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PJ.10-W2 PROSA

SEPARATION MANAGEMENT AND CONTROLLER TOOLS

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Abstract

Automatic Speech Recognition or ASR, as it is known in short, is the technology that allows human beings to use their voices to speak with a computer interface in a way that, by converting human speech into texts and the corresponding semantics, can provide a solution to significantly reduce ATCOs workload and increase ATM efficiency.

Considering the continuous growth of air traffic, ASR is a technology that can help the controller to carry out their task in a safer and more efficient way.

SESAR Solution PJ.10-W2-96 ASR deals with new methods of controller interaction with the Human Machine Interface (HMI), applying mature technologies from other domains to ATM. This will increase controller productivity, reduce workload, reduce stress level and enable the use of SESAR advanced tools, safely facilitating performance-based operations.

This document aims at presenting the technical specification (TS) of the Automatic Speech Recognition function at technology readiness level (TRL) 6 and provides a consolidated set of technical requirements focused on Automatic Speech Recognition.

The enabler addressed is ER APP ATC 180 – Controller productivity enhancements by Automatic Speech Recognition at the ER/APP CWP/HMI.

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1 Executive summary

Automatic Speech Recognition or ASR, as it is known in short, is the technology that allows human beings to use their voices to speak with a computer interface in a way that, by converting human speech into texts and the corresponding semantics, can provide a solution to significantly reduce ATCOs workloads and increase ATM efficiency.

Considering the continuous growth of air traffic, ASR is a technology that can help the controller to carry out their task in a safer and more efficient way.

SESAR Solution PJ.10-W2-96 ASR deals with new methods of controller interaction with the Human Machine Interface (HMI), applying mature technologies from other domains to ATM. This will increase controller productivity, reduce workload, reduce stress level and enable the use of SESAR advanced tools, safely facilitating performance-based operations.

This document aims to present the technical specification (TS) of the Automatic Speech Recognition function at technology readiness level (TRL) 6 and provides a consolidated set of technical requirements focused on Automatic Speech Recognition for industrialisation.

As most inputs come from the ATCO-pilot spoken dialog, ASR is the appropriate technology to reduce ATCO's workload by directly using the spoken commands instead of manually inputting them into the system. ASR also enables highlighting radar labels during ATCO-Pilot dialogue

The solution also includes HMI requirements developed to present the results of the speech recognition (highlighting of targets, user-friendly and intuitive operation etc.) in the best way to the controllers.

ASR in the ATC environment is not perfect yet, the solution aims to a commands recognition rate better than overall 85% which is quite ambitious. Further research is needed with regards to acceptable recognition rates, considering that they may vary depending on the use case. Comparison algorithms have been developed avoiding that wrong recognitions are missed by the controller and used by subsequent systems. This requires integration of artificial intelligence (AI) and machine learning algorithms for the intelligent data provision to the controllers. In addition, the solution also investigated how ASR may be used to enable faster and more predictable navigation in 3D visualizations of the air space sectorisation when using dynamic air space configuration (DAC). One of the challenges addressed is how to combine using speech to communicate with pilots and other ATCOs with using speech to control the 3D navigation.

The enabler addressed is ER APP ATC 180 – Controller productivity enhancements by Automatic Speech Recognition at the ER/APP CWP/HMI.

2 Introduction

2.1 Purpose of the document

This document is used to capture and consolidate the set of Technical Requirements for SESAR Solution PJ.10-W2-96 ASR. These requirements are applicable to implement automatic speech recognition in ATC systems, using controllers' and pilots' voice and doing the transcription.

2.2 Scope

This is the TS/IRS for SESAR Solution PJ.10-W2-96 ASR, for the TRL-6 maturity level and constitutes the technical reference for the TRL-6 Data Pack.

On the one hand, the Technical Specification Requirements describe the functions that the system must fulfil to satisfy the Safety, Performance and Interoperability requirements. System requirements lie in the solution domain and are captured in this TS/IRS document.

On the other hand, The Technical Specification Requirements describe functional and capabilities specifications, covering performance, physical characteristics, environmental and facility conditions under which the functional blocks enabling a SESAR Solution have to perform, requirements to interfaces and data definitions, security specifications, design constraints.

Additionally, it is important to highlight that the requirements on this Technical Specifications are restricted to improvements on the ER APP ATC Domain System, mainly for the Automated Speech Recognition Functional block where the transcription is implemented.

2.3 Intended readership

Belonging to a SESAR Technological solution, this Technical Specification is of particular interest for all enabled SESAR ATM Solutions focusing on defining improved operational processes based on Human machine interface:

- **SESAR 2020 PJ.10-W2-96 ASR** consortium members in order to be aware of activities and methods being used to allow for coherency, consistency and comparability of the validation results through all solution 96 activities.
- **ER4 HAAWAIL project** members, so that they know what the expectations from industry to research are.
- **SESAR 3 JOINT UNDERTAKING** as SESAR 2020 Programme coordinator.
- **SESAR 2020 PJ.19 Content Integration** that aims at assuring coherency, consistency, and comparability of the validation results throughout all SESAR2020 Solutions.
- Representatives of civil stakeholders: **ANSPs**.
- Representatives of airspace users
- **SESAR 2020 Solution PJ.05-W2-97** consortium members, in order to have a common and shared view on all technologies related to the CWP HMI.

2.4 Background

Automatic Speech Recognition origins date back to 1952, when Davis, Biddulph and Balashek, at Bell Laboratories, designed and built a system able to recognize digits pronounced by a speaker, evaluating the frequencies of the vowels for each word [30]. Nowadays, after seven decades of development, Automatic Speech Recognition has extended broadly and can easily be found on personal computers and mobile phones.

Regarding its introduction in the ATM environment, Automatic Speech Recognition application to Air Traffic Control was already investigated by The Massachusetts Institute of Technology in 1987 by means of a proof of concept to identify required capabilities for advanced ASR systems for operational use [31]. About thirty years later, the Horizon 2020 SESAR project MALORCA (Machine Learning of Speech Recognition Models for Controller Assistance) [34] investigated the application of machine learning processes to adapt the recognition engines to local accents and other environmental variables, and therefore ease and cheapen deployment of ASR in operational systems [32].

PJ.16-04 was a SESAR 2020 solution in Wave 1 dealing with new methods of controller interaction with the Human Machine Interface. Several technologies were investigated for application to the ATM domain, namely Automatic Speech Recognition, Multi Touch Inputs, Attention Guidance, User Profile Management Systems and Qualification of CWP Virtualisation. Automatic Speech Recognition matured up to TRL-4 and enabled the definition of rules for transformation of a sequence of ATC words into ATC concepts (by means of the so called “ontology”) and exploratory usage. PJ.16-04 concluded that speech recognition engines needed adaptation to achieve acceptable results.

2.5 Structure of the document

The TS/IRS is composed of several parts.

Part I covers the main body of the Technical Specification and Interface Requirements Specification:

- Sections 1 and 2 constitute the *Executive summary* and the *Introduction* as an overall approach to the solution and the present TS/IRS document.
- In section 3 *SESAR Solution Impacts on Architecture*, a solution overview is presented, together with the architectural high level aspects of the solution (links to Enablers and Capability Configurations).
- In section 4 *Technical Specifications*, the detailed EATMA diagrams are included in the first subsection, allowing a more detailed architectural description of the solution. In the second subsection, the requirements for the systems can be found; first, a general introduction to the ASR system, and then the requirements are classified on the improvements made to the ASR system.
- Section 5 *Recommendations for implementation* and 6 *Assumptions* include final considerations the deployment and assumptions made for the development of this solution.
- *Appendix A* is left blank as no Service Description Document (SDD) is necessary.
- *Appendix B* contains the *Ontology*.

Part II covers the Technological Safety Assessment Report (SAR) that describes the safety assessment work done for the SESAR Solution.

Part III covers the Security Assessment Report (SeAR) that describes the security assessment work done for the SESAR Solution. This Part III is developed locally by the project according to the template in the Security Reference Manual, but it is not included in the TS/IRS pack of Technological Solution.

Part IV covers the Human Performance Assessment Report (HPAR) that describes the Human Performance assessment work done for the SESAR Solution.

Part V covers the Environmental Assessment Report (ENVAR) that describes the Environmental assessment work done for the SESAR Solution.

2.6 Glossary of terms

Term	Definition	Source of the definition
Automatic Speech Recognition	An Automatic Speech Recognition (ASR) system gets an audio signal 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 ATC concepts (“text-to-concepts”) using an ontology. E.g: The word sequence “lufthansa two alpha altitude four thousand feet on qnh one zero one four reduce one eight zero knots or less turn left heading two six zero” is transcribed into “DLH2A ALTITUDE 4000 ft, DLH2A INFORMATION QNH 1014, DLH2A REDUCE 180 OR_LESS, DLH2A HEADING 260 LEFT”. The resulting concepts can be used for further applications such as visualization on an HMI.	PJ.16-04
Command Recognition Rate	The number of controller commands which are correctly recognized by ASR and are not rejected divided by number of total given commands; in other words: the percentage of given commands correctly shown on the controllers’ HMI. $CRR = \frac{\text{correctly recognised controller commands}}{\text{controller commands}} \cdot 100$ The term “command” is used in a generic way and might refer to the callsign itself for the applicable use cases.	PJ.16-04
Command (Recognition) Error Rate	The number of controller commands which are wrongly recognized by ASR and which are not rejected divided by number of total given commands; in other words: the percentage of given commands wrongly shown on the controllers’ HMI. $CER = \frac{\text{wrongly recognised controller commands}}{\text{controller commands}} \cdot 100$ The term “command” is used in a generic way and might refer to the callsign itself for the applicable use cases.	PJ.16-04
Command Hypotheses Predictor	Components needed for Assistant Based Speech Recognition which predicts a set of possible commands.	PJ.16-04

Command Prediction Error Rate	The number of controller commands which are not predicted by the Command Hypotheses Predictor divided by number of total given commands. $C_{PER} = \frac{\text{not predicted commands}}{\text{controller commands}} \cdot 100$ The term “command” is used in a generic way and might refer to the callsign itself for the applicable use cases.	PJ.16-04
Command (Recognition) Rejection Rate	The number of recognized controller commands which are correctly or wrongly rejected (plus number of given controller commands which are not recognized at all) divided by number of total given commands. $C_{RejR} = \frac{\text{rejected commands} + \text{not recognised commands}}{\text{controller commands}} \cdot 100$ The term “command” is used in a generic way and might refer to the callsign itself for the applicable use cases.	PJ.16-04
Functional Block	A logical and cohesive grouping of automated Functions in a Technical System	EATMA Guidance Material [1]
Assistant Based Speech Recognition (ABSR)	Automatic Speech Recognition system that benefits from input from an assistance system (e.g. arrival manager) to generate probable commands and improve speech recognition.	MALORCA project [34]
Ontology	An internal dictionary to Automatic Speech Recognition, containing the relation between regular spoken utterances and events they refer to in a logical way, i.e. the translation between human and machine languages.	PJ.10-W2-96 ASR

Table 1: Glossary

2.7 Acronyms and Terminology

Term	Definition
ABSR	Assistant Based Speech Recognition
ACC	Area Control Centre
AI	Artificial Intelligence
ANSP	Air Navigation Service Provider
APP	Approach
ASR	Automatic Speech Recognition
ASW	Air Situation Window
ATC	Air Traffic Control
ATCO	Air Traffic Controller
ATM	Air Traffic Management
ATS	Air Traffic Services
CC	Capability Configuration
CHMI	Controller HMI
CPDLC	Controller-Pilot Data Link Communications
CR	Change Request
CWP	Controller Working Position
DAC	Dynamic Airspace Configuration
EATMA	European Air Traffic Management Architecture
EC	Executive Controller
ENVAR	Environmental Assessment Report
ER	En-Route
EUROCAE	European Organisation for Civil Aviation Equipment
FPL	Flight Plan
HF	High Frequency
HLOR	High Level Operational Requirements
HMI	Human Machine Interface
HPAR	Human Performance Assessment Report
ICAO	International Civil Aviation Organisation

ID	Identifier
IRS	Interface Requirements Specification
MTI	Multi-Touch-Input
NSV	NATO System View
PC	Planning Controller
POI	Performance Operational Improvement
PTT	Push To Talk
SAR	Safety Assessment Report
SeAR	Security Assessment Report
SDD	Service Description Document
SESAR	Single European Sky ATM Research
SFPL	System Flight Plan
TLA	Target Location Assistance
TMA	Terminal Manoeuvring Area
TRL	Technology Readiness Level
TS	Technical Specification
UC	Use Case
VCS	Voice Communication System
VHF	Very High Frequency
VoIP	Voice over IP

Table 2: Acronyms and terminology

3 SESAR Solution Impacts on Architecture

Through this document, several architecture elements from EATMA are identified. The applicable Dataset reference to be considered is Dataset 22 (EATMA V15.0).

