www.nasa.gov/feature/ames/augmented-reality-air-traffic-management

for people on the ground to be aware of the operations of the uncrewed vehicles for emergency response, managing air traffic, or local governance.

Virtual reality is already used for the in-flight simulation training for pilots. Not only does it lead to pilot training programs being able to afford more simulators for better training but it also helps train more pilots in less time. AR can be utilised for ground crew training. The application of augmented reality in aircraft maintenance can result in significant benefits in terms of safety. Commercial flight engineers can potentially leverage AR to inspect and maintain their aircraft, while the technology itself offers real-time insights with a combination of other innovative solutions through 3D scanning, sensors and other new developments.

According to Boeing, almost half of all fatal accidents happen during a plane's takeoff or landing. Augmented reality (AR) technology can reduce the risks by enhancing the pilots' ability to access details like terrain, navigation, traffic and weather. AR can also superimpose safety information like emergency checklists on the panels.

- Automatic Speech Recognition

The STARFiSH[6] (Safety and Artificial Intelligence Speech Recognition) project integrates the AI-based speech recognition ABSR into an A-SMGCS monitoring system for ground traffic at Fraport AG. A joint application of ABSR and A-SMGCS recognizes the instructions given by air traffic controllers to pilots, extracts the commands (semantics) contained therein and integrates the results into the user interface of the A-SMGCS. An additional safety net for AI applications is intended to ensure that errors in AI-based speech recognition cannot have any negative effects on the overall system.

The application developed in STARFiSH is prototypically integrated into the simulation environment of Fraport AG. The data for training the AI-based components of the project are also recorded here as part of several simulations and supplemented by recordings from real operation from Frankfurt.

The automatic speech recognition has been also investigated on the airborne side. The Voice Crew Interaction (VOICI)[7] project under Clean Sky 2 has aimed to develop an intelligent "natural crew assistant" in a cockpit environment. The system comprises three main technologies, namely sound recording, speech recognition and artificial intelligence (AI). This includes a cockpit-embedded speech-processing system that understands aviation terminology, as well as an array of low-noise optical microphones and optimised array processing for it. The VOICI system also features a new and more efficient speech synthesis, adapted to aviation terminology and noise levels.

[6] See also homepage https://www.dlr.de/fl/en/desktopdefault.aspx/tabid-1149/1737_read-74905/
[7] See also homepage https://www.sintef.no/projectweb/voici/

4 Technical Safety Specification

The purpose of this section is to document the Technical Specification Safety Requirements for the corresponding Technological Solution.

4.1 Overview of activities performed

This section presents the Technical Specification Safety Requirements (TSSRs) that are derived from the intended use identified in section 3.3.

The Technical Safety Specification are expressed in terms of the data and functionalities provided according to required properties such as: type, scope / applicability, format, interface protocols, accuracy, resolution, latency / refresh rate, integrity, etc. These properties are to be defined by the intended users based on the corresponding operational uses as identified in section 3.3.

Safety assurance activities, presented in this section are in line with PJ05-W2-97 Safety Assessment Plan section 5. The activities were derived from Guidance A.2 and Guidance O of the Safety Reference Material as relevant for TRL4.

This section addresses the following activities:

- Review and analysis of the functional architecture description to ensure completeness of technical system description (based on the NSV-4 models)
- Walkthrough with SMEs using Sequence diagrams based on use cases
- Hazard identification session Walkthrough with SMEs
- The derivation of the Technical Specification Safety Requirements - TSSRs (functionality and performance) in normal and abnormal conditions – section 4.2
- The derivation of the Technical Specification Safety Requirements - TSSRs (integrity/reliability) to address functionality failures – section 4.3
- Process assurance of the Technical Safety Specification – section 4.4

The activities were performed for both solutions PJ.05-W2-97.1: Virtual/Augmented Reality applications for Tower and PJ.05-W2-97.2: ASR at the TWR CWP supported by AI and Machine Learning

4.2 Technical Specification Safety Requirements – TSSR (functionality and performance)

4.2.1 PJ.05-W2-97.1: TSSR from SESAR operational solution intended use and/or relevant standards

The following TSSRs has been retrieved from PJ05-W2-97TS/IRS based on the use cases for normal operations.

ID	Description
	Attention Guidance

TSSR-97.1-01	Attention Guidance system shall analyse the controller's activity in order to monitor his/her attention.
TSSR-97.1-02	Attention Guidance Logic shall determine a relevant event, such as a safety net alert. Radar, flight plan and other relevant external data are available to be used by the Attention Guidance Logic. The Attention Logic Guidance is fed with the level of priority for each potentially critical ATC situation.
TSSR-97.1-03	Attention Guidance system shall determine that a relevant event requires Attention Guidance measures in order to claim the controller's attention.
TSSR-97.1-04	The V/AR device shall present visual and (optionally) also auditory cues to the controller on the augmented reality interface to guide the controller's attention.
Virtual/Augmented reality	
TSSR-97.1-05	The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks.
TSSR-97.1-06	The V/AR system shall identify all active aircraft on the airport, i.e. aircraft that are lined up for landing or take off, aircraft moving over the surface and aircraft on the gate about to depart. For this purpose, the surveillance and flight plan data are taken into account. For instance, the surveillance data provided by the ADS-B surveillance is fed into the system and associated to the aircraft out-the-window images so that this information is correlated.
TSSR-97.1-07	V/AR system displays Tracking Labels in a manner permitting ATCO distinguishing each active aircraft, (using the label antioverlapping feature)
TSSR-97.1-08	The V/AR device shall allow the label to be selected by ATCO, e.g. by means of gazing.
TSSR-97.1-09	In case the label antioverlapping feature is not enabled, and the V/AR device presents labels overlapping, the Air Gestures Detector shall allow the controller to separate manually the labels and distinguish each landing/departing aircraft.
TSSR-97.1-010	The tracking label shall be updated taking into account the new aircraft status. a) Once the aircraft has landed and is on ground, the label changes to the ground mode b) Once the aircraft is airborne, the label changes to the airborne mode c) Description on clearance displayed
TSSR-97.1-011	A tracking label shall be either presented, or an existing one shall be highlighted, in the Augmented Reality overlay to indicate that an alert corresponding to a conflict in the airport (runway incursion, go-around detection) requires ATCO's attention.
Air gesture	
TSSR-97.1-012	An Air Gesture clearance for not-time-critical task (e.g. start-up, push-back) shall be displayed in the tracking label if that clearance is requested or ready to be issued.

TSSR-97.1-013	The V/AR device shall allow the label to be selected by ATCO, e.g. by means of air gesture.
TSSR-97.1-014	The label corresponding to the Air Gesture clearance that is ready to be issued shall be activated in the V/AR display.
TSSR-97.1-015	The system shall detect the clearance issued by the controller by means of Air Gestures interacting with the interface.
TSSR-97.1-016	The change shall be implemented on the tracking label once the clearance issued by Air Gesture is detected.
TSSR-97.1-017	The Controller shall be able to navigate through menus by means of Air Gestures.
TSSR-97.1-018	The Controller shall be able to select a piece of information by means of Air Gestures (e.g. filtering aircraft by distance, selection of a certain callsign, activation of LVP measures, etc.)
TSSR-97.1-019	The controller shall be able to select the menus and information to be provided by V/AR by means of Air Gestures.

Table 3 PJ05-W2-97.1 TSSR for normal conditions

The following abnormal conditions were identified as relevant for PJ05-W2-97.1

	Abnormal condition	**Effect**	**TSSR**
1	Unexpected / unplanned flight in airspace	Unplanned flight might arrive to the airspace and that may induce conflict with other traffic within the same area.	**TSSR-97.1-020** V/AR system shall enable, the detection of unexpected flights in the area of responsibility where ATC service is being provided.
2	Low visibility operations	The low visibility operations are activated in integrated manner for aerodrome. Low visibility operations may have impact on airport capacity	**TSSR-97.1-021** The V/AR system shall allow automatic or manual activation of LVC procedures when low visibility operations are applied at the aerodrome.
			TSSR-97.1-022 In LVC the V/AR device shall present additional operational information to the controller. This information consists of the previously provided information (i.e. when good visibility conditions applied), plus specific information needed when LVC procedures apply, such as the airport layout and runways. This information can be static and optionally a dynamic picture (e.g. runway colour

			changes according to its status, or whether it is occupied by a vehicle, etc.).

Table 4 PJ05-W2-97.1 TSSR for abnormal operations.

4.2.2 PJ.05-W2-97.1: TSSR from other intended use

Not applicable

4.2.3 PJ.05-W2-97.2: TSSR from SESAR operational solution intended use and/or relevant standards

The following TSSRs has been retrieved from PJ05-W2-97.2 TS/IRS based on the use cases for normal operations:

ID	Description
TSSR-97.2-01	Command predictor shall forecast possible future controller commands for the Tower environment, taking into account periodically received contextual information updates. This external data can be surveillance data, flight plan data, route information, clearance information, weather data, airspace data, and also historical data of those types.
TSSR-97.2-02	The Concept extraction function shall transform the sequence of spoken words into the corresponding ATC concepts (more general speech information), which are further combined to ATC commands.
TSSR-97.2-03	A callsign, which is being considered by the system shall be highlighted in the CWP HMI, after being recognised as part of ATCO's utterance.
TSSR-97.2-04	When the automatic acceptance is available, the command recognized and displayed by ASR shall be automatically accepted, if the controller does not reject it within an adjustable timeframe.
TSSR-97.2-05	When the automatic acceptance is not available, the command recognized and displayed by ASR shall be manually accepted by the ATCO.
TSSR-97.2-06	If a command recognised by ASR is identified as incorrect by the controller, he/she shall be able to manually to correct it and the corrected command shall be displayed.
TSSR-97.2-07	ATCO shall be able to manually reject the command identified by ASR, when the ASR output is a garbled utterance.

Table 5 PJ05-W2-97.2 TSSR for normal operations.

The following abnormal condition was identified as relevant for PJ05-W2-97.2

	Abnormal condition	Effect	TSSR for abnormal conditions
1	Adverse weather	in case the severe event occurs in TMA, the less frequent phraseology, and/or unusual (less-frequent) waypoints could be used.	**TSSR-97.2-08** ASR shall be able to process the ATCO utterances containing less frequent phraseology / way points with the same level of performance as for normal operations.

Table 6 PJ05-W2-97.2 TSSR for abnormal operations.

4.2.4 PJ.05-W2-97.2: TSSR from other intended use

Not applicable

4.3 Technical Specification Safety Requirements - TSSR (integrity /reliability)

4.3.1 PJ.05-W2-97.1 TSSR from SESAR operational solution intended use and/or relevant standards

ID	Description	Operational Effects	TSSR for Failure	Severity *(most probable effect)*
Hz-01	Failure of the V/AR system (e.g. freezing or Tracking Labels or perceptual cues complete loss) prevents the AR device from being updated.	V/AR system is unresponsive potentially impacting trajectory management and associated safety net.	**TSSR-97.1-023** The frequency of failure of the V/AR system (e.g. freezing or Tracking Labels or perceptual cues complete loss) shall not by higher than 1E-04 [per ops hour]	RWY-SC5
Hz-02	TL is erroneously associated to a wrong aircraft (wrong information)	ATCo may focus on the wrong aircraft and issues the clearance intended for another aircraft.	**TSSR-97.1-024** The frequency of TL erroneously associated to a wrong aircraft (wrong information) shall not by higher than 1E-04 [per ops hour]	RWY-SC5
Hz-03	Presentation of TL information within the V/AR does not support ATCo in task execution	If the presentation of TL on the AR device is inadequate (e.g. TLs overlapping, size issues – e.g. depth).	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks. **TSSR-97.1-07** V/AR system displays Tracking Labels in a manner permitting ATCO distinguishing each active aircraft, (using the label antioverlapping feature)	RWY-SC5

ID	Description	Operational Effects	TSSR for Failure	Severity *(most probable effect)*
Hz-04	The responsiveness of the V/AR system as a result of ATCO's input/gesture or flight information changes) is inadequate for the accomplishment of operations.	If the use of V/AR introduces delays in the display of information, this may cause the ATCo to focus on V/AR until verified that the information has been correctly processed and displayed. This may have negative impact on ATCo situational awareness.	**TSSR-97.1-025** The responsiveness of the V/AR system as a result of ATCO's input/gesture or flight information changes) shall be adequate for the task execution.	RWY-SC5
Hz-05	V/AR system fails to identify inputs (gestures) – no response	Unidentified inputs as a result of correct gestures may distract the ATCo from the primary task of ATS provision and results in temporary workload increase and reduction in situational awareness as failures in TL inputs may require increased concentration on the V/AR system.	**TSSR-97.1-026** The frequency of V/AR system failure to identify inputs (gestures) – no response, shall not by higher than 1E-04 [per ops hour]	RWY-SC5
OH-06	V/AR system wrongly identifies input (gesture) – provides erroneous output	In isolated instances the erroneous recognition of an input has no significant safety impact as the ATCo is able to correct the input. Assumption is that the instances of erroneous input recognitions happen at a low enough rate that the system performance is still above the specified gesture recognition threshold. In instances where the V/AR system makes erroneous gesture recognitions continuously and/or below the specified gesture recognition threshold the ATCo will be required to perform manual	**TSSR-97.1-027** The frequency of erroneous identification of inputs (gestures) by V/AR system, shall not by higher than 1E-04 [per ops hour]	RWY-SC5

ID	Description	Operational Effects	TSSR for Failure	Severity *(most probable effect)*
		changes to correct the ATM-system inputs performed by the V/AR system. If the TV/AR system fails to perform in accordance with the specified gesture recognition threshold this may have a human performance impact causing disruption to the expected workflow and cognitive processes.		

Table 7 PJ05-W2-97.1 TSSRs for failure conditions

4.3.2 PJ.05-W2-97.1 TSSR from other intended use

Not applicable

4.3.3 PJ.05-W2-97.2 TSSR from SESAR operational solution intended use and/or relevant standards

ID	Description	Operational Effects	TSSR for Failure	Severity *(most probable effect)*
Hz1	Significant differences in recognition rates of different command type(s)	If the ASR system performs at an acceptable recognition rate for some command types but below the required threshold for other command types, this may disrupt the ATCo workflow and introduce variations to ATCo workload even if traffic levels and complexity remain constant.	**TSSR-97.2-09** The ASR system shall perform at an acceptable recognition rate for all command types.	RWY-SC5
Hz2	Significant delay in ASR command recognition and/or display.	If the use of ASR introduces delays in the usage of speech information (display of inputs, identification of aircraft, etc.) this may cause the ATCo to focus on specific flight/area of the AoR until they can verify that the action induced by ASR has been correctly processed and displayed. This may have negative impact on ATCo situational awareness.	**TSSR-97.2-010** There shall be no significant delay in the display of inputs induced by ASR system on the HMI. Tolerable delay values depend on the OE and ANSP specific use cases.	RWY-SC5
Hz3	ASR fails to identify an aircraft – no aircraft is highlighted	If ATCo performs the radio call it is assumed the impact is minor as the ATCo attention is focused on the aircraft being called and the impact is negligible	**TSSR-97.2-03** A callsign, which is being considered by the system shall be highlighted in the CWP HMI, after being recognised as part of ATCO's utterance.	RWY-SC5
Hz4	ASR erroneously identifies an aircraft – wrong aircraft is highlighted	If the aircraft performs the radio call and erroneous flight is highlighted, the ATCo may focus on the highlighted	**TSSR-97.2-011** The frequency of erroneous identification of aircraft by ASR	MAC-SC4b

ID	Description	Operational Effects	TSSR for Failure	Severity *(most probable effect)*
		aircraft and issue the clearance intended for the calling aircraft to the wrong flight.	system, shall not by higher than 1E-04 [per ops hour].	
Hz5	Presentation of ASR information on the CWP does not support ATCo task execution	If the presentation of ASR data on the CWP is insufficient it may not lead to reduced workload due to more effort of information reading/understanding task of the display by the ATCo.	**TSSR-97.2-012** Inputs generated by an ASR-system displayed on the CWP HMI shall be consistent with other displayed data, complete, and fit-for-purpose. Consistency, completeness, and assessment of fit-for-purpose is dependent on the ATM-system and other system functions used.	RWY-SC5
Hz6	ATCo fails to recognise incorrect command proposed by ASR and thus wrong information is entered into the ATC system	Same impact as today situation, when ATCo enters wrong inputs or misses to enter commands.	**TSSR-97.2-013** The frequency of erroneous information entered into the ATC system due to the incorrect command recognition by ASR system, shall not by higher than 1.2e-05 [per ops hour].	MAC-SC4b

ID	Description	Operational Effects	TSSR for Failure	Severity *(most probable effect)*
			1e-4 [per fh] x 6 [fh/ops hour] = 6e-04 ATCO is assumed P=0.2 6e-04 x 0.2 =1.2e-05	

Table 8 PJ05-W2-97.2 TSSRs for failure conditions

4.3.4 PJ.05-W2-97.2 TSSR from other intended use

Not applicable

4.4 Process assurance of the Technical Safety Specification

The safety assessment was conducted according to SRM [2]. The Technical Specification Safety Requirements (TSSRs) identified refer to the functionalities & performance characteristics derived from the (potential) operational uses envisaged for the technological solution limited to the potential safety implication on the side of the operational users (i.e. ATS service provider).

For this reason, the current safety assessment was initiated by a preliminary safety impact assessment, including initial hazard identification, involving operational experts which are relevant for the use of the technological concept. This approach allowed to understand the potential safety implication of the solution.

The following safety activities were performed (Table 15) with the participation of PJ05-W2-97 solution partners including air traffic controllers, concept designers, ATM engineers, human factors and safety experts.

Safety assessment activity	Scope	Deliverable receiving the outcome
HP&SAF Scoping & Change Assessment session	Definition safety strategy Safety planning	Safety Plan
Safety Metrics and Indicators session	Identification of applicable metrics and indicators to be applied in the exercises for safety evidence.	Safety Plan
HAZID workshop	Hazard identification Safety System Requirements	Initial SAR, Interim TS/IRS

Table 9 Safety assessment activities conducted for PJ.05-W2-97 to derive TSSRs.

5 Safe Design of the Technical System

The purpose of this section is to document the **Technical Safety Requirements at Design level (TSRDs)** for the PJ05 Sol.97 Technological Solution.

The TSRDs are design characteristics of the technical system which ensure that the system operates as specified and is able to achieve the Design Safety Drivers of the technological solution.

The safety assurance activities feeding this section has been conducted at the initial design level in TRL4 and result in the set of the iTSRD – Technical Safety Requirements at Initial Design level.

5.1 Overview of activities performed

This section addresses the following activities:

- introduction of the design model (initial or refined) of the Solution technical system – section 5.2
- derivation of Technical Safety Requirements (functionality & performance) at Design level (TSRD) in normal and abnormal conditions of operation from the TSSRs (functionality and performance) of section 4.2, and supported by the analysis of the initial or refined design model - section 5.3
- assessment of the adequacy of the design (initial or refined) in the case of internal failures and mitigation of the Solution functionality hazards (identified in section 4.3) through derivation from TSSRs (integrity/reliability) of Technical Safety Requirements (functionality & performance) and Technical Safety Requirements (integrity/reliability) at Design level (TSRD) - section 5.4
- realism of the refined safe design (i.e. achievability and “testability” of the TSRD) - section 5.5
- process assurance at the initial or refined safe design level – section 5.6.

5.2 Design Model of the Solution Technical System

5.2.1 Description of the Technical System Design Model

The Design Models of the Solution technical system used as a high-level architectural representation of the Solution systems design for the identification of the Technical Safety Requirements (functionality & performance) at Design level (TSRD) in normal and abnormal conditions of operation from the TSSRs (functionality and performance) are the NSV-4 diagrams produced by the project team [Part I of TS/IRS].

5.3 Deriving Technical Safety Requirements at Design level for Normal and Abnormal conditions

The purpose of this section is to derive Safety Requirements at Design level (TSRD) in normal and abnormal conditions of operations. The TSRDs (functionality and performance) are derived from the TSSRs (functionality and performance) which have been identified in sub-section 4.2.

5.3.1 PJ.05-W2-97.1 Technical Safety Requirements at Design level for Normal and Abnormal conditions

The consolidated list of Technical Safety Requirements at Design level (functionality and performance) for Normal and Abnormal conditions of operations derived by mapping the Technical Specification Safety Requirements (TSSRs) documented in section 4.2 onto the related elements of the Design Model is provided in Table 10. For each TSRD is indicated the element of the design model on which the TSRD is placed, as well as the associated TSSR.