3.1 Target Solution Architecture

3.1.1 SESAR Solution(s) Overview

Solution PJ.10-W2-96 ASR aims at introducing Automatic Speech Recognition in the ATM domain, as a means to improve ATCO's situational awareness, reduce workload and increase productivity. Several commands can be recognised from the controller-pilot spoken dialog, and they can be directly presented (and input) on the CHMI instead of manually inputting them into the system. Highlighting of targets upon callsign pronunciation from the ATCO or pilot is also considered, as well as the use of functions in the CWP such as visualisation of sectorisation changes and 3D navigation. Artificial intelligence (AI) and machine learning algorithms are required for speech recognition engine training.

The solution operates in a medium TMA and En-Route operating environment.

SESAR Solution ID and Title	Functional Blocks/Role impacted by the SESAR Solution (from EATMA)	Enabler ID (from EATMA)	Enabler (from EATMA)	Title	Enabler coverage
PJ.10-W2-96 ASR (Automatic Speech Recognition)	Automatic Speech Recognition	ER APP ATC 180	Controller productivity enhancements by Automatic Speech Recognition at the ER/APP CWP/HMI		Fully

Table 3: SESAR Solution PJ.10-W2-96 ASR Scope and related Functional Blocks/roles & Enablers

ER APP ATC 180 is linked to POI-0055-SDM – Improving controller productivity by Automatic Speech Recognition (ASR) at the ER/APP CWP/HMI.

The addressed technical system is En-Route/Approach ATC.

Two main functional blocks are within the scope of solution PJ.10-W2-96 ASR:

- Automatic Speech Recognition, performing recognition functions.
- Controller Human Machine Interaction Management ER/APP, displaying recognised commands and adjusting display following ASR inputs.

Those main functional blocks interface with the following functional blocks in the scope of this solution:

- Flight Planning Lifecycle Management Data Distribution
- A/G datalink communications

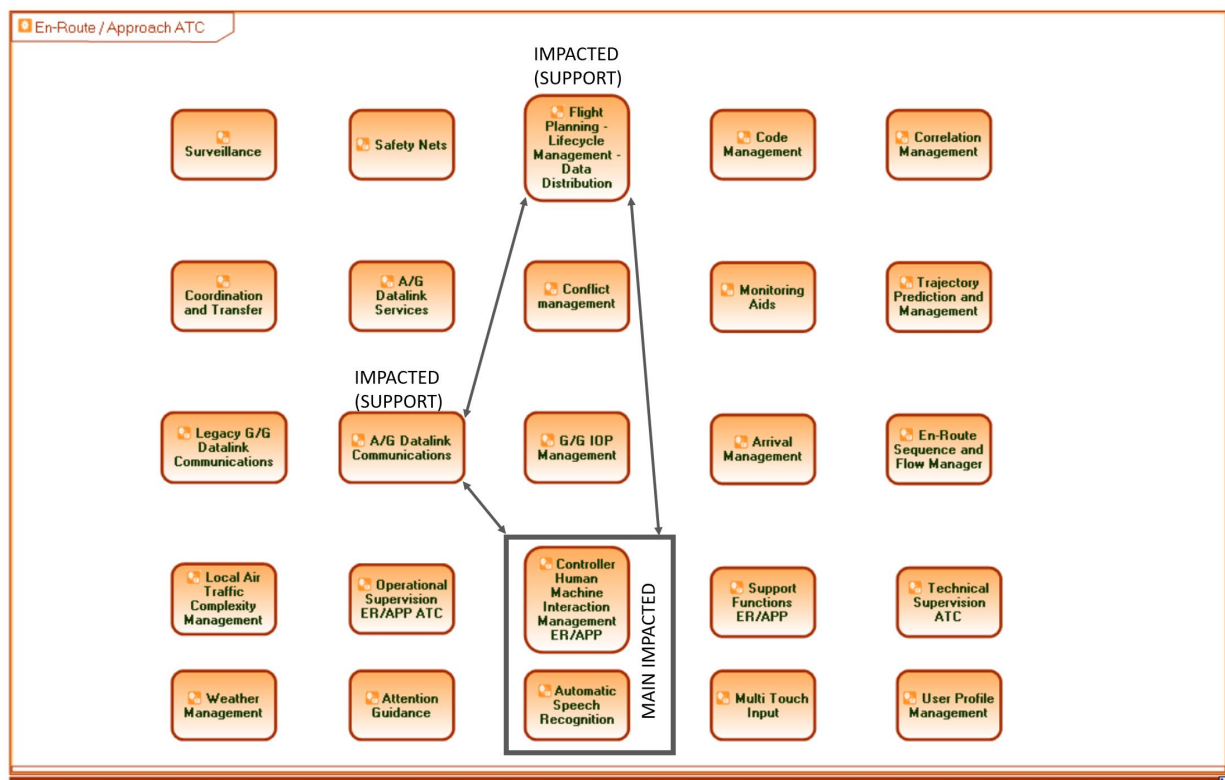


Fig. 1 Functional blocks context and interfacing

The main and strongest interaction among functional blocks for this solution is defined between the main impacted functional blocks Controller Human Machine Interaction Management ER/APP and Automatic Speech Recognition, as it can be seen in NSV-4 views.

One role is considered to be within the scope of this solution:

- ATC Executive Controller, being the role that mainly benefits from Automatic Speech Recognition.

No changes to system ports are required at capability configuration and technical system levels.

Note that the Pilot role appears in some use cases, but it is not considered in this specification as it only acts as trigger for use cases when acting as in today's operations. The introduction of ASR is transparent for this role.

3.1.1.1 Deviations with respect to the SESAR Solution(s) definition

No deviations have been detected.

3.1.1.2 Relevant Use Cases

This section contains a detailed description of the Use Cases selected to depict how the SESAR Solution PJ.10-W2-96 ASR works. The Use Cases cover the whole scope of the Solution with a focus on nominal situations, but not only:

Use Case	Use Case Title	Description
#3.1	Highlight of callsigns on the CWP from pilot utterances.	This use of the ASR technology will increase controller's situational awareness and reduce their workload, by quickly identifying new flights entering the sector or flight crews requesting actions from ATCOs (e.g. trajectory change, flight level change or information)
#3.2	Highlight of callsigns on the CWP from controllers' utterances.	The illumination of the callsign coming from a controller utterance provides a safety check to the controller that will be able to detect if there is a difference between the callsign mentioned and the flight in the CWP where the command is being introduced.
#3.3	Annotation of controllers' commands.	A historical annotation of the provided commands will be available to the controller for consultation. This will, at the same time, increase controllers' situational awareness and provide a safety check as they will be able to check the instructions given to the flights. This UC is an intermediate step before the semi-automatic/automatic input of commands in the CWP using ASR.
#3.4	Pre-filling of commands in the CWP	In this use case ATCOs will be presented with the recognized (and validated) command types together with the command values in the CWP. ATCOs will then be able to accept/reject or correct the commands.
#3.5	Voice commands for highlighting an upcoming sectorization change in the CWP	When using dynamic airspace configuration (DAC), it is important for the ATCOs to understand the upcoming changes (both horizontally and vertically) in the airspace configuration, both in the sector being

Use Case	Use Case Title	Description
		controlled by an ATCO, and to the neighbouring sectors. This use case will provide special voice commands for the ATCOs to investigate such changes before they occur.
#3.6	Voice commands for highlighting the fights that will be affected by an upcoming sectorization change in the CWP	When using dynamic airspace configuration (DAC), it is important for the ATCOs to understand how the current traffic is affected by the sector changes, particularly flights that need to be handed over to a different sector as a consequence of the sector changes. This use case will provide special voice commands for the ATCOs to highlight affected flights before and just after a sectorization change.
#3.7	Voice commands for navigating the 3D visualization of the air space in the CWP	One of the tools provided in the CWP to increase the ATCOs understanding of changes in the airspace configuration is a 3D visualization of the air space. This use case will provide special voice commands for navigating the 3D visualization and for highlighting certain parts of it.
#3.8	Prefilling of Datalink commands	After the Logon and Connecting procedure have been fulfilled, ATCOs will utter the datalink commands and the CWP will prefill the command values to be accepted/rejected or corrected by the ATCOs.

Table 4: List of Use Cases

The following subsections describe the nominal, alternate and failure flows of the use cases.

3.1.1.2.1 UC-96-TRL6-TS-3.1 / Highlight of callsigns on the CWP from pilots' utterances.

Scope/Description

The ASR recognizes a callsign from pilot utterances and highlights it in the controllers' HMI for the relevant time duration. The ASR technology will increase controller's situational awareness and reduce

their workload, by quickly identifying new flights entering the sector or flight crews requesting actions from ATCOs

Actors

En-Route Executive Controller (En-route EC), Approach Executive Controller (APP EC) and Flight Crew.

Preconditions

ATC and Voice systems relevant for the ATCO are available and running with Automatic Speech Recognition functionalities equipped. Radar, flight plan and other relevant external data are available and fed to the ASR.

Pilot emits utterance with callsigns

Post conditions

The correct callsign identified as part of the Pilot's utterance is highlighted.

Trigger

ASR receives external data from pilot to highlight callsigns.

Nominal Flow

1. Pilot emits utterance containing a callsign.
2. The ASR recognises a callsign as part of Pilot's utterance.
3. Recognised callsign is part of list of flights.
4. Recognised callsign is highlighted in the CWP HMI.

Failure Flow 1

1. Existing wrong callsign is recognized.
2. Wrong callsign is highlighted in the CWP HMI.

Failure Flow 2

1. Wrong callsign, not matching to anyone considered by the system, is recognized.
2. No existing callsign is highlighted.

3.1.1.2.2 UC-96-TRL6-TS-3.2 / Highlight of callsigns on the CWP from controllers' utterances.

Scope/Description

The ASR recognizes a callsign from Controller utterances and highlights it in the controllers' HMI for the relevant time duration. This will provide a safety check to the controller that will be able to detect if there is a difference between the callsign mentioned and the flight in the CWP where the command is being introduced.

Actors

En-Route Executive Controller (En-route EC) and Approach Executive Controller (APP EC)

Preconditions

ATC and Voice systems relevant for the ATCO are available and running with Automatic Speech Recognition functionalities equipped. Radar, flight plan and other relevant external data are available and fed to the ASR.

Post conditions

The correct callsign identified as part of the ATCO's utterance is highlighted.

Trigger

ASR receives external data from controller to highlight callsigns.

Nominal Flow

1. ATCO emits utterance containing a callsign.
2. A callsign, is recognised as part of ATCO's utterance.
3. Recognised callsign is part of list of flights.
4. Recognised callsign is highlighted in the CWP HMI.

Alternative Flow 1

1. Command Prediction function forecasts possible future ATCO's commands, taking into account relevant external data.
2. ATCO emits utterance containing a callsign.
3. A callsign, is recognised as part of ATCO's utterance.
4. Recognised callsign is part of list of flights.
5. Recognised callsign is highlighted in the CWP HMI.

Alternative Flow 2 / ATCO emits a utterance without a callsign

1. ATCO emits an utterance without a callsign.
2. No callsign is recognized, hence no callsign is highlighted.

Failure Flow 1

1. Existing wrong callsign is recognized.
2. Recognised wrong callsign is part of list of flights.
3. Wrong callsign is highlighted in the CWP HMI.

Failure Flow 2

1. Wrong callsign, not matching to anyone considered by the system, is recognized.
2. No existing callsign is highlighted.

3.1.1.2.3 UC-96-TRL6-TS-3.3 / Annotation of controllers' commands.

Scope/Description

A historical annotation of the provided commands will be available to the controller for consultation. This will, at the same time, increase controllers' situational awareness and provide a safety check as they will be able to check the instructions given to the flights. This UC is an intermediate step before the semi-automatic/automatic input of commands in the CWP using ASR.

Actors

En-Route Executive Controller (En-route EC) and Approach Executive Controller (APP EC)

Preconditions

ATC and Voice systems relevant for the ATCO are available and running with Automatic Speech Recognition functionalities equipped. Radar, flight plan and other relevant external data are available and fed to the ASR.

Post conditions

The correct callsign identified as part of the ATCO's utterance is highlighted and sequence of ATC concepts is displayed on CWP HMI in the form of a historical annotation.

Trigger

ASR receives external data.

Nominal Flow 1

1. ATCO emits utterance.

2. The sequence of words is transformed into a sequence of ATC concepts, based on a predefined ontology.
3. A callsign, which is being considered by the system, is recognised as part of ATCO's utterance.
4. Sequence of ATC concepts is displayed in the CWP HMI

Nominal Flow 2

1. Command Prediction function forecasts possible future ATCO's commands, taking into account relevant external data.
2. ATCO emits utterance containing a callsign.
3. A callsign is recognised as part of ATCO's utterance.
4. The utterance is transformed into a sequence of ATC concepts, based on a predefined ontology.
5. Sequence of ATC concepts is displayed in the CWP HMI.

Failure Flow 1

1. Existing wrong callsign is recognized.
2. The utterance is transformed into a sequence of ATC concepts, based on a predefined ontology.
3. Sequence of ATC concepts is displayed in the CWP HMI at the wrong callsign.

3.1.1.2.4 UC-96-TRL6-TS-3.4 / Pre-filling of commands in the CWP

Scope/Description

In this use case, ATCOs will be presented with the recognized (and validated) command types together with the command values in the CWP. ATCOs will then be able to accept/reject or correct the commands.

Actors

En-Route Executive Controller (En-route EC) and Approach Executive Controller (APP EC)

Preconditions

ATC and Voice systems relevant for the ATCO are available and running with Automatic Speech Recognition functionalities equipped. Radar, flight plan and other relevant external data are available and fed to the ASR.

Post conditions

The correct callsign identified as part of the ATCO's utterance is highlighted and the ATCO accepted ATC concepts are displayed in the CWP HMI and used by the ATC systems as inputs.

Trigger

ASR Command Prediction function receives external data to forecast potential ATCO's commands.

Nominal Flow

1. ATCO emits utterance.
2. The sequence of words is transformed into a sequence of ATC concepts, based on a predefined ontology.
3. A callsign, which is being considered by the system, is recognised as part of ATCO's utterance.
4. Sequence of ATC concepts is displayed in the CWP HMI for ATCO acceptance/rejection
5. ATCO accepts or rejects the sequence of ATC concepts.
6. Sequence of accepted ATC concepts is displayed in the CWP HMI and will be used by other ATC systems (as applicable).

Failure Flow 1

1. ATCO emits utterance.
2. The sequence of words is transformed into a sequence of ATC concepts, based on a predefined ontology.
3. An incorrect callsign, which is being considered by the system, is recognised as part of ATCO's utterance.
4. Sequence of ATC concepts is displayed for the incorrect flight in the CWP HMI for ATCO acceptance/rejection
5. ATCO accepts or rejects the sequence of ATC concepts.
6. Sequence of incorrectly accepted ATC concepts will be displayed in the CWP HMI and will be used by other ATC systems (as applicable).

Failure Flow 2

1. ATCO emits utterance.
2. The sequence of words is transformed into an incorrect sequence of ATC concepts, based on a predefined ontology.
3. A callsign, which is being considered by the system, is recognised as part of ATCO's utterance.

4. The incorrect sequence of ATC concepts is displayed in the CWP HMI for ATCO acceptance/rejection
5. ATCO accepts or rejects the sequence of ATC concepts.
6. Sequence of incorrectly accepted ATC concepts is displayed in the CWP HMI and will be used by other ATC systems (as applicable).

3.1.1.2.5 UC-96-TRL6-TS-3.5 / Voice commands for highlighting an upcoming sectorization change in the CWP

Scope/Description

When using dynamic airspace configuration (DAC), it is important for the ATCOs to understand the upcoming changes (both horizontally and vertically) in the airspace configuration, both in the sector being controlled by an ATCO, and to the neighbouring sectors.

The ASR will be used to input commands affecting only the HMI in the CWP. These special voice commands will allow the ATCO to investigate such changes before they occur. There will be special voice commands to let the ATCO highlight the current and upcoming layout of the sector being controlled and the neighbouring sectors. In addition, there will be voice commands for highlighting current and upcoming layout of an arbitrary sector in the ACC. Typical form of a voice command will be "Highlight current|upcoming <sector id> layout". There will also be commands for showing the current or upcoming layout of all sectors (alternative flow).

Actors

En-Route Executive Controller (En-route EC) and En-Route planner Controller (En-route PC)

Preconditions

ATC and Voice systems relevant for the ATCO are available and running with Automatic Speech Recognition functionalities equipped. Relevant external data are available and fed to the ASR.

Post conditions

The desired layout (current or upcoming) of a sector is highlighted.

Trigger

ATCO pushes the speech button and utters a sector highlight command.

Nominal Flow

1. ATCO utters a legal and understandable command addressing one specific sector
2. The corresponding sector is highlighted

Alternative Flow 1 / command for showing the upcoming layout of all sectors

1. ATCO utters a command for showing the current or upcoming layout of all sectors

2. The corresponding layouts are shown

Failure Flow 1

1. ATCO utters a legal and understandable command addressing a sector that is not part of the ACC
2. An error message is briefly shown, and the ATCO needs to say the command again

Failure Flow 2

1. ATCO utters an illegal/not understandable command
2. An error message is briefly shown, and the ATCO needs to say the command again

3.1.1.2.6 UC-96-TRL6-TS-3.6 / Voice commands for highlighting the flights that will be affected by an upcoming sectorization change in the CWP

Scope/Description

When using dynamic airspace configuration (DAC), it is important for the ATCOs to understand how the current traffic is affected by the sector changes, particularly flights that need to be handed over to a different sector as a consequence of the sector changes.

The ASR will be used to input commands affecting only the HMI in the CWP. These special voice commands will let the ATCO highlight flights that need special attention before and just after a sectorization changes.

Actors

En-Route Executive Controller (En-route EC) and En-Route planner Controller (En-route PC).

Preconditions

ATC and Voice systems relevant for the ATCO are available and running with Automatic Speech Recognition functionalities equipped. Relevant external data are available and fed to the ASR.

Post conditions

The relevant flights are highlighted on the radar screen and in the flight list(s).

Trigger

ATCO pushes the speech button and utters a flight highlight command.

Nominal Flow

1. ATCO utters a legal and understandable flight highlight command
2. The relevant flights are highlighted on the radar screen and in the flight list(s).

Failure Flow 1

1. ATCO utters an illegal/not understandable command
2. An error message is briefly shown, and the ATCO needs to say the command again

3.1.1.2.7 UC-96-TRL6-TS-3.7 / Voice commands for navigating the 3D visualization of the air space in the CWP

Scope/Description

One of the tools provided in the CWP to increase the ATCOs understanding of changes in the airspace configuration is a 3D visualization of the air space.

The ASR will be used to input commands affecting only the HMI in the CWP. These special voice commands will let the ATCO navigate the 3D visualization and for highlighting certain parts of it. Commands will typically be on the form "reset view", "view from top", "view from front", "rotate (counter) clockwise [<x> degrees]", "raise|lower [<x> degrees]", "look at <sector id>", "highlight <sector id>".

Actors

En-Route Executive Control (En-route EC) and En-Route planner Control (En-route PC).

Preconditions

ATC and Voice systems relevant for the ATCO are available and running with Automatic Speech Recognition functionalities equipped. Relevant external data are available and fed to the ASR.

Post conditions

The 3D view changes to reflect the content of the command.

Trigger

ATCO pushes the speech button and utters a 3D navigation command.

Nominal Flow

1. ATCO utters a legal and understandable command for moving viewpoint
2. The 3D view is adjusted accordingly

Alternative Flow 1 / command for showing the upcoming layout of all sectors

1. ATCO utters a command for highlighting one or more sectors
2. The corresponding sector(s) is/are highlighted

Failure Flow 1

1. ATCO utters a legal and understandable command addressing a sector that is not part of the ACC
2. An error message is briefly shown, and the ATCO needs to say the command again

Failure Flow 2

1. ATCO utters an illegal/not understandable command
2. An error message is briefly shown, and the ATCO needs to say the command again

3.1.1.2.8 UC-96-TRL6-TS-3.8 / Prefilling of Datalink commands

Scope/Description

The ASR will be used to input Datalink commands in the CWP. The CPDLC messages which will be taken into account will be the following:

- ATC clearances: MAINTAIN (level), CLIMB TO (level), DESCEND TO (level)
- SPEED: MAINTAIN (speed), MAINTAIN (speed) OR GREATER, MAINTAIN (speed) OR LESS, RESUME NORMAL SPEED
- ROUTE: FLY HEADING, TURN [direction] HEADING [degrees], CONTINUE PRESENT HEADING, TURN [direction][degrees] DEGREES, PROCEED DIRECT TO [position]]

Actors

En-Route Executive Control (En-route EC), Approach Executive Control (APP EC) and Flight Crew.

Preconditions

The flights are Datalink equipped. Logon and connection executed.

Post conditions

ATCO workload is reduced due to the less manual input needed.

Trigger

ATCO pushes the speech button and utters a datalink command.

Nominal Flow

1. ATCO utters in the ASR microphone.
2. The ASR provides in input of the CWP a datalink command that is presented on the relevant mask of the CWP.
3. The ATCO checks the command and acknowledges it.
4. The command is executed and the flight plan is updated.

Alternative Flow

1. ATCO utters in the ASR microphone.
2. The ASR provides in input of the CWP a datalink command that is presented on the relevant mask of the CWP.
3. The ATCO checks the command and corrects it manually before acknowledging it
4. The command is executed and the flight plan is updated.

Failure Flow

1. ATCO utters in the ASR microphone.
2. The ASR provides in input of the CWP a datalink command that is presented on the relevant mask of the CWP.
3. The ATCO checks the command and rejects it.
4. The command is not executed.
5. The ATCO inputs the command manually.
6. The command is executed and the flight plan is updated.

Failure Flow 2

1. ATCO utters in the ASR microphone.
2. The ASR is not able to provide an output because it fails to identify a datalink command.
3. No datalink command is presented on the HMI.
4. The ATCO inputs the command manually.
5. The command is executed and the flight plan is updated.

3.1.1.3 Applicable standards and regulations

EUROCAE ED-137 (Interoperability Standards for VoIP ATM Components) has been identified as the applicable standard for VoIP communications in ATC environments. Therefore, the integration of the ASR system in the ATS architecture, at least regarding VoiceFlow forwarding from VCS to ASR, should comply with this standard to assure interoperability with Voice Communication Systems.

Chapter 12 in ICAO Doc 4444 refers to Phraseology. Communication procedures and standard phraseology are detailed in this document.

3.1.2 Capability Configurations required for the SESAR Solution

SESAR Solution and Title	ID	Capability Configurations (CCs) (from EATMA)	Sub-Operating Environment(s) where the CCs operate	Capabilities (from EATMA)	Nodes (from EATMA)	Stakeholders (from EATMA)
PJ.10-W2-96 ASR (Automatic Speech Recognition)	En-Route ACC	High Complexity	Controller Machine Interface Design	En-Route/Approach ATS	Civil ATS Approach Service Provider	
		Medium Complexity			Civil ATS En-Route Service Provider	
		Low Complexity				
	Approach ACC	High Complexity	Controller Machine Interface Design	En-Route/Approach ATS	Civil ATS Approach Service Provider	
		Medium Complexity			Civil ATS En-Route Service Provider	
		Low Complexity				

Table 5: List of Capability Configuration required for the SESAR Solution.

Note that the Civil Aircraft Capability Configuration is used in the Resource Orchestration views but it is not considered within the scope of the solution as it acts as trigger for use cases when acting as in today's operations. No changes are applicable to the Civil Aircraft CC for the introduction of ASR, being it transparent for the mentioned CC.

3.2 Changes imposed by the SESAR Solution on the baseline Architecture

Enabler ID (from EATMA)	Enabler (from EATMA)	Title	Changes
ER APP ATC 180	Controller productivity enhancements by Automatic Speech Recognition at the ER/APP CWP/HMI		The following functional blocks have been modified to add the listed functions: • Automatic Speech Recognition: - o Command Prediction - o Recognise Voice Words - o Apply Ontology and Logical Check • Controller Human Machine Interaction Management ER/APP - o Adjust Display - o Highlight Sectors or Flights Affected by Sectorization Change - o Highlight Flight - o Display Full Recognised Command - o Display Proposed Clearance for Acceptance or Rejection - o Wait for Acceptance or Rejection - o Discard Proposed Clearance - o Edit Proposed Clearance

Table 6: List of changes due to the SESAR Solution

4 Technical Specifications

4.1 Functional architecture overview

This section describes the functional architecture including the following system views: resource connectivity model, resource orchestration view and the infrastructure connectivity model.

4.1.1 Resource Connectivity view

This solution does not require any modifications to resource interactions between the applicable capability configurations, as changes are local to the ER/APP ATC capability configuration and do not have any impact beyond their architectural boundaries. The following resource connectivity view is presented to provide a context to the reader, showing the applicable resource interaction for this solution.