TSR ID	Technical Safety Requirement description (functionality & performance)	Derived from TSSR (ID)
REQ-05-W2-97.1-TS-AG02.0001	**Detection of Operator's Attention** The attention guidance system shall identify the operator's attention focus on the airport traffic situation.	**TSSR-97.1-01**
REQ-05-W2-97.1-TS-AG02.0004	**Identification of a safety relevant event** Attention Guidance Logic shall determine a safety relevant event based on the input coming from: • the relevant safety tools • Radar, • Flight plan • and other relevant external data available to be used by the Attention Guidance Logic.	**TSSR-97.1-02**
REQ-05-W2-97.1-TS-AG02.0002	**Priority of Critical Events Input** The attention guidance system shall receive a set of events that are critical to be noted by the operator, with its corresponding severity/priority.	**TSSR-97.1-02**
REQ-05-W2-97.1-TS-AG01.0004	**Ensuring Safety and User Comfort** The Attention Guidance system shall provide a toggle mode (to switch on/off Attention Guidance functionality) in order to not disturb regular controller operations, to allow a clear interpretation of the information displayed, and to enable easy interaction for the user.	**TSSR-97.1-04**
REQ-05-W2-97.1-TS-VAR1.0004	**Tracking label update** The tracking label shall be updated taking into account the new aircraft status. a) Once the aircraft has landed and is on ground, the label changes to the ground mode	**TSSR-97.1-010**

	b) Once the aircraft is airborne, the label changes to the airborne mode c) Description on clearance displayed	
REQ-05-W2-97.1-TS-VAR1.0001	**Conformal Information** The V/AR system shall depict conformal information as overlapped to the real object it is associated to.	**TSSR-97.1-05**
REQ-05-W2-97.1-TS-VAR1.0002	**Clear field of view** The V/AR system shall not obstruct the natural field of view of the ATCO with augmented reality elements.	**TSSR-97.1-05**
REQ-05-W2-97.1-TS-VAR1.0003	**Decluttering** The V/AR system shall be able to declutter the synthetic elements in view as much as possible to prevent obstruction of the real view or overlap with other information.	**TSSR-97.1-07**
REQ-05-W2-97.1-TS-AIRG.0001	**Type of Gestures** The Air Gesture system shall be able to recognize different gestures and assign each of them to a specific function.	**TSSR-97.1-015** **TSSR-97.1-017**
REQ-05-W2-97.1-TS-AIRG.0002	**Multimodal Interaction** The air gesture system shall be able to point at an object by means of gaze interaction and command it by means of air gesture.	**TSSR-97.1-013** **TSSR-97.1-017**
REQ-05-W2-97.1-TS-AIRG.0003	**Contactless Air Gesture** The air gesture system shall be able to provide contactless interaction (as opposed to multi touch interaction)	**TSSR-97.1-013** **TSSR-97.1-017**
REQ-05-W2-97.1-TS-AG01.0002	**Display of Attention Guidance Elements with Varying Intensity** The Attention Guidance system shall set different escalation (intensity) levels for the critical events under consideration (e.g. conflicts).	**TSSR-97.1-02** **TSSR-97.1-03** **TSSR-97.1-04**
REQ-05-W2-97.1-TS-VAR2.0004	**Minimum field of view** The V/AR system shall have a 30° x 15° minimum field of view for the augmented viewing port.	**TSSR-97.1-05**
REQ-05-W2-97.2-TS-VAR2.0001	**Available sources of data** The V/AR system shall be fed by primary identification tools (radar, ADS-B)	**TSSR-97.1-020**

Table 10: TSRD (functionality and performance) satisfying TSSRs for Normal and Abnormal conditions

5.3.2 PJ.05-W2-97.1 Additional TSRD from Static/dynamic analysis of the technical system behaviour

TSRD ID	Source	Technical Safety Requirement content	TSSR (ID)
REQ-05-W2-97.1-TS-VAR1.0005	EXE-05.97.1-TRL4-TVALP-VAR-001	**Suitability of the safety alert display** The V/AR system shall remove a safety alert if the criticality of the situation decreases (it will reappear in case that the criticality continues to evolve).	**TSSR-97.1-02**
REQ-05-W2-97.1-TS-AG01.0003	EXE-05.97.1-TRL4-TVALP-VAR-005	**Attention Guidance Alert Visibility** The Attention Guidance alert shall be visible from all the angles in the tower	**TSSR-97.1-04**
REQ-05-W2-97.1-TS-VAR1.0006	EXE-05.97.1-TRL4-TVALP-VAR-002 EXE-05.97.1-TRL4-TVALP-VAR-005	**Depth of the conformal information** The V/AR system shall indicate the depth of the real object by its presentation as part of the conformal information associated to it.	**TSSR-97.1-07**
REQ-05-W2-97.1-TS-PERF.0007	EXE-05.97.1-TRL4-TVALP-VAR-005	**Smoothing of conformal information presentation** The V/AR system shall enhance the presentation of the object localization data, including flight tag, by data smoothing interpretation algorithm.	**TSSR-97.1-07**
REQ-05-W2-97.1-TS-VAR2.0002	EXE-05.97.1-TRL4-TVALP-VAR-002	**V/AR display elements brightening** The V/AR system shall allow the customization of the brightness of the VA/R displayed elements and the saving in a user set profile.	**TSSR-97.1-05** **TSSR-97.1-07**
REQ-05-W2-97.1-TS-VAR2.0003	EXE-05.97.1-TRL4-TVALP-VAR-002 EXE-05.97.1-TRL4-TVALP-VAR-005	**Customization of Tracking Labels information** The V/AR system shall allow the customization of the information provided in the TLs from the list of predefined set of information and the saving in a user profile.	**TSSR-97.1-05** **TSSR-97.1-07**

REQ-05-W2-97.1-TS-VAR1.0007	EXE-05.97.1-TRL4-TVALP-VAR-002	**Limits of V/AR system** The V/AR system shall display a visual indication of the limit of the augmented reality field of view in the Head-up display.	**TSSR-97.1-05** **TSSR-97.1-06**
REQ-05-W2-97.1-TS-VAR2.0005	EXE-05.97.1-TRL4-TVALP-VAR-005	**Contingency procedures for LVC** The V/AR system failure shall be considered in the contingency procedures, in case V/AR is used as in LVC operations.	**TSSR-97.1-05** **TSSR-97.1-022**

Table 11: Additional PJ.05-W2-97.1 TSRDs derived from static and dynamic analysis of the technical system behaviour (normal and abnormal conditions of operation)

5.3.3 PJ.05-W2-97.2 Technical Safety Requirements at Design level for Normal and Abnormal conditions

TSR ID	Technical Safety Requirement description (functionality & performance)	Derived from TSSR (ID)
REQ-05-W2-97.2-TS-ASR0.0001	**Area of interest** ASR shall be able to process different traffic flows within the Area of Interest of the Control Unit.	TSSR-97.2-01
REQ-05-W2-97.2-TS-ASR0.0002	**Recognition of Commands** ASR shall recognize commands of different command categories.	TSSR-97.2-02
REQ-05-W2-97.2-TS-ASR0.0003	**Multiple Commands** ASR should be able to process ATCO utterances containing multiple commands.	TSSR-97.2-02
REQ-05-W2-97.2-TS-ASR0.0005	**Multiple Callsigns** ASR should be able to process ATCO utterances containing more than one callsign.	TSSR-97.2-03
REQ-05-W2-97.2-TS-HMI0.0001	**Callsign highlighting** The HMI shall highlight the Track Label (Electronic Flight Strips) after recognizing the corresponding callsign or clicking on the callsign.	TSSR-97.2-03
REQ-05-W2-97.2-TS-HMI2.0002	**HMI for Command Values** The HMI shall present the recognized command types together with the command values in the Electronic Flight Strip or in a dedicated place on the HMI.	TSSR-97.2-02
REQ-05-W2-97.2-TS-HMI0.0003	**Input acceptance** The ASR HMI should enable acceptance of automatically inserted value by ATCO clicking on the value, by clicking on confirmation button in the dialog line or by enabling automatic acceptance of recognized command values if the controller does not correct them within a predefined time frame (e.g. 10 seconds).	TSSR-97.2-04

REQ-05-W2-97.2-TS-HMI0.0004	**Manual correction** The ASR HMI shall enable manual correction/update of automatically proposed command value/type.	TSSR-97.2-06
REQ-05-W2-97.2-TS-ReTi.0001	**Provide callsign information immediately** ASR should give a response not later than 1.0 second after the controller has pressed the push-to-talk-button, by sending the recognized callsign to the cooperating ATC system.	TSSR-97.2-03
REQ-05-W2-97.2-TS-ReTi.0002	**Reaction Time** For the ATCO utterances except callsign itself, on average, the system should be able to give the final speech-to-text and text-to-concept result latest one second after the ATCO has released the push-to-talk button.	TSSR-97.2-02
REQ-05-W2-97.2-TS-Perf.0001	**Command Recognition Error Rate** The Command Recognition Error Rate of ASR should be less than 2.5%.	TSSR-97.2-02
REQ-05-W2-97.2-TS-Perf.0002	**Command Prediction Error Rate** The Command Prediction Error Rate should not be higher than 10% and also not be higher than 50% of the opposite command recognition rate (i.e. 100% minus the command recognition rate), without using the checker.	TSSR-97.2-01
REQ-05-W2-97.2-TS- ReTi.0003	**System reaction time** The use of ASR shall have no influence on the reaction time of the different systems/functional blocks used in the controller HMI.	TS/IRS
REQ-05-W2-97.2-TS- ReTi.0004	**System recognition time** The ASR shall start with the recognition of utterance directly after the first word has been spoken.	TSSR-97.2-02
REQ-05-W2-97.2-TS-Perf.0005	**Command Recognition Rate** The Command Recognition Rate of ASR shall be higher than 95%.	TSSR-97.2-02

5.3.4 PJ.05-W2-97.2 Additional TSRD from Static/dynamic analysis of the technical system behaviour

TSRD ID	Source	Technical Safety Requirement content	TSSR (ID)
REQ-05-W2-97.2-TS-Safe.0001	EXE-05.97.2-TRL4-TVALP-ASR-004	**ASR and Safety nets** ASR shall be interoperable with other safety nets available.	**new**

REQ-05-W2-97.2-TS-ASR0.0010	EXE-05.97.2-TRL4-TVALP-ASR-004EXE-05.97.2-TRL4-TVALP-ASR-006 EXE-05.97.2-TRL4-TVALP-ASR-007	**Silent/passive acknowledgement** ASR should acknowledge the clearance uttered in a silent/passive manner with the time out.	**TSSR-97.2-04**
REQ-05-W2-97.2-TS-HMI0.0002	EXE-05.97.2-TRL4-TVALP-ASR-006	**AI feed callsign recognition levels visualisation** The ASR HMI shall highlight the recognised callsign in a different colour in case of uncertainty in callsign recognition in a range of percentage to be assessed.	**new**
REQ-05-W2-97.2-TS-Safe.0003	EXE-05.97.2-TRL4-TVALP-ASR-004EXE-05.97.2-TRL4-TVALP-ASR-006 EXE-05.97.2-TRL4-TVALP-ASR-007	**Representative ontology and voice samples** ASR shall be trained with local operations ontology sample, which is representative of the different circumstances that occur during the operations.	**new**
REQ-05-W2-97.2-TS-Safe.0004	EXE-05.97.2-TRL4-TVALP-ASR-004	**Integration into the existing system** ASR shall be fully integrated into existing operating system.	**new**
REQ-05-W2-97.2-TS-ASR0.0009	EXE-05.97.2-TRL4-TVALP-ASR-004	**ASR switch off/on** ASR shall provide the ATCO with a switch on/Switch off function.	TS/IRS

Table 12: Additional PJ.05-W2-97.2 TSRDs derived from static and dynamic analysis of the technical system behaviour (normal and abnormal conditions of operation).