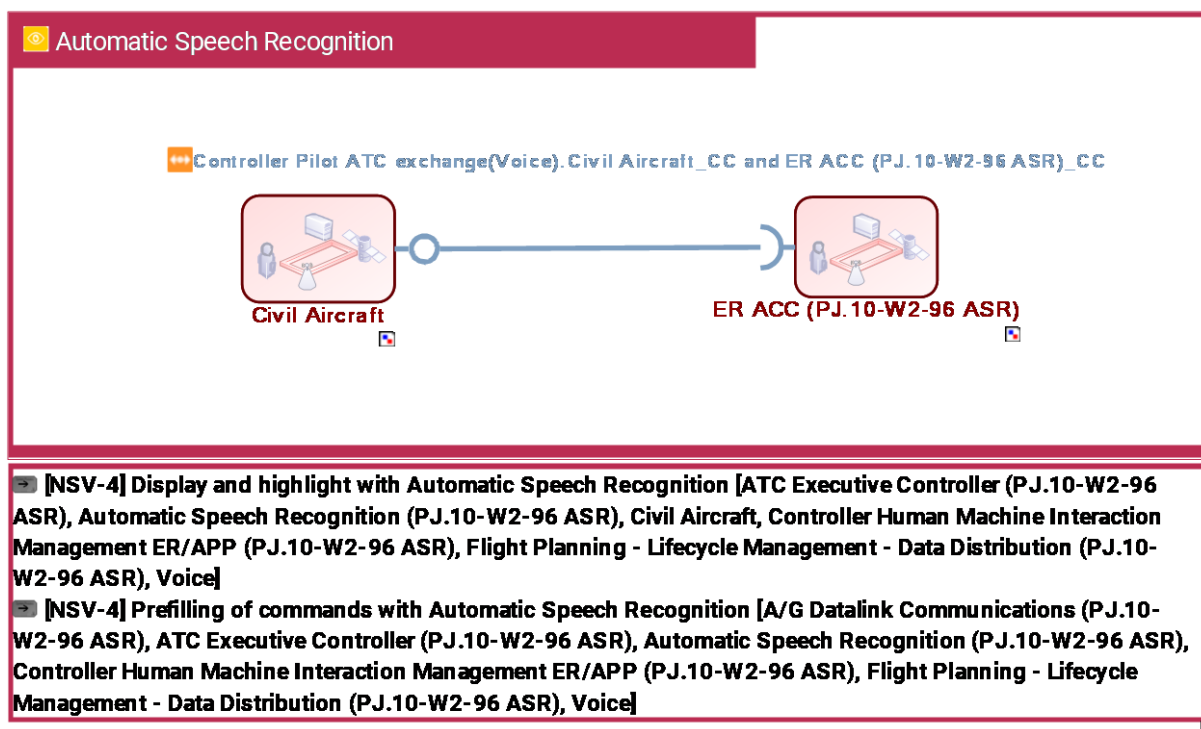


Fig. 2 Resource architecture connectivity view (NSV-1)

At a technical system level and to assure good integration within EATMA, a new resource interaction needs to be deployed between technical systems En-route/Approach ATC and Voice both in ER ACC and APP ACC capability configurations. This is because Voice is in charge of the reception and transmission of audio between the controller and the flight crew. However, the Automatic Speech

Recognition functional block, which constitutes the core of PJ.10-W2-96 ASR, is located within the ER/APP ATC technical system. Therefore, a simple voice forwarding resource interaction is deployed between those technical systems: Voice Flow Forwarding.

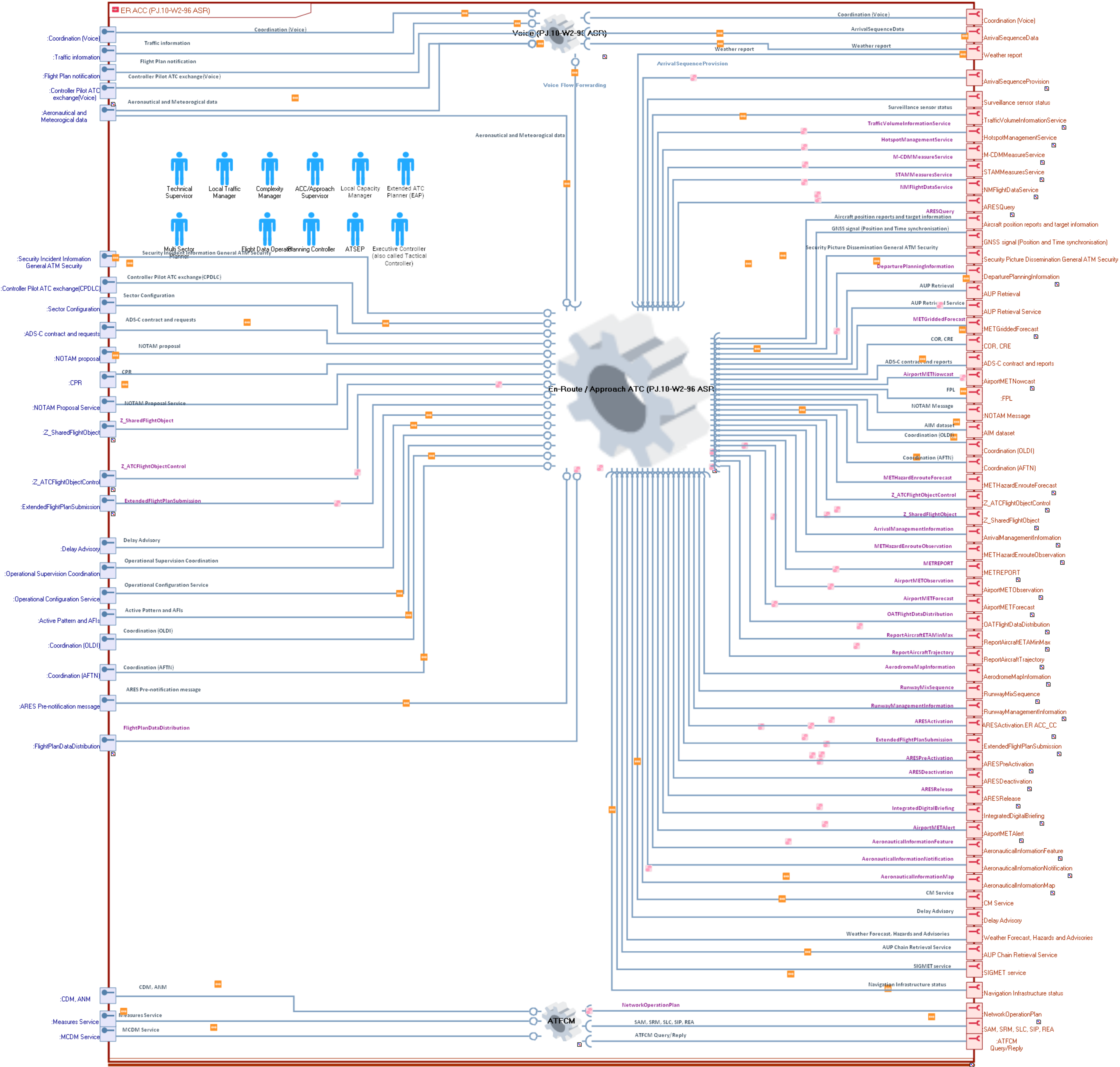


Fig. 3 Resource architecture structure for ER ACC (PJ.10-W2-96 ASR)

4.1.1.1 Resource Infrastructure view

This solution does not require any modifications to existing system ports and connectors between the applicable capability configurations. The following resource infrastructure view is presented as context.

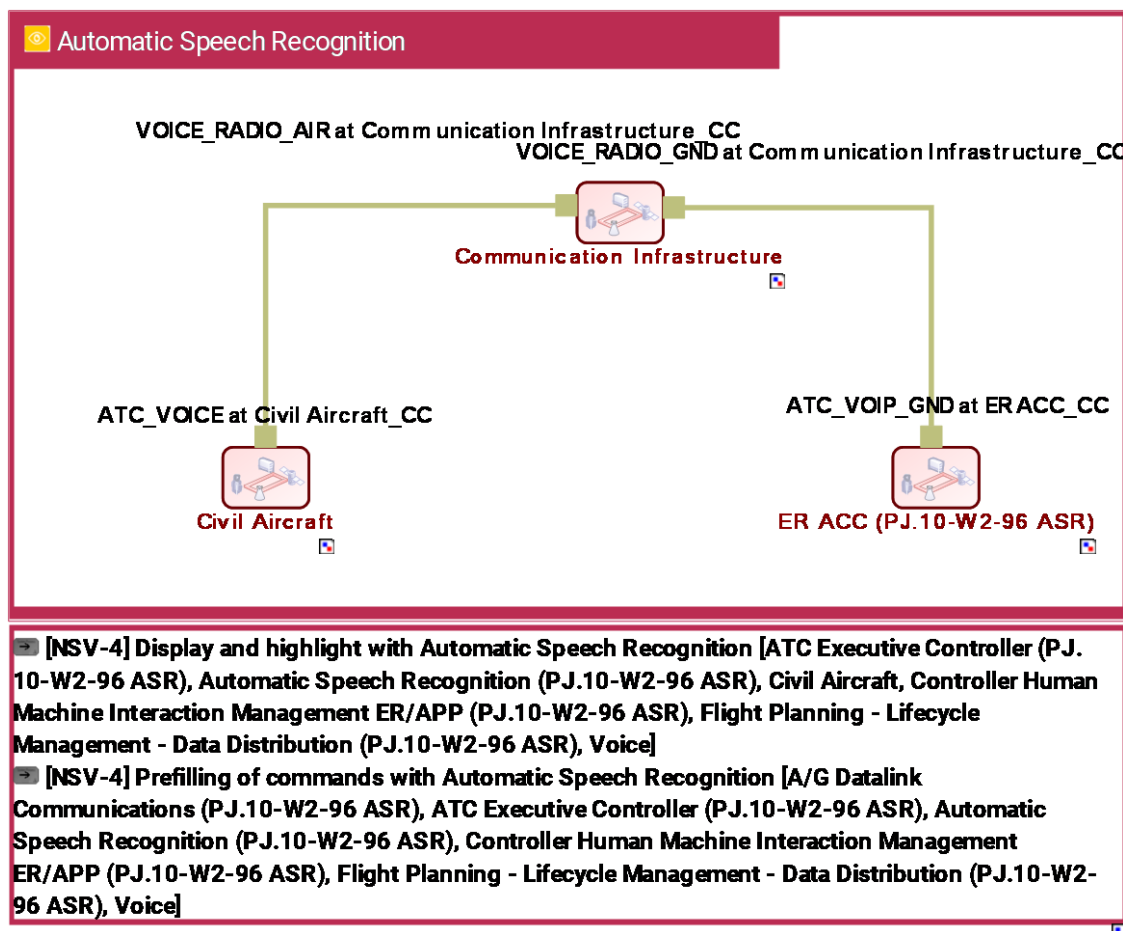


Fig. 4 Resource architecture infrastructure view (NSV-2)

At a technical system level and according to what was presented previously, resource interaction Voice Flow Forwarding has been deployed. This resource interaction follows existing Proprietary Standard system port connector between Voice and En-Route/Approach ATC, so no modifications are needed at infrastructure level between technical systems within ER ACC (also applicable to APP ACC). The following figure is shown for completeness.

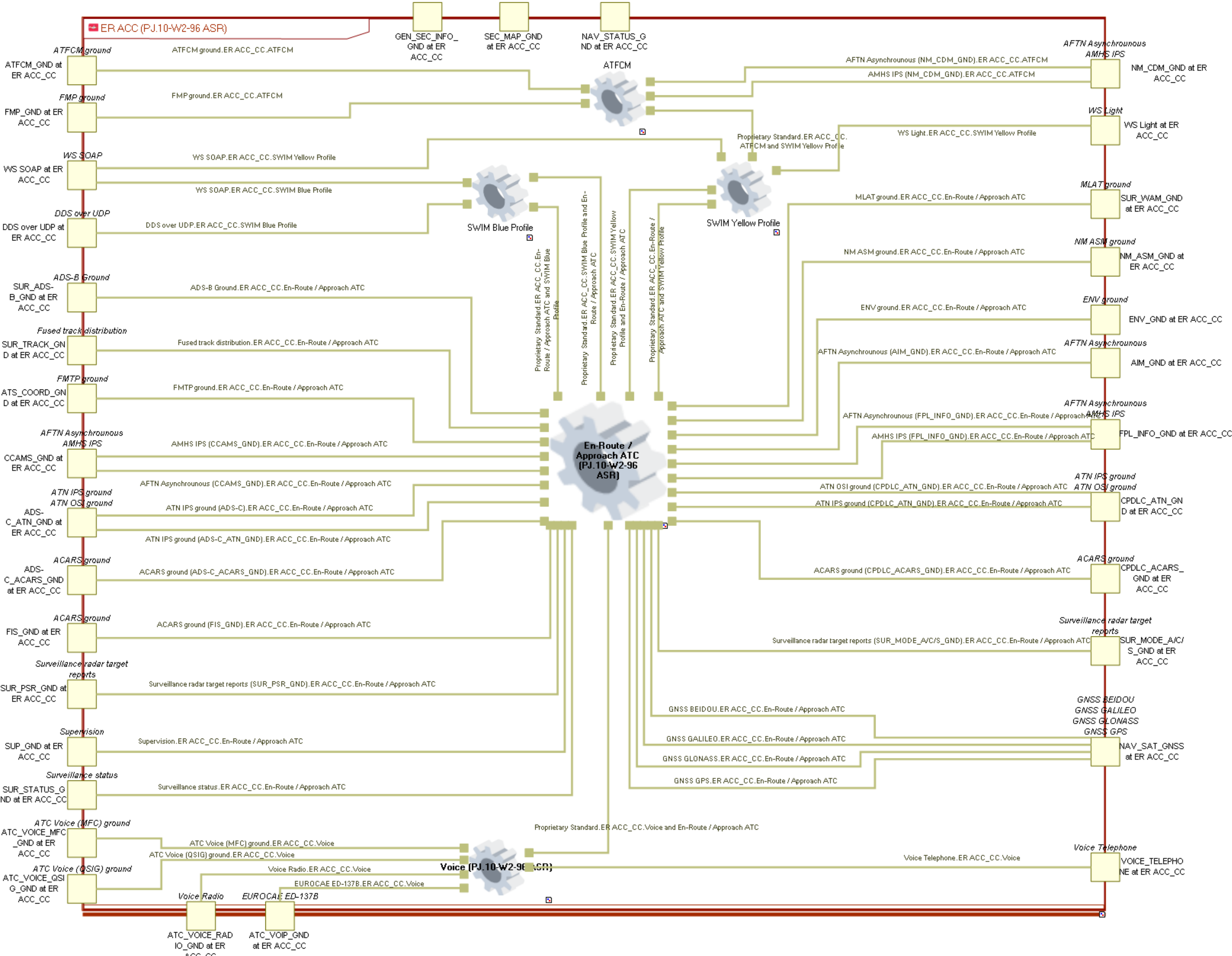


Fig. 5 Resource architecture infrastructure for ER ACC (PJ.10-W2-96 ASR)

The system ports used for the deployed Voice Flow Forwarding resource interaction are:

- ATC_VOICE_GND_PROPRIETARY_GND at Voice
- ATC_VOICE_GND_PROPRIETARY_GND at En-Route/Approach ATC

The following diagrams show these relationships.