5.4 Technical Safety Requirements at design level addressing Internal System Failures

The purpose of this section is to present the Technical Safety Requirements at Design level (TSRDs) addressing internal system failures (e.g. failure of the technical system component).

TSRDs are derived from the TSSRs (integrity/reliability) and TSSR (functionality &performance) which have been identified when addressing failure conditions in the technical safety specification.

The following TSRDs are derived from a bottom-up failure modes and effects analysis encompassing the analysis of common causes and from the TSSR (functionality & performance) aimed at the protective mitigation of the functionality hazards).

5.4.1 PJ.05-W2-97.1 Technical Safety Requirements at design level addressing internal system failures

Technical Safety Requirement ID	Technical Safety Requirement description (integrity/ reliability)	Derived from TSSR integrity/reliability (ID)
REQ-05-W2-97.1-TS-PERF.0008	**Frequency of system failure** The frequency of failure of the V/AR system (freezing or Tracking Labels or perceptual cues complete loss) shall not by higher than 1E-04 [per ops hour	**TSSR-97.1-023**
REQ-05-W2-97.1-TS-PERF.0009	**Frequency of TL wrongly associated** The frequency of TL erroneously associated to a wrong aircraft (wrong information) shall not by higher than 1E-04 [per ops hour]	**TSSR-97.1-024**
REQ-05-W2-97.1-TS-PERF.0010	**Frequency of failure in input identification** The frequency of V/AR system failure to identify inputs (gestures) – no response, shall not by higher than 1E-04 [per ops hour]	**TSSR-97.1-026**
REQ-05-W2-97.1-TS-PERF.0011	**Frequency of erroneous input identification** The frequency of erroneous identification of inputs (gestures) by V/AR system, shall not by higher than 1E-04 [per ops hour]	**TSSR-97.1-027**

5.4.2 PJ.05-W2-97.2 Technical Safety Requirements at design level addressing internal system failures

Technical Safety Requirement ID	Technical Safety Requirement description (functionality & performance)	Derived from TSSR (ID) or Common cause failure
REQ-05-W2-97.2-TS-Safe.0002	**Failure of ASR** A failure of the ASR shall have no negative influence on the Tower ATC system.	TS/IRS

REQ-05-W2-97.2-TS-HMI0.0005	**ASR failure indication** The HMI shall indicate a failure of the ASR by displaying either an error message or using status icons.	TS/IRS
REQ-05-W2-97.2-TSSR-09.0001	**Commands recognition rate** The ASR system shall perform at an acceptable recognition rate for all command types	**TSSR-97.2-09**

Table 13. Additional TSRDs (functionality & performance) to mitigate functionality hazards

The detail of the derivation process can be found in Appendix C.

Technical Safety Requirement ID	Technical Safety Requirement description (integrity/ reliability)	Derived from TSSR integrity/reliability (ID)
REQ-05-W2-97.2-TS-Perf.0006	**Erroneous identification rate** The frequency of erroneous identification of aircraft by ASR system, shall not by higher than 1E-04 [per ops hour].	**TSSR-97.2-011**
REQ-05-W2-97.2-TS-Perf.0007	**Incorrect command recognition rate** The frequency of erroneous information entered into the ATC system due to the incorrect command recognition by ASR system, shall not by higher than 1.2e-05 [per ops hour].	**TSSR-97.2-013**
REQ-05-W2-97.2-TS-Safe.0005	**Contingency procedures** The contingency procedure in case of ASR failure shall be established.	**TSSR-97.2-03** **TSSR-97.2-11** **TSSR-97.2-13**

Table 14. TSRD (integrity/ reliability) to mitigate functionality hazards

5.5 Realism and testability of the Safe Design

The initial technical safety requirements at the design level (iTSRD) derived in this assessment target mainly two domains: equipment and human factors.

Equipment related iTSRD, including functionality and system performance, are provided in qualitative manner for success approach or quantified for failure approach. The lowest quantified failure rate corresponds to the order of 1e-4, therefore well within the range of typical reliability requirement imposed on equipment in civil aviation.

Human factors' related Safety Requirements were derived through assessment done jointly by Human performance, safety and in cooperation with controllers participating in validation exercises, therefore are considered fully achievable.

Therefore, iTSRD defined in this SAR are considered achievable.

5.6 Process assurance of the Safe Design

The safety assessment was conducted according to SRM [2]. In order to identify Initial set of Technical Safety Requirements at Design Level (TSRD) a dedicated workshop with subject matters experts was conducted addressing both success approach (defining at the level of each component what it is required to fulfil in terms of functionality and performance) and failure approach (defining at the level of each component what it is required to fulfil in terms of integrity and additional functionalities). During the workshop the potential HP and safety issues were discussed and accordingly the mitigation actions were identified.

The following safety activities were performed (Table 15) with the participation of PJ05-W2-97 solution partners including air traffic controllers, concept designers, ATM engineers, human factors, and safety experts.

Safety assessment activity	Scope	Deliverable receiving the outcome
Initial Technical Safety Requirements at Design Level (TSRD) validation workshop	Technical Safety Design Requirements validation (mitigation efficiency & realism)	SAR Final TS/IRS

Table 15 Safety assessment activities conducted for PJ.05-W2-97 to derive TSRDs.

6 Demonstration of achievability of the Technical System Safety Specification

Achievability of the iTSSRs has been demonstrated through the satisfaction of the success criteria of the safety validation objective defined for Solution PJ05-W2-97 and validated during exercises and additional specific safety assessment activities. (i.e. data analysis, Safety and HP workshops).

The following subsection presents the summary of results coming from the validation exercises.

6.1 Safety related results for Solution PJ05-W2-97.1

HZ ID	Hazard	Hazard Impact	EXE-001 (NLR)	EXE-002 (ENAV)	EXE-005 (ENAIRE)
Hz1	Failure of the V/AR system (e.g. freezing of Tracking Labels or perceptual cues complete loss) prevents the AR device from being updated.	V/AR system is unresponsive potentially impacting trajectory management and associated safety nets.		No failure of the V/A-R system identified during the exercise. ATCOs only commented on the design, especially the position, of the Tracking Labels.	
Hz2	TL is erroneously associated to a wrong aircraft (wrong information)	ATCo may focus on the wrong aircraft and issues the clearance intended for another aircraft.	The controllers mentioned that the alert notice disappeared when facing the direction of the conflict, but reappeared after a certain interval when the separation remained below the set minima, even if the conflict was solved.	One ATCO mentioned that the TL was not always well aligned with the corresponding aircraft. Moreover, ATCOs commented repeatedly that the TLs were covering each other as well as the background. However, these issues did not lead to errors in associating the right TL to the aircraft.	adequacy (level and quality) of information provided by V/A-R: 100% of the users responded favorably, and an average of the normalized responses show a 63% favourable response rate.
Hz3	Presentation of TL information within the V/AR does not	If the presentation of TL on the AR device is inadequate (e.g. TLs	The HMI can be improved, by not placing the notification in the	ATCOs commented repeatedly that the TLs were covering each other	Further study should be taken on to determine the proper

	support ATCo in task execution	overlapping, size issues – e.g. depth).	middle of the field of view and improving the rules for reappearance of the notification.	as well as the background. However, ATCOs were able to execute their tasks without too much difficulty (subjective SA and workload were acceptable).	size of the flight tags and tracking ball that balances sufficient information, ease of viewing, and occupies the minimal field of view.
Hz4	The responsiveness of the V/AR system as a result of ATCO's input/gesture or flight information changes) is inadequate for the accomplishment of operations.	If the use of V/AR introduces delays in the display of information, this may cause the ATCo to focus on V/AR until verified that the information has been correctly processed and displayed. This may have negative impact on ATCo situational awareness.	N/A	This hazard has not been identified in the exercise. ATCO subjective situational awareness was above the tolerable threshold.	ATCOs can apply operating methods in an accurate, efficient and timely manner: 75% of the users responded favourably, and an average of the normalized responses show a 59% favourable response rate.
Hz5	V/AR system fails to identify inputs (gestures) – no response	Unidentified inputs as a result of correct gestures may distract the ATCo from the primary task of ATS provision and results in temporary workload increase	N/A	Air gestures were not always recognised easily. This led to frustration, and in some cased decreased SA and increased workload, for the ATCO.	adequacy (level and quality) of information provided by V/A-R Air Gestures: 75% of the users responded favourably, and an average of the normalized responses

		and reduction in situational awareness as failures in TL inputs may require increased concentration on the V/AR system.			show a 60% favourable response rate.
Hz6	V/AR system wrongly identifies input (gesture) – provides erroneous output	In isolated instances the erroneous recognition of an input has no significant safety impact as the ATCo is able to correct the input. If the TV/AR system fails to perform in accordance with the specified gesture recognition threshold this may have a human performance impact causing disruption to the expected workflow and cognitive processes.	N/A	Air gestures were not always recognised easily. This led to frustration, and in some cased decreased SA and increased workload, for the ATCO.	adequacy (level and quality) of information provided by V/A-R Air Gestures: 75% of the users responded favourably, and an average of the normalized responses show a 60% favourable response rate. The air gestures used to control the menu could be a bit more intuitive, but after some time practicing them, were easily understood and accomplished.

Table 16 PJ05-W2-97.1 Hazards related results

Success Criteria ID	Success Criteria	EXE-001 (NLR)	EXE-002 (ENAV)	EXE-005 (ENAIRE)
CRT-05.971-TLR4-TVALP-SAFE -1011	The changes related to the implementation of Virtual/Augmented Reality applications do not increase potential for human error and therefore not reducing safety levels.	No errors were noticed in the experiment. Furthermore, the system does not interfere with actions to be taken by the controller. The A-R device provides additional information to the controller but has no effect on the operating methods or procedures.	Six out of ten ATCOs agreed that the V/A-R system did not increase potential for human error compared to current operations. 40% (2 out of 5) of the ATCOs responses it that the V/A-R Air Gestures increase the potential for human error due to usability issues.	The average of the normalized responses shows a 64% favourable response rate.
CRT-05.971-TLR4-TVALP-SAFE -1012	ATCO's workload with the implementation of Virtual/Augmented Reality applications is maintained at acceptable level and therefore not reducing safety levels.	The influence of A-R on workload was rated 'positive' to 'very positive', both during normal operation and in case of an alert. Nevertheless, the post-run ratings of Workload show no significant differences between A-R and baseline.	Feedback from controllers (90%) shows that the prototype for V/AR supports controllers in maintaining an acceptable level of workload. Minority of ATCOs (40%) responses is that V/A-R Air Gestures supports ATCO in maintaining workload at acceptable level. Several ATCOs had difficulties using Air Gestures which increased their workload.	It can be seen that 75% of the users responded favourably, and an average of the normalized responses show a 50% favourable response rate.

CRT-05.971-TLR4-TVALP-SAFE -1013	ATCO's situational awareness with the implementation of Virtual/Augmented Reality applications is maintained at acceptable level and therefore not reducing safety levels.	The influence of A-R on Situational Awareness was rated (post-experiment) 'positive' to 'very positive', both during normal operation and in case of an alert. The post-run ratings of Situational Awareness show no significant differences between A-R and baseline, which means that a sufficient level of SA is maintained. The controllers stated that, not having to search for information about where the conflict is and which a/c (call signs) are involved, was a substantial improvement.	Majority of ATCOs (90%) responses is that V/A-R HMI supports ATCO in maintaining an adequate level of situation awareness. Only 60% (3 out of 5) of ATCOs responses is that V/A-R Air Gestures HMI supports ATCO in maintaining an adequate level of situation awareness. This was again due to the fact that they were not always able to give the clearance with the air gesture.	It can be seen that only 50% of the users responded favourably, but an average of the normalized responses show a 69% favourable response rate.

Table 17 PJ05-W2-97.1 Safety Success Criteria results

6.2 Safety related results for Solution PJ05-W2-97.2

HZ ID	Hazard	Hazard Impact	EXE-004 (INDRA, HC)	EXE-006 (DLR)	EXE-007 (LDO)
Hz1	Significant differences in recognition rates of different command type(s)	If the ASR system performs at an acceptable recognition rate for some command types but below the required threshold for other command types, this may disrupt the ATCo workflow and introduce variations to ATCo workload even if traffic levels and complexity remain constant.	According to the results, the system performed best with the callsign recognition (66.7% positive feedback), and the other parameters (66.7% positive feedback), followed by the clearance recognition (55.5%).	Offline recognition rates for 13 command types that appeared at least 24 times in trials AND relevant in electronic flight strips range between 72% (ENTER_CTR) and 100% (LINEUP_BEHIND). 12 of those 13 command types have recognition rates >87%. It also seems easily improvable if going to TRL6. No comments on different recognition rates for different command types.	The recognition rates were above the threshold for all commands. The manual correction was not recorded by the platform but by subjective means and positive feedback from ATCOs was received. ATCOs provided positive feedback on command recognition rate
Hz2	Significant delay in ASR command recognition and/or display.	If the use of ASR introduces delays in the usage of speech information (display of inputs, identification of aircraft, etc.) this may cause the ATCo to focus on specific	One of the weaknesses of the system was its responsiveness. The evidence show that the latency was not	*Results on another ATC data set with the same online mechanism:*	The ASR delay was rated acceptable, with an average of 1.55 seconds for recognized commands and 2.1 seconds for rejected

		flight/area of the AoR until they can verify that the action induced by ASR has been correctly processed and displayed. This may have negative impact on ATCo situational awareness.	appropriate- only 50% of the ATCOs gave positive feedback. ATCOs also emphasized that the system must become much faster because they do not want to continuously check the system during work.	*-Command extraction time: 32 ms after utterance completed* *-Start of speaking, until first words are extracted: 1.3 seconds* *-Start of speaking, until first extracted command is shown: 2.1 s* *No statement about time between finalizing the utterance of words of a callsign/command until showing the extracted callsign/command, but <2s.* Callsign highlighting was perceived to be fast enough. Command (type/value) highlighting was perceived to be fast enough form some ATCos, some wanted to have the output faster.	commands. Positive subjective feedback was received on the latency of the system.

Hz3	ASR fails to identify an aircraft – no aircraft is highlighted	If ATCo performs the radio call it is assumed the impact is minor as the ATCo attention is focused on the aircraft being called and the impact is negligible .		Callsign recognition rate in offline mode >98%, so negligible.	The missed callsign recognition rate was not recorded by the platform, nor was the manual correction rate. However, positive feedback from ATCOs was received regarding the overall ASR recognition rates.
Hz4	ASR erroneously identifies an aircraft – wrong aircraft is highlighted	If the aircraft performs the radio call and erroneous flight is highlighted, the ATCo may focus on the highlighted aircraft and issue the clearance intended for the calling aircraft to the wrong flight.		Callsign recognition error rate in offline mode <1%, so negligible. Callsign recognition error rate in offline mode <1%, so negligible.	The use of context based data supported ASR operation in callsign recognition. This feature minimized the risk of highlighting an erroneous callsign. ATCOs provided positive feedback on ASR recognition rates

Hz5	Presentation of ASR information on the CWP does not support ATCo task execution.	If the presentation of ASR data on the CWP is insufficient it may lead to increased workload due to more effort of information reading/understanding task of the display by the ATCo.		ABSR output did support ATCos given the reported recognition and error rates (same mechanism as if ATCo would have done electronic flight strip maintenance manually). Some ATCos felt supported, others saw room for improvement.	No concerns were reported concerning the ASR HMI output presentation. Recommendations were collected in order to improve performance and usability.

Hz6	ATCo fails to recognize incorrect command proposed by ASR and thus wrong information is entered into the ATC system	Same impact as today situation, when ATCo enters wrong inputs or misses to enter commands.		This happened from time to time especially if ATCos relied too much on ABSR output after it worked well in the beginning (observation by validation observer), but even in such rare cases ATCos often noticed later, because the procedural model of the electronic flight strip system made them wondering where the flight strip was, and not where it was expected to be (bay for expected procedural step in tower ATC). This happened from time to time especially if ATCos relied too much on ABSR output after it worked well in the beginning (observation by ATCos themselves).	The recognition rates were rated acceptable for the relevant ASR commands. The manual correction was not recorded by the CWP but by subjective means and positive feedback from ATCOs was received. ATCOs provided positive feedback on command recognition.

Table 18 PJ05-W2-97.2 Hazards related results

Success Criteria ID	Success Criteria	EXE-004 (INDRA, HC)	EXE-006 (DLR)	EXE-007 (LDO)
CRT-05.972-TLR4-TVALP-SAFE -2011	The changes related to the implementation of Automatic Speech Recognition do not increase potential for human error and therefore not reducing safety levels.	Not applicable as human error could not be measured during the tests	Feedback from ATCos questionnaire ratings showed that potential for human errors have not been increased. In addition, ASR was not found to induce safety issues or to increase the potential for human errors with mean values below the scale mean of 5.5.	66% of ATCOs responded ASR does not increase the potential for human error compared to current operations.
CRT-05.972-TLR4-TVALP-SAFE -2012	ATCO's workload with the implementation of Automatic Speech Recognition is maintained at acceptable level and therefore not reducing safety levels.	Not applicable as workload could not be measured during the tests	No significant differences in workload were found between reference and solution scenario. While the secondary task (sorting cards) and the ISA tend to show a workload reduction of ATCos when being supported by ASR, NASA-TLX and Bedford Workload Scale tend into the opposite way. However, the statement "I think that ASR supports me in maintaining workload at	ATCO's workload with the implementation of Automatic Speech Recognition is maintained at acceptable level. 83% ATCOs agreed safety level was at least equal to today operations

			acceptable level" was rated with 7.8 on a 10 point scale (90% of ATCos rated this item with 7 or above).	
CRT-05.972-TLR4-TVALP-SAFE -2013	ATCO's situational awareness with the implementation of Automatic Speech Recognition is maintained at acceptable level and therefore not reducing safety levels.	Not applicable as situational awareness could not be measured during the tests	No significant differences in SASHA score (situation awareness assessment) were found between reference and solution scenario. The statement "I think that ASR supports me in maintaining an adequate level of situation awareness" was rated with 7.7 on a 10 point scale (90% of ATCos rated this item with 7 or above).	ATCO situational awareness is maintained at acceptable levels with ASR and therefore does not reduce safety levels

Table 19 PJ05-W2-97.2 Safety Success Criteria results

7 Acronyms

Acronym	Definition
ABSR	Assistance Based Speech Recognition
ADD	Architecture Description Document
AG	Attention Guidance
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
AR	Augmented Reality
ASR	Automatic Speech Recognition
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
A-SMGCS	Advanced Surface Movement Guidance and Control System
CC	Capability Configuration
COTS	Commercial Off-The-Shelf
CWP	Controller Working Position
DTT	Digital Tower Technology
EATMA	European ATM Architecture
EFS	Electronic Flight Strips
EN	Enabler
E-OCVM	European Operational Concept Validation Methodology
ER	En-Route
E-ATMS	European Air Traffic Management System
FAA	Federal Aviation Administration
FB	Functional Block
GND	Ground

HMD	Head-Mounted-Display
HMI	Human Machine Interface
IER	Information Exchange Requirement
INTEROP	Interoperability Requirements
IRS	Interface Requirements Specification
ISRM	Information Services Reference Model
LVC	Low Visibility Conditions
ML	Machine Learning
MTI	Multi-touch Interaction
NAF	NATO Architecture Framework
NFR	Non- Functional Requirements
NSOV	NAF Service Oriented View
NOV	NAF Operational View
NSV	NAF System View
PTT	Press-To-Talk
POI	Performance Operational Improvement
OSED	Operational Service and Environment Definition
OTW	Out-The-Window
QoS	Quality of Service
RWY	Runway
SDD	Service Description Document
SESAR	Single European Sky ATM Research Programme
S3JU	SESAR3 Joint Undertaking (Agency of the European Commission)
SoaML	Service Oriented Architecture Modelling Language
SPR	Safety and Performance Requirements
SPR-INTEROP/OSED	Safety and Performance Requirements – Interoperability Requirements / Operational Service and Environment Definition

SUT	System Under Test
SWIM	System Wide Information Model
TRL	Technology Readiness Level
TS	Technical Specification
TS/IRS	Technical Specification/Interface Requirements Specification
TSAP	Technical Safety Assessment Plan
TVALP	Technological Validation Plan
TVALR	Technological Validation Report
TWR	Tower
UC	Use Case
UML	Unified Modelling Language
V&V	Validation and Verification
VALS	Validation Strategy
VCS	Voice Communication System
VR	Virtual Reality
V/AR	Virtual/Augmented Reality
WSDL	Web Services Definition Language
XSD	XML Schema Definition

Table 20: Acronyms

8 References

Safety

[1] (EU) No 2017/373 laying down common requirements for service providers and the oversight in air traffic management/air navigation services and other air traffic management network functions, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011 and (EU) No 1035/2011 and amending Regulation (EU) No 677/2011 (and associated AMC and GM)

[2] SESAR Safety Reference Material

Appendix A Defining the Technical Safety Specification based on other intended use

A.1 Define TSSRs for Normal and Abnormal conditions

The TSSRS are presented in the main body of the document

A.1.1 Static analysis of the technical specification

The TSSRS are presented in the main body of the document.