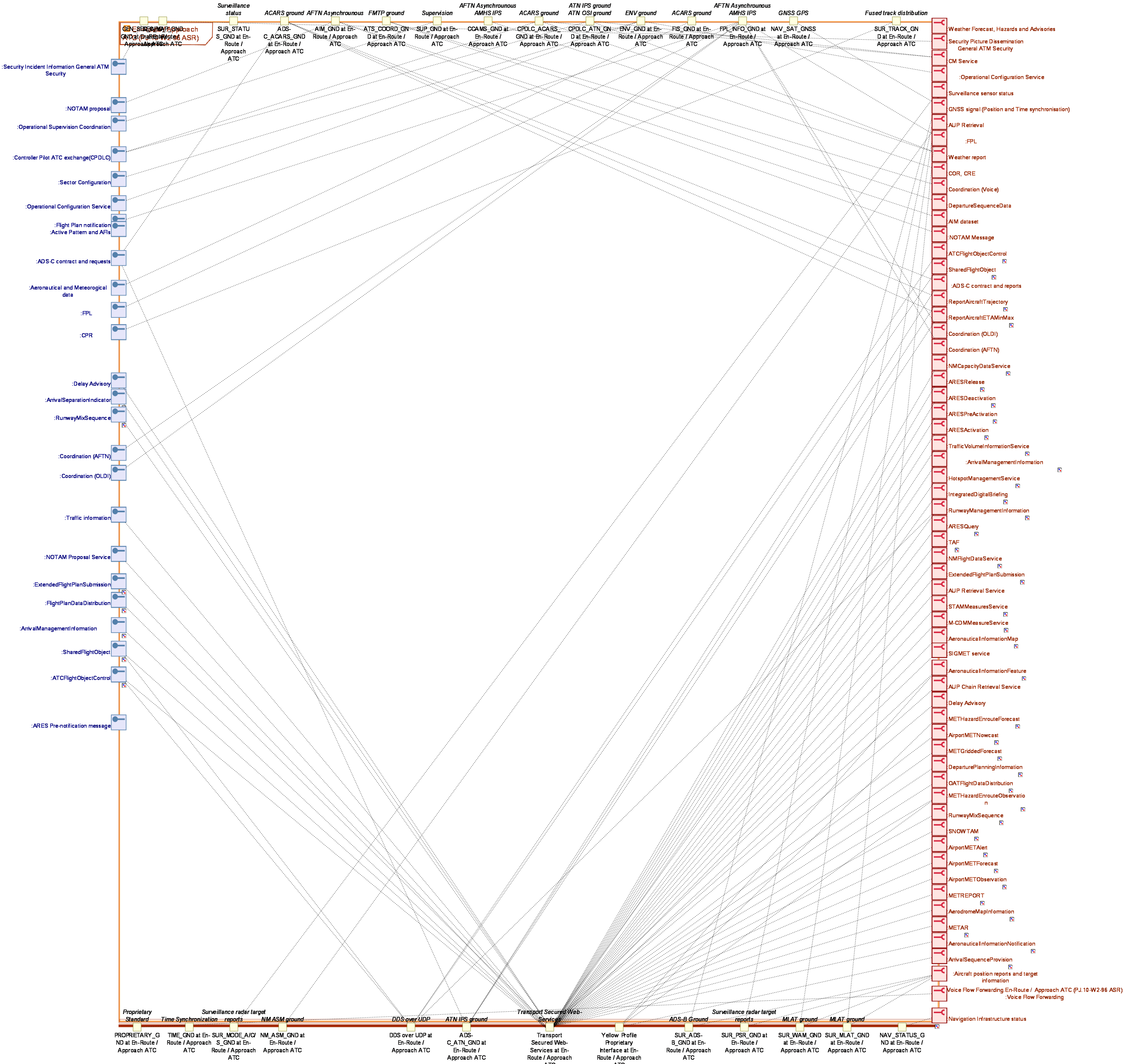


Fig. 6 Artefact assembly diagram for En-Route/Approach ATC (PJ.10-W2-96 ASR)

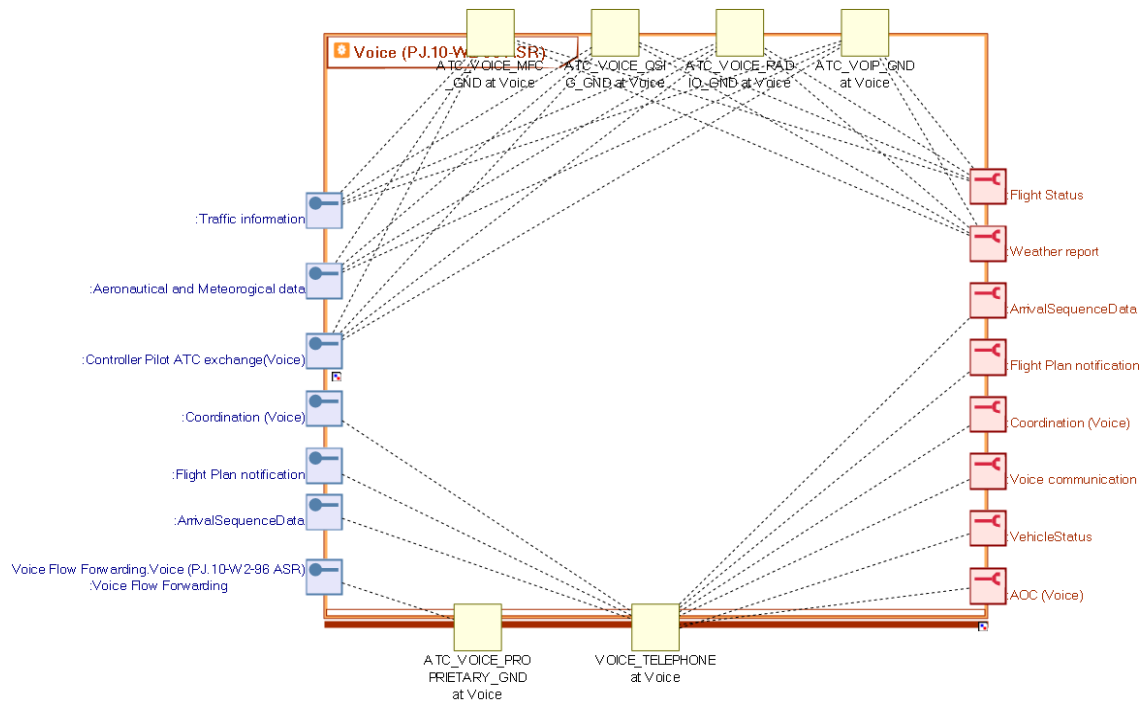


Fig. 7 Artefact assembly diagram for Voice (PJ.10-W2-96 ASR)

4.1.1.2 Resource Orchestration view: Display and highlight with Automatic Speech Recognition

View [NSV-4] *Display and highlight with Automatic Speech Recognition* is related to the following use cases:

- Use case 1: Highlight of callsigns on the CWP from pilot's utterances
- Use case 2: Highlight of callsigns on the CWP from controller's utterances
- Use case 3: Annotation of controller's commands
- Use case 5: Voice commands for highlighting an upcoming sectorization change in the CWP
- Use case 6: Voice commands for highlighting the flights that will be affected by an upcoming sectorization change in the CWP
- Use case 7: Voice commands for navigating the 3D visualization of the airspace in the CWP

The descriptions of the functions used in this view are detailed below:

Function	Description
Adjust Display	The current point of view in the CHMI is modified according to the uttered command.
Apply Ontology and Logical Check	The text string is analysed and transformed into a set of predefined commands by using the Ontology, and a logical check is performed to discard incoherent commands.
Command Prediction	Forecasting of possible future controller commands taking into account external data. This external data can be radar data, flight plan data, weather data, airspace data, and also historic data of those types.
Display Full Recognised Command	A command recognised as part of an ATCO's utterance is displayed in the CWP HMI
Highlight Flight	A callsign, which is being considered by the system, is highlighted in the CWP HMI, after being recognised as part of an ATCO's or pilot's utterance.
Highlight Sectors or Flights Affected by Sectorization Change	Sectors or flights affected by an upcoming sectorization change are highlighted.
Recognise Voice Words	The voice flow is analysed and transformed into a text string.
Send Flight Plan and/or Sectorization Updates	All relevant information concerning existing flight plans and sectorization changes is sent.

Table 7: Function description for [NSV-4] Display and highlight with Automatic Speech Recognition

Below is the applicable NSV-4 view.

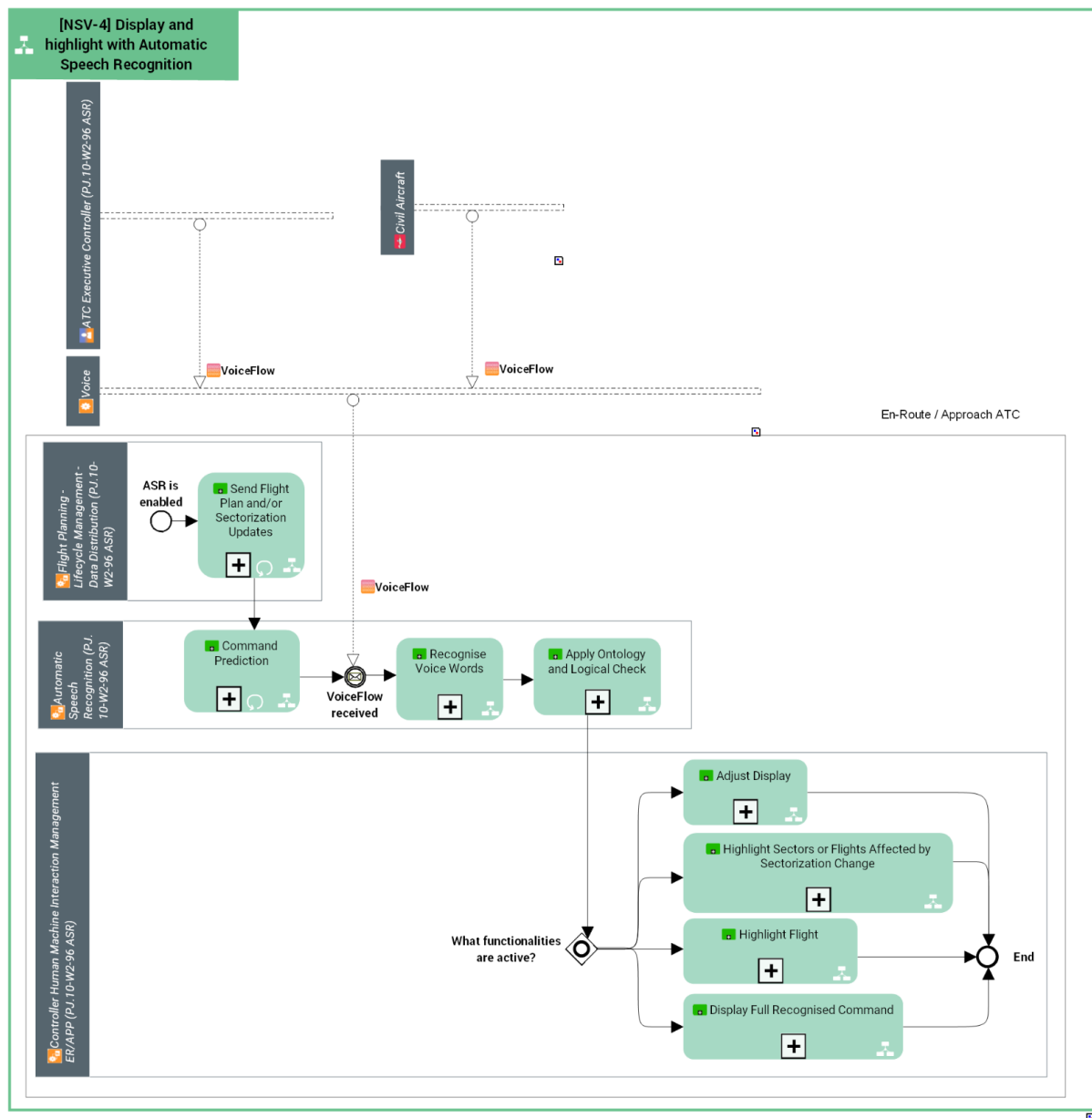


Fig. 8 Resource orchestration view: [NSV-4] Display and highlight with Automatic Speech Recognition