A.1.2 Dynamic analysis of the technical specification

A.2 The TSSRS are presented in the main body of the document

A.3 Define TSSRs addressing failure conditions

A.3.1 FHA Workshop

Two separated FHA workshops (for each sub-solution) were organised as online sessions PJ05-W2-97 solution partners including air traffic controllers, concept designers, ATM engineers, human factors and safety experts.

The FHA outputs (including Hazards description, operational effect mitigation and hazard severities) can be found in the main body of the document.

Appendix B Designing the Solution technical system for normal and abnormal conditions

B.1 Deriving TSRDs from TSSRs for Solution 97.1

TSR ID	Technical Safety Requirement description (functionality & performance)	Derived from TSSR (ID)
REQ-05-W2-97.1-TS-AG02.0001	**Detection of Operator's Attention** The attention guidance system shall identify the operator's attention focus on the airport traffic situation.	**TSSR-97.1-01** Attention Guidance system shall analyse the controller's activity in order to monitor his/her attention
REQ-05-W2-97.1-TS-AG02.0004	**Identification of a safety relevant event** Attention Guidance Logic shall determine a safety relevant event based on the input coming from: • the relevant safety tools • Radar, • Flight plan • and other relevant external data available to be used by the Attention Guidance Logic.	**TSSR-97.1-02** Attention Guidance Logic shall determine a relevant event, such as a safety net alert. Radar, flight plan and other relevant external data are available to be used by the Attention Guidance Logic. The Attention Logic Guidance is fed with the level of priority for each potentially critical ATC situation
REQ-05-W2-97.1-TS-AG02.0002	**Priority of Critical Events Input** The attention guidance system shall receive a set of events that are critical to be noted by the operator, with its corresponding severity/priority.	**TSSR-97.1-02** Attention Guidance Logic shall determine a relevant event, such as a safety net alert. Radar, flight plan and other relevant external data are available to be used by the Attention Guidance Logic. The Attention Logic Guidance is fed with the level of priority for each potentially critical ATC situation **TSSR-97.1-03** Attention Guidance system shall determine that a relevant event requires Attention Guidance measures in order to claim the controller's attention
REQ-05-W2-97.1-TS-AG01.0004	**Attention Guidance switch on/off** The Attention Guidance system shall provide a toggle mode (to switch on/off Attention Guidance functionality) in order to not disturb regular controller	**TSSR-97.1-04** The V/AR device shall present visual and (optionally) also auditory cues to the controller on the augmented reality

	operations, to allow a clear interpretation of the information displayed, and to enable easy interaction for the user.	interface to guide the controller's attention
REQ-05-W2-97.1-TS-VAR1.0004	**Tracking label update** The tracking label shall be updated taking into account the new aircraft status. a) Once the aircraft has landed and is on ground, the label changes to the ground mode b) Once the aircraft is airborne, the label changes to the airborne mode c) Description on clearance displayed	**TSSR-97.1-010** The tracking label shall be updated taking into account the new aircraft status. a) Once the aircraft has landed and is on ground, the label changes to the ground mode b) Once the aircraft is airborne, the label changes to the airborne mode c) Description on clearance displayed
REQ-05-W2-97.1-TS-VAR1.0001	**Conformal Information** The V/AR system shall depict conformal information as overlapped to the real object it is associated to.	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks
REQ-05-W2-97.1-TS-VAR1.0002	**Clear field of view** The V/AR system shall not obstruct the natural field of view of the ATCO with augmented reality elements.	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks
REQ-05-W2-97.1-TS-VAR1.0003	**Decluttering** The V/AR system shall be able to declutter the synthetic elements in view as much as possible to prevent obstruction of the real view or overlap with other information.	**TSSR-97.1-07** V/AR system displays Tracking Labels in a manner permitting ATCO distinguishing each active aircraft, (using the label antioverlapping feature)
REQ-05-W2-97.1-TS-AIRG.0001	**Type of Gestures** The Air Gesture system shall be able to recognize different gestures and assign each of them to a specific function.	**TSSR-97.1-015** The system shall detect the clearance issued by the controller by means of Air Gestures interacting with the interface **TSSR-97.1-017** The Controller shall be able to navigate through menus by means of Air Gestures

REQ-05-W2-97.1-TS-AIRG.0002	**Multimodal Interaction** The air gesture system shall be able to point at an object by means of gaze interaction and command it by means of air gesture.	**TSSR-97.1-013** The V/AR device shall allow the label to be selected by ATCO, e.g. by means of air gesture **TSSR-97.1-017** The Controller shall be able to navigate through menus by means of Air Gestures
REQ-05-W2-97.1-TS-AIRG.0003	**Contactless Air Gesture** The air gesture system shall be able to provide contactless interaction (as opposed to multi touch interaction)	**TSSR-97.1-013** The V/AR device shall allow the label to be selected by ATCO, e.g. by means of air gesture. **TSSR-97.1-017** The Controller shall be able to navigate through menus by means of Air Gestures
REQ-05-W2-97.1-TS-AG01.0002	**Display of Attention Guidance Elements with Varying Intensity** The Attention Guidance system shall set different escalation (intensity) levels for the critical events under consideration (e.g. conflicts).	**TSSR-97.1-02** Attention Guidance Logic shall determine a relevant event, such as a safety net alert. Radar, flight plan and other relevant external data are available to be used by the Attention Guidance Logic. The Attention Logic Guidance is fed with the level of priority for each potentially critical ATC situation. **TSSR-97.1-03** Attention Guidance system shall determine that a relevant event requires Attention Guidance measures in order to claim the controller's attention. **TSSR-97.1-04** The V/AR device shall present visual and (optionally) also auditory cues to the controller on the augmented reality interface to guide the controller’s attention.

REQ-05-W2-97.1-TS-VAR2.0004	**Minimum field of view** The V/AR system shall have a 30° x 15° minimum field of view for the augmented viewing port.	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks.
REQ-05-W2-97.1-TS-VAR2.0001	**Available sources of data** The V/AR system shall be fed by primary identification tools (radar, ADS-B)	**TSSR-97.1-020** V/AR system shall enable, the detection of unexpected flights in the area of responsibility where ATC service is being provided

B.1.1 Static and dynamic analysis of the technical system for 97.1

TSRD ID	Source	Technical Safety Requirement content	TSSR (ID)
REQ-05-W2-97.1-TS-VAR1.0005	EXE-05.97.1-TRL4-TVALP-VAR-001	**Suitability of the safety alert display** The V/AR system shall remove a safety alert if the criticality of the situation decreases (it will reappear in case that the criticality continues to evolve).	**TSSR-97.1-02** Attention Guidance Logic shall determine a relevant event, such as a safety net alert. Radar, flight plan and other relevant external data are available to be used by the Attention Guidance Logic. The Attention Logic Guidance is fed with the level of priority for each potentially critical ATC situation.
REQ-05-W2-97.1-TS-AG01.0003	EXE-05.97.1-TRL4-TVALP-VAR-005	**Attention Guidance Alert Visibility** The Attention Guidance alert shall be visible from all the angles in the tower	**TSSR-97.1-04** The V/AR device shall present visual and (optionally) also auditory cues to the controller on the augmented reality interface to guide the controller's attention.

REQ-05-W2-97.1-TS-VAR1.0006	EXE-05.97.1-TRL4-TVALP-VAR-002 EXE-05.97.1-TRL4-TVALP-VAR-005	**Depth of the conformal information** The V/AR system shall indicate the depth of the real object by its presentation as part of the conformal information associated to it.	**TSSR-97.1-07** V/AR system displays Tracking Labels in a manner permitting ATCO distinguishing each active aircraft, (using the label antioverlapping feature)
REQ-05-W2-97.1-TS-PERF.0007	EXE-05.97.1-TRL4-TVALP-VAR-005	**Smoothing of conformal information presentation** The V/AR system shall enhance the presentation of the object localization data, including flight tag, by data smoothing interpretation algorithm.	**TSSR-97.1-07** V/AR system displays Tracking Labels in a manner permitting ATCO distinguishing each active aircraft, (using the label antioverlapping feature)
REQ-05-W2-97.1-TS-VAR2.0002	EXE-05.97.1-TRL4-TVALP-VAR-002	**V/AR display elements brightening** The V/AR system shall allow the customization of the brightness of the VA/R displayed elements and the saving in a user set profile.	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks. **TSSR-97.1-07** V/AR system displays Tracking Labels in a manner permitting ATCO distinguishing each active aircraft, (using the label antioverlapping feature)

REQ-05-W2-97.2-TS-VAR2.0003	EXE-05.97.1-TRL4-TVALP-VAR-002 EXE-05.97.1-TRL4-TVALP-VAR-005	**Customization of Tracking Labels information** The V/AR system shall allow the customization of the information provided in the TLs from the list of predefined set of information and the saving in a user profile.	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks. **TSSR-97.1-07** V/AR system displays Tracking Labels in a manner permitting ATCO distinguishing each active aircraft, (using the label antioverlapping feature)
REQ-05-W2-97.1-TS-VAR1.0007	EXE-05.97.1-TRL4-TVALP-VAR-002	**Limits of V/AR system** The V/AR system shall display a visual indication of the limit of the augmented reality field of view in the Head-up display.	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks. **TSSR-97.1-06** The V/AR system shall identify all active aircraft on the airport, i.e. aircraft that are lined up for landing or take off, aircraft moving over the surface and aircraft on the gate about to depart. For this purpose, the surveillance and flight plan data are taken into account. For instance, the surveillance data provided by the ADS-B surveillance is fed into the system and associated to the aircraft out-the-window images so that this information is correlated.

REQ-05-W2-97.1-TS-VAR2.0005	EXE-05.97.1-TRL4-TVALP-VAR-005	**Contingency procedures for LVC** The V/AR system failure shall be considered in the contingency procedures, in case V/AR is used as in LVC operations.	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks. **TSSR-97.1-022** In LVC the V/AR device shall present additional operational information to the controller.

B.2 Deriving TSRDs from TSSRs for Solution 97.2

TSR ID	Technical Safety Requirement description (functionality & performance)	Derived from TSSR (ID)
REQ-05-W2-97.2-TS-ASR0.0001	**Area of interest** ASR shall be able to process different traffic flows within the Area of Interest of the Control Unit.	**TSSR-97.2-01** Command predictor shall forecast possible future controller commands for the Tower environment, taking into account periodically received contextual information updates.
REQ-05-W2-97.2-TS-ASR0.0002	**Recognition of Commands** ASR shall recognize commands of different command categories.	**TSSR-97.2-02** The Concept extraction function shall transform the sequence of spoken words into the corresponding ATC concepts (more general speech information), which are further combined to ATC commands.
REQ-05-W2-97.2-TS-ASR0.0003	**Multiple Commands** ASR should be able to process ATCO utterances containing multiple commands.	**TSSR-97.2-02** The Concept extraction function shall transform the sequence of spoken words into the corresponding ATC concepts (more general speech information), which

		are further combined to ATC commands.
REQ-05-W2-97.2-TS-ASR0.0005	**Multiple Callsigns** ASR should be able to process ATCO utterances containing more than one callsign.	**TSSR-97.2-03** A callsign, which is being considered by the system shall be highlighted in the CWP HMI, after being recognised as part of ATCO's utterance.
REQ-05-W2-97.2-TS-HMI0.0001	**Callsign highlighting** The ASR HMI shall highlight the Track Label (Electronic Flight Strips) after recognizing the corresponding callsign or clicking on the callsign.	**TSSR-97.2-03** A callsign, which is being considered by the system shall be highlighted in the CWP HMI, after being recognised as part of ATCO's utterance.
REQ-05-W2-97.2-TS-HMI2.0002	**HMI for Command Values** The ASR HMI shall present the recognized command types together with the command values in the Electronic Flight Strip or in a dedicated place on the HMI.	**TSSR-97.2-02** The Concept extraction function shall transform the sequence of spoken words into the corresponding ATC concepts (more general speech information), which are further combined to ATC commands.
REQ-05-W2-97.2-TS-HMI0.0003	**Input acceptance** The ASR HMI should enable acceptance of automatically inserted value by ATCO clicking on the value, by clicking on confirmation button in the dialog line or by enabling automatic acceptance of recognized command values if the controller does not correct them within a predefined time frame (e.g. 10 seconds).	**TSSR-97.2-04** When the automatic acceptance is available, the command recognized and displayed by ASR shall be automatically accepted, if the controller does not reject it within an adjustable timeframe.
REQ-05-W2-97.2-TS-HMI0.0004	**Manual correction** The HMI shall enable manual correction/update of automatically proposed command value/type.	**TSSR-97.2-06** If a command recognised by ASR is identified as incorrect by the controller, he/she shall be able to manually to correct it and the corrected command shall be displayed.
REQ-05-W2-97.2-TS-ReTi.0001	**Provide callsign information immediately** ASR should give a response not later than 1.0 second after the controller has	**TSSR-97.2-03**

	pressed the push-to-talk-button, by sending the recognized callsign to the cooperating ATC system.	A callsign, which is being considered by the system shall be highlighted in the CWP HMI, after being recognised as part of ATCO's utterance.
REQ-05-W2-97.2-TS-ReTi.0002	**Reaction Time** For the ATCO utterances except callsign itself, on average, the system should be able to give the final speech-to-text and text-to-concept result latest one second after the ATCO has released the push-to-talk button.	**TSSR-97.2-02** The Concept extraction function shall transform the sequence of spoken words into the corresponding ATC concepts (more general speech information), which are further combined to ATC commands.
REQ-05-W2-97.2-TS-Perf.0001	**Command Recognition Error Rate** The Command Recognition Error Rate of ASR SHOULD be less than 2.5%.	**TSSR-97.2-02** The Concept extraction function shall transform the sequence of spoken words into the corresponding ATC concepts (more general speech information), which are further combined to ATC commands.
REQ-05-W2-97.2-TS-Perf.0002	**Command Prediction Error Rate** The Command Prediction Error Rate should not be higher than 10% and also not be higher than 50% of the opposite command recognition rate (i.e. 100% minus the command recognition rate), without using the checker.	**TSSR-97.2-01** Command predictor shall forecast possible future controller commands for the Tower environment, taking into account periodically received contextual information updates.
REQ-05-W2-97.2-TS- ReTi.0003	**System reaction time** The use of ASR shall have no influence on the reaction time of the different systems/functional blocks used in the controller HMI.	**TS/IRS**
REQ-05-W2-97.2-TS- ReTi.0004	**System recognition time** The ASR shall start with the recognition of the spoken language directly after the first word has been spoken.	**TSSR-97.2-02** The Concept extraction function shall transform the sequence of spoken words into the corresponding ATC concepts (more general speech information), which

		are further combined to ATC commands.
REQ-05-W2-97.2-TS-Perf.0005	**Command Recognition Rate** The Command Recognition Rate of ASR shall be higher than 95%.	**TSSR-97.2-02** The Concept extraction function shall transform the sequence of spoken words into the corresponding ATC concepts (more general speech information), which are further combined to ATC commands.

B.2.1 Static and dynamic analysis of the technical system for 97.2

TSRD ID	Technical Safety Requirement content	TSSR (ID)
REQ-05-W2-97.2-TS-Safe.0001	**ASR and Safety nets** ASR shall be interoperable with other safety nets available.	**new**
REQ-05-W2-97.2-TS-ASR0.0010	**Silent/passive acknowledgement** The ASR should acknowledge the clearance uttered in a silent/passive manner with the time out.	**TSSR-97.2-04** When the automatic acceptance is available, the command recognized and displayed by ASR shall be automatically accepted, if the controller does not reject it within an adjustable timeframe.
REQ-05-W2-97.2-TS-HMI0.0002	**AI feed callsign recognition levels visualisation** The ASR HMI shall highlight the recognised callsign in a different colour in case of uncertainty in callsign recognition in a range of percentage to be assessed.	**new**
REQ-05-W2-97.2-TS-Safe.0003	**Representative ontology and voice samples** ASR shall be trained with local operations ontology sample, which is representative of the different circumstances that occur during the operations.	**new**

REQ-05-W2-97.2-TS-Saf.0004	**Integration into the existing system** ASR shall be fully integrated into existing operating system.	**new**
REQ-05-W2-97.2-TS-ASR0.0009	**ASR switch off/on** ASR shall provide the ATCO with a switch on/Switch off function.	**TS/IRS**

Appendix C Designing the technical system for addressing Internal System Failures

This appendix presents the detailed risk evaluation and mitigation of the functionality hazards identified at Section 4.3, performed at the level of the technical system design.

C.1 Deriving TSRD from TSSR (integrity/reliability) for 97.1

Hz-01	Failure of the V/AR system (e.g. freezing or Tracking Labels or perceptual cues complete loss) prevents the AR device from being updated. RWY-SC5	V/AR system is unresponsive potentially impacting trajectory management and associated safety net.	**TSSR-97.1-023** The frequency of failure of the V/AR system (e.g. freezing or Tracking Labels or perceptual cues complete loss) shall not by higher than 1E-04 [per ops hour]	REQ-05-W2-97.1-TS-PERF.0008 The frequency of failure of the V/AR system (freezing or Tracking Labels or perceptual cues complete loss) shall not by higher than 1E-04 [per ops hour
Hz-02	TL is erroneously associated to a wrong aircraft (wrong information) RWY-SC5	ATCo may focus on the wrong aircraft and issues the clearance intended for another aircraft.	**TSSR-97.1-024** The frequency of TL erroneously associated to a wrong aircraft (wrong information) shall not by higher than 1E-04 [per ops hour]	REQ-05-W2-97.1-TS-PERF.0009 The frequency of TL erroneously associated to a wrong aircraft (wrong information) shall not by higher than 1E-04 [per ops hour]
Hz-03	Presentation of TL information within the V/AR does not support ATCo in task execution RWY-SC5	If the presentation of TL on the AR device is inadequate (e.g. TLs overlapping, size issues – e.g. depth).	**TSSR-97.1-05** The V/AR shall provide the controller with the relevant airport, weather and flight information to perform the RWY or GND tasks. **TSSR-97.1-07** V/AR system displays Tracking Labels in a manner permitting ATCO distinguishing each active	REQ-05-W2-97.1-TS-VAR1.0006 REQ-05-W2-97.2-TS-PERF.0007 REQ-05-W2-97.2-TS-VAR2.0002 REQ-05-W2-97.2-TS-VAR2.0003 REQ-05-W2-97.1-TS-VAR1.0007 REQ-05-W2-97.1-TS-VAR2.0005

			aircraft, (using the label antioverlapping feature)	
Hz-04	The responsiveness of the V/AR system as a result of ATCO's input/gesture or flight information changes) is inadequate for the accomplishment of operations. RWY-SC5	If the use of V/AR introduces delays in the display of information, this may cause the ATCo to focus on V/AR until verified that the information has been correctly processed and displayed. This may have negative impact on ATCo situational awareness.	**TSSR-97.1-025** The responsiveness of the V/AR system as a result of ATCO's input/gesture or flight information changes) shall be adequate for the task execution.	REQ-05-W2-97.1-TS-PERF.0010 The frequency of V/AR system failure to identify inputs (gestures) – no response, shall not by higher than 1E-04 [per ops hour
Hz-05	V/AR system fails to identify inputs (gestures) – no response RWY-SC5	Unidentified inputs as a result of correct gestures may distract the ATCo from the primary task of ATS provision and results in temporary workload increase and reduction in situational awareness as failures in TL inputs may require increased concentration on the V/AR system.	**TSSR-97.1-026** The frequency of V/AR system failure to identify inputs (gestures) – no response, shall not by higher than 1E-04 [per ops hour]	REQ-05-W2-97.1-TS-PERF.0010 The frequency of V/AR system failure to identify inputs (gestures) – no response, shall not by higher than 1E-04 [per ops hour
Hz-06	V/AR system wrongly identifies input (gesture) – provides erroneous output	In isolated instances the erroneous recognition of an input has no significant safety impact as the ATCo is able to	**TSSR-97.1-027** The frequency of erroneous identification of inputs (gestures) by V/AR system, shall	REQ-05-W2-97.1-TS-PERF.0011