4.1.1.3 Resource Orchestration view: Prefilling of commands with Automatic Speech Recognition

View [NSV-4] Prefilling of commands with Automatic Speech Recognition is related to the following use cases:

- Use case 4: Prefilling of commands in the CWP
- Use case 8: Prefilling of datalink commands

Function	Description
Accept Clearance	The ATCO accepts the clearance shown, either the original one proposed by the system or the corrected one.
Apply Ontology and Logical Check	The text string is analysed and transformed into a set of predefined commands by using the Ontology, and a logical check is performed to discard incoherent commands.
Check Proposed Clearance	The ATCO checks if the clearance proposed by the system is correct or not.
Command Prediction	Forecasts possible future controller commands taking into account external data. This external data can be radar data, flight plan data, weather data, airspace data, and also historic data of those types.
Compose and Send CPDLC Message	Tailor the CPDLC message with the clearance input and send it.
Correct Proposed Clearance	The ATCO corrects a wrong clearance proposed by the ASR.
Discard Proposed Clearance	The proposed clearance command is discarded.
Display Proposed Clearance for Acceptance or Rejection	The CHMI shows the proposed clearance to be accepted or rejected.
Edit Proposed Clearance	An input is made to edit a proposed clearance.
Input Clearance	ATCO input clearance into the CWP
Recognise Voice Words	The voice flow is analysed and transformed into a text string.
Reject Proposed Clearance	The ATCO completely rejects a clearance proposed by the system.
Send Flight Plan and/or Sectorization Updates	All relevant information concerning existing flight plans and sectorization changes is sent.
Update SFPL	Update SFPL
Wait for Acceptance or Rejection	The CHMI awaits a response for acceptance or rejection. If a response is not received within a defined time parameter, the timer triggers the timeout flow.

Table 8: Function description for [NSV-4] Prefilling of commands with Automatic Speech Recognition

Below is the applicable NSV-4 view.

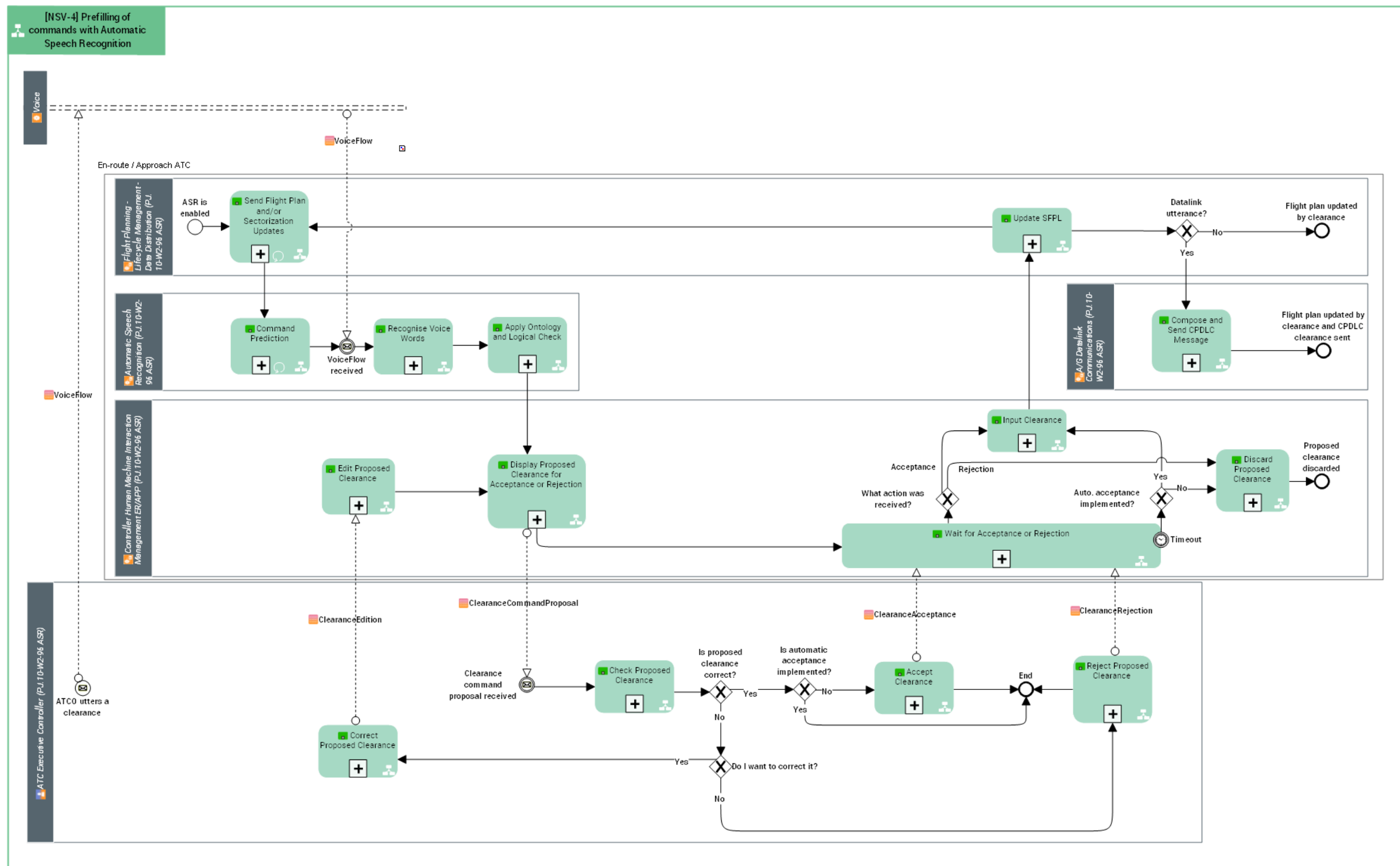


Fig. 9 Resource orchestration view: [NSV-4] Prefilling of commands with Automatic Speech Recognition

4.1.2 Resource Composition

The following functional blocks and role have been modified to include new functions:

- **Automatic Speech Recognition:** encompasses the steps to perform the pure process of speech recognition and the transformation of the sequence of words to an event by means of the ontology. The speech recognition process may be enhanced based on the input from Flight Planning Lifecycle Management Data Distribution functional block both by command prediction—run on a cyclical basis— and by logical checks performed after the event recognition.
- **Controller Human Machine Interaction Management ER/APP:** this functional block includes now the specific functions related to display and highlight that can be activated by ASR and the prefilling of commands with the information previously recognised, and its presentation for acceptance, rejection or automatic acceptance.
- **ATC Executive Controller:** this is the role who benefits from the Automatic Speech Recognition. This is the initiator of the process by utterances. In case of display and highlight, the ATC Executive Controller would see the changes in the CHMI and see their situational awareness improved, but no specific functions are required afterwards. In case of the use cases related to prefilling commands, the ATC Executive Controller incorporates functions to check their correctness, and perform acceptance, rejection and correction of the presented commands.

Other relevant functional blocks are:

- **Flight Planning Lifecycle Management Data Distribution:** this functional block already provides flight plan and sectorisation updates that are now consumed by the ASR so that the latter has access to relevant information regarding the entities able to be affected by speech recognition.
- **A/G datalink communications:** this functional block is provided for context within the architecture views. It is not supposed to require modifications, as its objective will be composing and sending CPDLC messages as in today's operations at the request of the Flight Planning Lifecycle Management Data Distribution functional block.

4.1.3 Service view

This solution does not require new services. Only legacy interactions are needed.

4.2 Functional and non-Functional Requirements

Most of the presented functional and non-functional requirements presented in this section were already developed within solution PJ.16-04-ASR in Wave-1. A recommendation of Wave 1 was to update some (only some) of the requirements.

No HLOR are identified for PJ.10-W2-96 ASR in D2.0.002 – High Level Operational Requirements for Wave 2 Solutions.

Note that traceability links are referenced based on the specific content of the requirement, so a requirement of a defined category will not have defined traceability links to elements of the architecture not affected by the content of the requirement.

The requirements may apply to all use cases or only some of them. In general, the requirements are relevant only to the exercises that have validated them. In some cases further information has been included for clarification.

4.2.1 Functional requirements

[REQ]

Identifier	REQ-10.96-01-TS.0010
Title	Cover all traffic flows with En-route and TMA
Requirement	ASR shall be able to process different traffic flows within the Area of Interest of the Control Unit.
Status	<Validated>
Rationale	To cover the whole traffic within the Area of Interest in TMA and En-route. The different traffic flows are: • Inbounds, • Outbounds, • Overflights (En-route Traffic) This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
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<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition Flight Planning – Lifecycle Management Data Distribution
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check Send Flight Plan and/or Sectorization Updates
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS.0020
Title	Recognition of Commands
Requirement	The ASR shall recognize commands of different command categories.
Status	<Validated>
Rationale	Recognition of commands is the basic functionality of a speech recognizer used in ATC applications. The different command categories are provided (for each exercise) in the appendix. The command types (e.g. DESCEND, INFORMATION, CLEARED) are based on the ontology developed in PJ.16-04. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check

<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS.0030
Title	Multiple Commands
Requirement	ASR shall be able to process utterances containing multiple commands
Status	<Validated>
Rationale	Capability to be able to process multiple commands in a single utterance. The requirement is changed with respect PJ.16-04, because now also pilot utterances are relevant. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS.0040
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Title	English and local Languages
Requirement	The ASR shall be able to recognize commands in English and local language, if local procedures allow to issue commands in both languages
Status	<Validated>
Rationale	As commands on different states are given in local language and English dependent on the aircraft, the support by the ASR is increased when the ASR recognizes commands in both languages. Recognition of commands in local language is introduced as several partners have been developing speech recognition models for some years in local language, so these models can be assessed without impacting feasibility and cost-effectiveness of the concept. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Recognise Voice Words Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS.0050
Title	Multiple Callsigns
Requirement	ASR shall be able to process utterances containing more than one callsign.
Status	<Validated>

Rationale	The recognition rate for ATCO utterances with multiple callsigns will be better if controller uses ICAO phraseology with “break, break”. The requirement is changed with respect PJ.16-04, because now also pilot utterances are relevant. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS.0060
Title	Different Speakers in one utterance
Requirement	ASR shall be able to process utterance which contains different speakers
Status	<Validated>
Rationale	It cannot be guaranteed, especially in the ops room environment, that the voice utterances are perfectly splitted, especially in high traffic situation. Therefore, an utterance can contain two different pilots or both an utterance from the ATCO and from the pilot or even from two pilots and the ATCO. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS.0070
Title	Pure commands
Requirement	The ASR system shall allow uttering "pure" commands that are not part of a radio transmission or a call. Pure commands mean commands directed to the HMI, not being part of the voice communication between ATCOs and pilots.
Status	<Validated>
Rationale	To support UC #3.5-#3.7, there is a need for ATCOs to give commands directly to the CWP, by having a specific "push to give command" button. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition

<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-0080
Title	ASR interoperability with VCS
Requirement	ASR should be able to interact with VCS under standard ED-137 from EUROCAE.
Status	<Validated>
Rationale	In order to ease interoperability with existing Voice Communication Systems, EUROCAE ED-137 should be used as a reference for communications between ASR and VCS. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01.
Category	<Functional> <Interoperability>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<System>	Voice En-Route / Approach ATC
<ALLOCATED_TO>	<Resource Interaction>	Voice Flow Forwarding
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition

[REQ]

Identifier	REQ-10.96-01-TS-0090
Title	Artificial Intelligence applied to command prediction
Requirement	The command prediction functionality shall make use of Artificial Intelligence.
Status	<Validated>
Rationale	The command prediction functionality benefits from intellectual processes performed by Artificial Intelligence such as perception, ability to reason, generalize or learn from past experience. This requirement has been partly validated in EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-0100
Title	Artificial Intelligence applied to ASR training
Requirement	Artificial Intelligence shall be used for ASR training purposes.
Status	<Validated>

Rationale	The process of training the ASR engine benefits from intellectual processes performed by Artificial Intelligence such as perception, ability to reason, generalize, learn from past experience and use of language. The results of this requirement have been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05.
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check Recognise Voice Words
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-0110
Title	Artificial Intelligence trust
Requirement	Artificial Intelligence used in ASR should be trustworthy by complying with the principles established by the European Union in the Ethics Guidelines for Trustworthy AI (April 8 2019) or its subsequent updates.
Status	<Validated>
Rationale	Trustworthy Artificial Intelligence has to be lawful, ethical and robust. It relies on seven key requirements, namely human agency and oversight, technical robustness and safety, privacy and data governance, transparency, diversity, non-discrimination and fairness, societal and environmental well-being and accountability.