	RWY-SC5	correct the input. Assumption is that the instances of erroneous input recognitions happen at a low enough rate that the system performance is still above the specified gesture recognition threshold. In instances where the V/AR system makes erroneous gesture recognitions continuously and/or below the specified gesture recognition threshold the ATCo will be required to perform manual changes to correct the ATM-system inputs performed by the V/AR system. If the TV/AR system fails to perform in accordance with the specified gesture recognition threshold this may have a human performance impact causing disruption to the expected workflow and cognitive processes.	not by higher than 1E-04 [per ops hour]	The frequency of erroneous identification of inputs (gestures) by V/AR system, shall not by higher than 1E-04 [per ops hour]

Table 21 PJ05-W2-97.1 TSSRs for failure conditions

ID	Description	Operational Effects	TSSR for Failure	TSSD for Failure
Hz1	Significant differences in recognition rates of different command type(s) RWY-SC5	If the ASR system performs at an acceptable recognition rate for some command types but below the required threshold for other command types, this may disrupt the ATCo workflow and introduce variations to ATCo workload even if traffic levels and complexity remain constant.	**TSSR-97.2-09** The ASR system shall perform at an acceptable recognition rate for all command types.	REQ-05-W2-97.2-TSSR-09.0001 The ASR system shall perform at an acceptable recognition rate for all command types REQ-05-W2-97.2-TS-Perf.0006 The frequency of erroneous identification of aircraft by ASR system, shall not by higher than 1E-04 [per ops hour].
Hz2	Significant delay in ASR command recognition and/or display. RWY-SC5	If the use of ASR introduces delays in the usage of speech information (display of inputs, identification of aircraft, etc.) this may cause the ATCo to focus on specific flight/area of the AoR until they can verify that the action induced by ASR has been correctly processed and displayed. This may have negative impact on ATCo situational awareness.	**TSSR-97.2-010** There shall be no significant delay in the display of inputs induced by ASR system on the HMI. Tolerable delay values depend on the OE and ANSP specific use cases.	REQ-05-W2-97.2-TSSR-09.0001 The ASR system shall perform at an acceptable recognition rate for all command types REQ-05-W2-97.2-TS-Perf.0006 The frequency of erroneous identification of aircraft by ASR system, shall not by higher than 1E-04 [per ops hour].
Hz3	ASR fails to identify an aircraft – no aircraft is highlighted	If ATCo performs the radio call it is assumed the impact is minor as the ATCo attention is focused on	**TSSR-97.2-03** A callsign, which is being considered by	REQ-05-W2-97.2-TS-Safe 0005

ID	Description	Operational Effects	TSSR for Failure	TSSD for Failure
	RWY-SC5	the aircraft being called and the impact is negligible	the system shall be highlighted in the CWP HMI, after being recognised as part of ATCO's utterance.	The contingency procedure in case of ASR failure shall be established.
Hz4	ASR erroneously identifies an aircraft – wrong aircraft is highlighted MAC-SC4b	If the aircraft performs the radio call and erroneous flight is highlighted, the ATCo may focus on the highlighted aircraft and issue the clearance intended for the calling aircraft to the wrong flight.	**TSSR-97.2-011** The frequency of erroneous identification of aircraft by ASR system, shall not by higher than 1E-04 [per ops hour].	REQ-05-W2-97.2-TS-Perf.0006 The frequency of erroneous identification of aircraft by ASR system, shall not by higher than 1E-04 [per ops hour].
Hz5	Presentation of ASR information on the CWP does not support ATCo task execution RWY-SC5	If the presentation of ASR data on the CWP is insufficient it may not lead to reduced workload due to more effort of information reading/understanding task of the display by the ATCo.	**TSSR-97.2-012** Inputs generated by an ASR-system displayed on the CWP HMI shall be consistent with other displayed data, complete, and fit-for-purpose. Consistency, completeness, and assessment of fit-for-purpose	REQ-05-W2-97.2-TS-HMI0.0001

ID	Description	Operational Effects	TSSR for Failure	TSSD for Failure
			is dependent on the ATM-system and other system functions used.	
Hz6	ATCo fails to recognise incorrect command proposed by ASR and thus wrong information is entered into the ATC system MAC-SC4b	Same impact as today situation, when ATCo enters wrong inputs or misses to enter commands.	**TSSR-97.2-013** The frequency of erroneous information entered into the ATC system due to the incorrect command recognition by ASR system, shall not by higher than 1.2e-05 [per ops hour]. 1e-4 [per fh] x 6 [fh/ops hour] = 6e-04 ATCO is assumed P=0.2 6e-04 x 0.2 =1.2e-05	REQ-05-W2-97.2-TS-Perf.0007 The frequency of erroneous information entered into the ATC system due to the incorrect command recognition by ASR system, shall not by higher than 1.2e-05 [per ops hour].

Table 22 PJ05-W2-97.2 TSSRs and TRRD for failure conditions

Appendix D Assumptions, Safety Issues & Limitations

D.1 Assumptions log

No new safety assumptions were identified during the safety assessment process. The general concept assumptions are considered for the assessment.

D.2 Safety Issues log

No safety issues were identified during the assessment process

D.3 Operational Limitations log

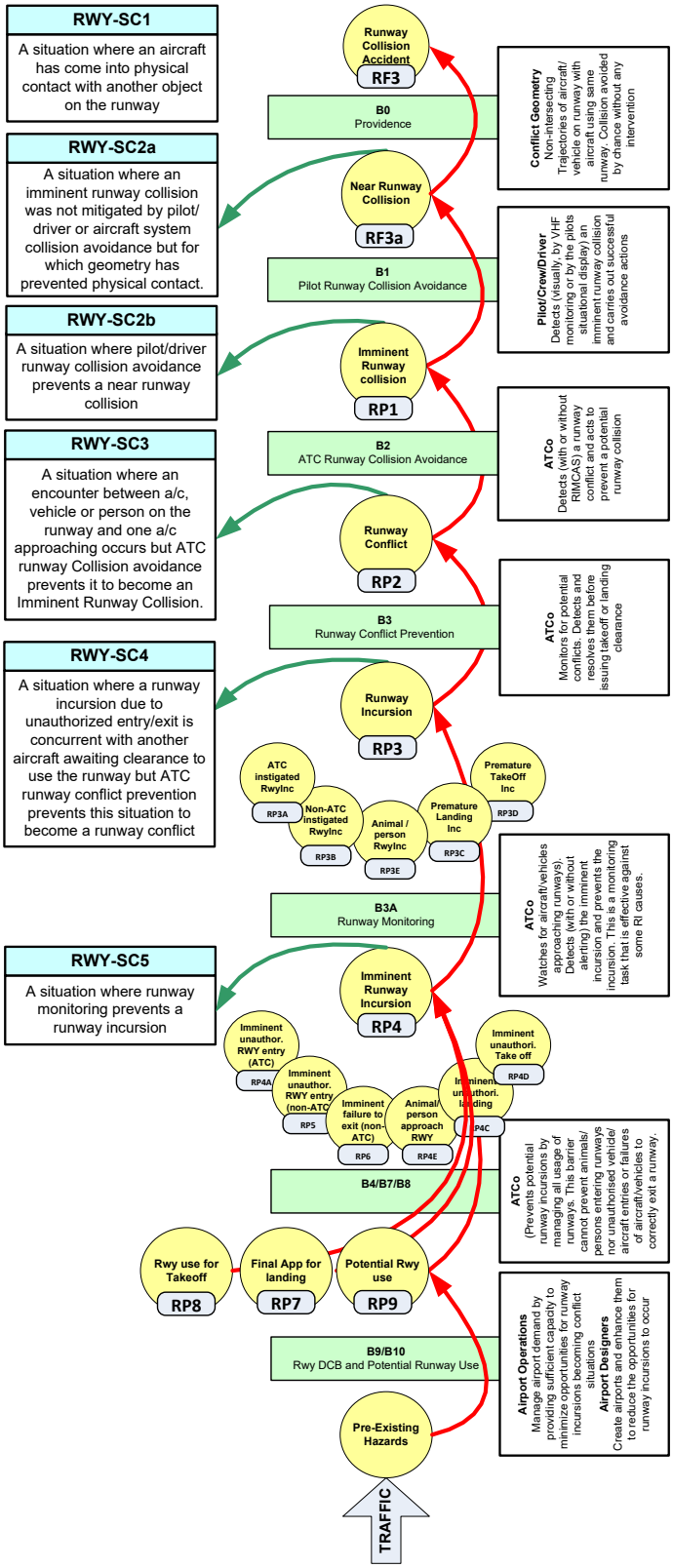
Appendix E Calculation of tolerable hazard's frequency

The method to calculate SO (TSSR) for a given hazard is as follows:

$$SO = \frac{MTFoO_{relevant\_severity\_class}}{N \times IM}$$

where:

- $MTFoO_{relevant\_severity\_class}$ stands for the Maximum Tolerable Frequency of Occurrence being the maximum probability of the hazard's effect as defined in Fehler! Verweisquelle konnte nicht gefunden werden. SRM
- N is the overall number of operational hazards for a given severity class at a given barrier as obtained from table 5 in E.4 (SRM) =100
- IM is the Impact Modification factor to take account of additional information regarding the operational effect of the hazard, in particular related to the number of aircraft exposed to the operational hazard=1



Severity Class Scheme for Runway Collision

AIM RWY BARRIER MODEL v0.2a

Severity Class	*Hazardous situation*	*Operational Effect*	*MTFoO [per movt.]*
RWY-SC1	A situation where an aircraft has come into physical contact with another object on the runway	Accident - Runway Collision (RF3)	1e-8
RWY-SC2a	A situation where an imminent runway collision was not mitigated by pilot/driver or aircraft system collision avoidance but for which geometry has prevented physical contact.	Near Runway Collision (RF3a)	1e-7
RWY-SC2b	A situation where pilot/driver runway collision avoidance prevents a near runway collision	Imminent runway collision (RP1)	1e-6
RWY-SC3	A situation where an encounter between a/c, vehicle or person on the runway and one a/c approaching occurs but ATC runway Collision avoidance prevents it to become an Imminent Runway Collision.	Runway Conflict (RP2)	1e-5
RWY-SC4	A situation where a runway incursion due to unauthorized entry/exit is concurrent with another aircraft awaiting clearance to use the runway but ATC runway conflict prevention prevents this situation to become a runway conflict	Runway incursion (RP3)	1e-4
RWY-SC5	A situation where runway monitoring prevents a runway incursion	Imminent Runway incursion (RP4)	1e-2

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