	This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01
Category	<Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check Command Prediction Recognise Voice Words
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0010
Title	Flight highlighting
Requirement	The HMI shall highlight the Track Label or part of it (or the track symbol) after recognizing the corresponding callsign.
Status	<Validated>
Rationale	This requirement enables use cases 3.1 and 3.2. As a support to use cases 3.4 and 3.8, if the recognized callsign is highlighted while the ATCO or pilot is speaking he/she knows already that the command will not be recognized correctly and that manual action is needed. In that case ATCO can reduce the number of commands he/she wants to give in an utterance.

	This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Highlight Flight
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0020
Title	HMI for Command Values
Requirement	The HMI should present the recognized (and validated) command types together with the command values in the radar label.
Status	<Validated>
Rationale	The controller needs the information of the given command value in the radar label. Otherwise he has to manually input them. In the annotation use case, a separate window could be used. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Display Full Recognised Command
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0030
Title	Input acceptance
Requirement	The HMI shall enable acceptance of automatically inserted values by ATCO clicking on the value, by clicking on confirmation button in the dialogue 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).
Status	<Validated>
Rationale	This requirement applies to use cases 3.4 and 3.8. The controller should be able to decide whether he/she wants to explicitly accept recognitions or whether he/she wants to explicitly reject recognitions. In the first case recognized commands are automatically rejected if they are not explicitly accepted by the ATCO within a predefined time frame (e.g. 10 seconds). In the second case recognized commands are automatically accepted if they are not explicitly rejected by the ATCO within a predefined time frame (e.g. 10 seconds). The automatic acceptance was the implementation of the AcListant-Strips® project. The preference with respect to automatic acceptance resp. automatic rejection will also depend on the achieved command recognition rate resp. depends on the achieved command recognition error rate. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02 using a time frame of 10 seconds, EXE-PJ.10-96-ASR-TRL6-01.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Wait for Acceptance or Rejection
<ALLOCATED_TO>	<Function View>	[NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0040
Title	Manual correction
Requirement	The HMI shall enable manual correction/update of automatically proposed command value/type.
Status	<Validated>
Rationale	This requirement applies to use cases 3.4 and 3.8. If a command is not correctly recognized, the ATCO needs the possibility to manually correct it (e.g. by mouse or keyboard). The ATCO is not able to repeat the clearance via voice. The manual input of the ATCO (e.g. correction/update of command) will have priority over automatically proposed command value/type within related utterance. Manual correction even makes sense, if recognized commands are manually confirmed, e.g. if four commands are given, all recognized commands could be first accepted and then one is manually corrected. That is easier than rejecting all of them and then manually inserting all four. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-01.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Edit Proposed Clearance
<ALLOCATED_TO>	<Function View>	[NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0050
Title	ASR failure indication
Requirement	The HMI shall indicate a failure of the ASR by displaying either an error message or using status icons.
Status	<Validated>
Rationale	If the ASR completely fails (is off) the controller needs to be informed about this as workflows might be affected and a higher level of manual input might be required. ASR failure is not related to misrecognitions, but to a complete shutdown of ASR support. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-05.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition

		Controller Human Machine Interface Interaction Management ER/APP
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0060
Title	ASR switch off/on
Requirement	The ASR system should provide the functionality to be switched off and switched on when necessary.
Status	<Validated>
Rationale	If the ASR recognition rate drops down, ATCO's workload might be higher than without using an ASR system. Therefore, the switch on/off functionality is needed. If the ASR is switched off, this is shown to the ATCO in his HMI, see requirement REQ-10.96-01-TS-HMI.0050. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interface Interaction Management ER/APP Automatic Speech Recognition
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition

<ALLOCATED_TO>	<System>	En-Route / Approach ATC
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[REQ]

Identifier	REQ-10.96-01-TS-HMI.0070
Title	Sectorization change highlighting
Requirement	The HMI shall enable the ATCOs to give special commands for highlighting upcoming changes to the sectorization.
Status	<Validated>
Rationale	This requirement applies to use case 3.5. When using dynamic airspace configuration (DAC), such commands are important for the ATCOs to understand the upcoming changes in the airspace configuration. A parameter to these commands shall be which sector(s) to highlight and means for navigating/zooming to the highlighted sectors both in the ASW and in the 3D visualization of the air space. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-05.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Highlight Sectors or Flights Affected by Sectorization Change Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0080
Title	Highlighting flights affected by sectorization changes
Requirement	The HMI shall enable the ATCOs to give special commands for highlighting how upcoming changes to the sectorization will affect the flights being controlled by an ATCO.
Status	<Validated>
Rationale	This requirement applies to use case 3.6. When using dynamic airspace configuration (DAC), such commands are important for the ATCOs to understand how the upcoming changes in the airspace configuration will affect the traffic being controlled, both regarding additional flights and flights that should be handed over to a different sector immediately after the sectorization change happens. It must be possible for the ATCO to distinguish between these two categorizes of flights both through the commands and the visual response, which should be given in the ASW, in flight list(s), and possibly also in the 3D visualization of the air space. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-05
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Highlight Sectors or Flights Affected by Sectorization Change Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0090
Title	3D navigation aids
Requirement	The HMI shall enable the ATCOs to give special commands for navigating the 3D visualization of the air space.
Status	<Validated>
Rationale	This requirement applies to use case 3.7. When using dynamic airspace configuration (DAC), such commands are important for the ATCOs to have efficient means for navigating the 3D visualization. ASR commands will offer an efficient supplement to MTI and mouse-based navigation, both as the ATCOs do not need to move hands and/or mouse cursor to the 3D screen, and because giving the voice commands can be faster than using MTI and/or mouse. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-05
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Adjust Display Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0100
Title	Different highlight for callsign from pilot and ATCO

Requirement	The HMI shall display in different ways callsigns recognised from controller's utterances and callsigns recognised from pilot's utterances.
Status	<Validated>
Rationale	This requirement applies to use cases 3.1 and 3.2 when implemented jointly. The controller has to be able to distinguish why a callsign is being highlight by ASR. This is particularly important in case of utterances following one another. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Highlight Flight
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-HMI.0110
Title	Disable highlighting for callsign from pilot and ATCO
Requirement	The HMI shall allow to enable and disable independently the highlighting of callsigns from pilot's and ATCO's utterances, when both are available.
Status	<Validated>
Rationale	This requirement applies to use cases 3.1 and 3.2 when implemented jointly. Controllers might require different support and this option will be a personal preference. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03.
Category	<HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Highlight Flight
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0030
Title	Disable ASR system from the HMI
Requirement	It shall be possible to disable the ASR system from the HMI to avoid continuously erroneously recognised commands to be automatically updated on the HMI in case of ASR failure or other condition leading to significant degradation of ASR performance and as a result impacting safety.
Status	<Validated>
Rationale	In cases where the ASR performance has significantly degraded due to e.g. failure of one or more of its functional components, software errors or interface issues the ASR system may be in a state where its command recognition rate is so degraded that the inputs provided to the HMI require constant manual corrections by the ATCO working at the CWP. Such a failure mode may have significant impacts on ATCO workload, situational awareness and allocation of cognitive resources. Therefore, if the system performance degrades to such a level as rendering the ASR system unusable, an automated (e.g. self-test/check facility) or manual function to disable the ASR system and reverting back to current operating method should be made available. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02 (e.g. during baseline runs which were without ASR support), EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01.
Category	<Safety><HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check Command Prediction Recognise Voice Words
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0040
Title	HMI display of complex clearances
Requirement	The associated HMI associated with ASR output shall enable the display of all parts of a complex clearance affecting the trajectory of a flight to ensure that no flight profile changes potentially impacting safety of operations are updated in the ATM-system without ATCO awareness.
Status	<Validated>
Rationale	This requirement applies to use cases 3.3, 3.4 and 3.8. ATCOs may issue complex clearances which comprise of a single command with multiple parts involving both e.g. vertical and lateral trajectory changes. In a modern ATM-system these profile changes impact how the system safety nets and ATCO monitoring aids function and assist the ATCO in conflict detection and resolution. Wrong trajectory related system inputs may result e.g. in false/missing safety net indications and as a result impact the safety of operations. In current operating method the ATCO may need to manually input a complex clearance to several different label/menu fields and can confirm the correctness of such clearances through the step-by-step process of updating the FPL data in

	the system. Therefore, it is essential that all parts of a 'complex clearance' issued by the ATCO when using an ASR system are displayed on the HMI for ATCO visual confirmation. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-02. EXE-PJ.10-96-ASR-TRL6-01.
Category	<Safety><HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Display Proposed Clearance for Acceptance or Rejection
<ALLOCATED_TO>	<Function view>	[NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0070
Title	ASR-system displayed on the CWP HMI
Requirement	Inputs generated by an ASR-system displayed on the CWP HMI shall be consistent with other displayed data, complete, and fit-for-purpose to ensure that ATCO execution, and as a result safety, are not impaired when using ASR. Consistency, completeness and assessment of fit-for-purpose is dependent on the ATM-system and other system functions used.
Status	<Validated>
Rationale	Modern ATM-systems utilise colours, frames and other graphic cues to advise ATCOs of the progress and intentions of a flight. It is essential that the inputs provided by the ASR system are consistent and non-conflicting with the existing visual indications of flight progress displayed on the HMI. This is especially true when ASR may be used for applications such as TLA and the ATM-system also uses Attention

	Guidance or other similar applications to draw ATCO attention to specific flight/area. There should be no risk misinterpreting the cues provided by ASR and other support systems. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01.
Category	<Safety><HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Adjust Display Display Full Recognised Command Display Proposed Clearance for Acceptance or Rejection Highlight Flight Highlight Sectors or Flights Affected by Sectorization Change
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0090
Title	Voice flow to text string
Requirement	The voice flow (spoken words) shall be analysed and transformed into a text string.
Status	<Validated>
Rationale	This functionality is also known as speech-to-text or automatic speech recognition.

	If controller's utterance (voice flow/spoken words) is not analysed and transformed into a text string, the callsign and the command uttered will not be further transformed into a set of ATC commands to be displayed on the CWP HMI. In these cases, the controller would have to input information manually resulting in workflow disruptions and workload increase and situational awareness reduction as there is a default expectation by the ATCO that ASR is functional and assisting in inputting commands in the labels. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05.
Category	<Safety><Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Recognise Voice Words
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0100
Title	Ontology and logical check
Requirement	The Apply Ontology and Logical Check function shall analyse the text string and transform it into the corresponding ATC concepts (following the Ontology) and perform a logical check to discard incoherent commands.
Status	<validated>
Rationale	The ontology presents standardized information to controller. To prevent displayed ATC commands that might be incoherent and erroneous. In these cases, controller would have to correct input information

	manually resulting in workflow disruptions and workload increase and situational awareness reduction as there is a default expectation by the ATCO that ASR is functional and assisting in inputting commands in the labels. Possible contextual information that may be used for analysed taking into consideration includes surveillance data, flight plan data, route information, clearance information, weather data, airspace data, and also historical data of those types. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05.
Category	<Safety><Functional>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0110
Title	Input rejection
Requirement	The HMI associated with ASR shall enable the ATCO to reject recognized command values for pre-filling radar label values by clicking on a rejection button.
Status	<Validated>
Rationale	This requirement applies to use case 3.4. The controller has to be able to explicitly reject recognitions. In case the information provided by the ASR system is erroneous, the controller may

	decide whether to correct the erroneous input or to reject ASR recognition of the utterance as a whole. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02.
Category	<Safety><HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Discard Proposed Clearance
<ALLOCATED_TO>	<Function View>	[NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0130
Title	Display of callsign in the historical annotation
Requirement	The HMI shall display a callsign recognised by ASR from ATCO's utterance in the form of a historical annotation to the ATCO.
Status	<Validated>
Rationale	This requirement applies to use case 3.3. If the recognized callsign is displayed in the CWP in the form of historical annotation, it makes it available to the controller for consultation. This will, at the same time, increase controllers' situational awareness and provide a safety check as they will be able to check the instructions given to the flights. This UC is an intermediate step before the semi-automatic/automatic input of commands in the CWP using ASR. This requirement enables use case 3.3. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03
Category	<Safety><HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Display Full Recognised Command
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0140
Title	Highlight of a single sector
Requirement	The HMI shall enable the ATCOs to give special commands for highlighting a sector of interest.
Status	<Validated>
Rationale	This requirement applies to use case 3.5. When using dynamic airspace configuration (DAC), such commands are important for the ATCOs to obtain a clearer view on the sector of interest. A parameter to these commands shall be which sector to highlight and means for navigating/zooming to the highlighted sector both in the ASW and in the 3D visualization of the air space. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-05.
Category	<Safety><HMI>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP

<ALLOCATED_TO>	<Function>	Highlight Sectors or Flights Affected by a Sectorization change
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

4.2.2 Non-functional requirements

4.2.2.1 Performance requirements

[REQ]

Identifier	REQ-10.96-01-TS-ReTi.0010
Title	Provide callsign information immediately
Requirement	ASR should send not later than 1.0 second a recognized callsign to the cooperating ATC system when the controller has pressed the push-to-talk-button and fully said the callsign (aircraft identifier).
Status	<Validated>
Rationale	Callsign is one of the most important information. If a long instruction, containing multiple commands, is spoken (e.g. duration > 3 seconds), the controller wants an early feedback, that ASR has recognized the correct callsign. This could be immediately displayed by highlighting the aircraft label on the radar screen. If the callsign is not recognized immediately after the callsign is said, ASR should send recognized callsign together with the whole recognized command (e.g. if ASR needs the other contextual information to recognize the callsign properly). If the ATCO gives the callsign information at the end of the utterance, it cannot be extracted at the beginning anyway. If the whole command of multiple commands is already extracted, when the callsign information is available, the callsign information could be sent separately or together with the already extracted command. If an utterance contains more than one callsign (break, break), only the first callsign may be sent first. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03.
Category	<Performance>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180

<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Recognise Voice Words Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-ReTi.0020
Title	Reaction Time
Requirement	The system shall be able to give the output in less than two seconds after the ATCO has released the push-to-talk button.
Status	<Validated>
Rationale	There is a need to know the aircraft the ATCO is speaking to after the callsign is said. Sufficient response time has to be kept under all conditions even in case of long ATCO transmission. For the other 0.1% percent a reaction time of less than 3 seconds or a rejection with "NO_CONCEPT" is required. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-03.
Category	<Performance>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction Recognise Voice Words Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition

<ALLOCATED_TO>	<System>	En-Route / Approach ATC
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[REQ]

Identifier	REQ-10.96-01-TS-ReTi.0030
Title	System reaction time
Requirement	The use of ASR shall have no influence on the reaction time of the different systems/functional blocks used in the controller HMI.
Status	<Validated>
Rationale	The ASR is only an add-on intended to support the controller and reduce the workload, with the goal to speed up operation. If any other system is slowed down by the usage of ASR due to e.g. system requirements that goal is no longer given. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05.
Category	<Performance>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction Recognise Voice Words Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-Perf.0010
Title	ATCO Command Recognition Error Rate
Requirement	The Command Recognition Error Rate of ASR should be less than 2.5% for ATCOs.
Status	<Validated>
Rationale	The Command Error Rate is the most important indicator from the operational perspective as it influences the trust of the ATCO in ASR (Command Error Rate and Command Rejection Rate have to be distinguished). This requirement has been validated /addressed in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-01.
Category	<Performance>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction Recognise Voice Words Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-Perf.0030
Title	Pilot Command Recognition Error Rate
Requirement	The Command Recognition Error Rate of ASR SHOULD be less than 5% for pilots

Status	<Validated>
Rationale	This requirement applies to use case 3.2. The Command Error Rate is the most important indicator from the operational perspective as it influences the trust of the ATCO in ASR (Command Error Rate and Command Rejection Rate have to be distinguished). Pilot Command refers to callsign from pilot's utterance in this case. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03
Category	<Performance>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction Recognise Voice Words Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-Perf.0020
Title	Command Prediction Error Rate
Requirement	If ASR is used, 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.
Status	<Validated>

Rationale	If we have a command recognition rate of 84%, the command prediction error rate should not be higher than $0.5 \cdot (100\% - 84\%) = 8\%$. The speech recognizer relies on the input of the predicted commands. Commands, which are not predicted (normally), cannot be recognized. So if command prediction accuracy is worse than recognition accuracy itself, the command prediction functionality might have no benefits for the recognition engine any more. Note, that we have different ASR performance for pilot and ATCO utterances. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02 with respect to callsign prediction accuracy.
Category	<Performance>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-Perf.0040
Title	ATCO Command Recognition Rate
Requirement	The Command Recognition Rate of ASR of ATCOs should be higher than 85%.
Status	<Validated>
Rationale	There is a clear operational need to have high recognition rate (of at least 85%) so that controllers are not distracted from work by manual corrections and they are able to keep the situational awareness and good mental picture of the situation.

	This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05
Category	<Performance>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check Command Prediction Recognise Voice Words
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-Perf.0050
Title	Pilot Command Recognition Rate
Requirement	The Command Recognition Rate of ASR for pilots SHOULD be higher than 75%.
Status	<Validated>
Rationale	This requirement applies to use case 3.1. There is a clear operational need to have high recognition rate (of at least 75%) so that controllers are not distracted and they are able to keep the situational awareness and good mental picture of the situation. This requirement has been addressed in EXE-PJ.10-96-ASR-TRL6-03.
Category	<Performance>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

4.2.2.2 Safety requirements

[REQ]

Identifier	REQ-10.96-01-TS-SF.0020
Title	Voice communications
Requirement	The quality of voice communications and voice communication peripherals used shall be good enough to ensure that the required ASR command recognition rate is not endangered due to the quality of communications resulting in potentially increased ATCO workload and as a result impacting safety.
Status	<Validated>
Rationale	The required ASR command recognition rate will need to be achievable in simulation and laboratory conditions as well as in operational conditions. It should be ensured that the VCS equipment (including peripherals such as headsets and PTTs) used does not increase command recognition error rates in operational conditions when compared to simulated/laboratory conditions. If ASR is used to verify pilot readback of clearances, the use of VHF communications in the ASR system imposes additional communications quality requirements to ensure that the number of erroneous ASR command recognitions (effectively nuisance alerts) stays within tolerable limits. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01.

Category	<Safety>
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[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<System>	Voice
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0050
Title	Recognition rates of different command
Requirement	The ASR system shall have no significant differences in the recognition rates of different command types, if the command types are not very seldom use (e.g. less than 1% of the time).
Status	<Validated>
Rationale	ASR system and the resulting use of the voice communication information may be used for different application. Some applications may be considered time-critical (e.g. trajectory changes) while others may be considered non-time critical (e.g. opening of a menu for the purpose of manipulating the CWP map view). As such, ASR should perform on the same recognition/error rate level for all commands used in the specific application, especially in the case of time critical applications. If e.g. altitude changes are recognised by nearly 100% recognition rate, but route changes recognised only in 60% of cases this will lead to a situation where the route changes will require manual corrections 4 times out of 10 clearances issued. This may be considered a nuisance by the ATCOs and reduce overall system acceptability as well as potentially increase ATCO workload especially in an environment where complex clearances are common (e.g. TMA in approach phase). This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-05 and considered in EXE-PJ.10-96-ASR-TRL6-02.

Category	<Safety>
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[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Apply Ontology and Logical Check Command Prediction Recognise Voice Words
<ALLOCATED_TO>	<Function view>	[NSV-4] Prefilling of commands with Automatic Speech Recognition [NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0080
Title	The impact of ASR on other systems
Requirement	The performance, availability and/or reliability of other systems installed at the CWP shall not be impacted by the use of an ASR system in a way which may compromise ATCO task execution and as a result, safety.
Status	<Validated>
Rationale	While the ASR-system is a separate add-on to the VCS and CWP, it interacts with various systems as indicated in Functional architecture overview. Therefore, it is essential that the ASR-system does not interfere with the other systems and components installed at the CWP and that if interference between ASR and other systems is identified, the system can be isolated and disabled. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02, EXE-PJ.10-96-ASR-TRL6-03, EXE-PJ.10-96-ASR-TRL6-01, EXE-PJ.10-96-ASR-TRL6-05.
Category	<Safety>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction Recognise Voice Words Apply Ontology and Logical Check
<ALLOCATED_TO>	<Function View>	[NSV-4] Display and highlight with Automatic Speech Recognition [NSV-4] Prefilling of commands with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0120
Title	Less used phraseology/waypoints
Requirement	ASR shall be able to process and recognize less used phraseology/ waypoints.
Status	<Validated>
Rationale	In abnormal conditions, ASR has to be able to process the ATCO utterances containing less frequent phraseology / waypoints with enough level of performance to be able to support them. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-03.
Category	<Safety>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Automatic Speech Recognition
<ALLOCATED_TO>	<Function>	Command Prediction

		Apply Ontology and Logical Check Recognise Voice Words
<ALLOCATED_TO>	<Function View>	[NSV-4] Prefilling of commands with Automatic Speech Recognition [NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

[REQ]

Identifier	REQ-10.96-01-TS-SF.0150
Title	Display of callsigns with low confidence level
Requirement	If the confidence level of the callsign recognition is not sufficiently high, it shall not be highlighted.
Status	<Validated>
Rationale	If an 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. If the ATCO issues the clearance to the wrongly highlighted aircraft and may result in an unintended trajectory change. Thus, the callsigns with low recognition rate shall not be highlighted to avoid misconception on ATCO side. This requirement has been validated in EXE-PJ.10-96-ASR-TRL6-02.
Category	<Safety>

[REQ Trace]

Relationship	Linked Element Type	Identifier
<ALLOCATED_TO>	<SESAR Solution>	PJ.10-W2-96 ASR
<SATISFIES>	<Enabler>	ER APP ATC 180
<ALLOCATED_TO>	<Functional block>	Controller Human Machine Interaction Management ER/APP
<ALLOCATED_TO>	<Function>	Highlight Flight
<ALLOCATED_TO>	<Function View>	[NSV-4] Prefilling of commands with Automatic Speech Recognition [NSV-4] Display and highlight with Automatic Speech Recognition
<ALLOCATED_TO>	<System>	En-Route / Approach ATC

5 Recommendation for Implementation

Two options are possible for the implementation of Automatic Speech Recognition regarding its deployment in the system architecture of ER ACC or APP ACC capability configuration (regardless of sub-operating environment):

- Centralised architecture: the recognition engine is deployed as several instances running on the same server, giving service to all the controllers and positions able to use Automatic Speech Recognition. Initially, there would be one ASR server and several clients connected to the server although, if performance requires so, there may be several ASR servers providing service, and even load balancers may be used to achieve better result.
- Distributed architecture: each controller working position is connected to a dedicated instance of the recognition engine.

Note that there is no difference in applicable requirements with regards to the chosen option for deployment.

Specific training regarding voice recognition and specific ontology and logical rules should be provided to the ASR engine depending on Capability Configuration, Operating Environment and sub-operating environment in which to be deployed, as phraseology varies widely.

Having separate acoustical models for ATCO and for pilots should be considered as well, as there are differences between their utterances that should be considered for speech recognition, such as differences in pronunciation and structure of utterances and readbacks.

The command prediction function (ABSR) is not considered necessary for the implementation of Automatic Speech Recognition, but its availability is considered beneficial for event recognition in all situations.

6 Assumptions

Assumption 1:

The Voice Communication System forwards the voice stream flow when the Push-To-Talk button (PTT) is pressed (for controller communications) and when the Squelch function activates (pilot communications). For utterances not desired to be transmitted, a specific button is provided to allow interacting with the ASR without transmitting the message to VHF or HF transmitters.

7 References and Applicable Documents

7.1 Applicable Documents

Content Integration

- [1] D2.15: PJ19-W2 EATMA Guidance (2020) (edition 01.00.00)
- [2] EATMA Community pages
- [3] SESAR ATM Lexicon

Content Development

- [4] D2.5: SESAR 2020 Concept of Operations (edition 01.00.00)
- [5] D2.0.002: High Level Operational Requirements for Wave 2 Solutions (edition 00.01.02)

System and Service Development

- [6] 08.01.01 D52: SWIM Foundation v2
- [7] 08.01.01 D49: SWIM Compliance Criteria
- [8] 08.01.03 D47: AIRM v4.1.0
- [9] 08.03.10 D45: ISRM Foundation v00.08.00
- [10] B.04.03 D102 SESAR Working Method on Services
- [11] D2.3 PJ19 W2 CI: ADD(2020) (edition 01.00.01)
- [12] B.04.05 Common Service Foundation Method

Performance Management

- [13] D4.0.30 S2020 Common Assumptions (edition 01.00.00)
- [14] D4.7: PJ19.04: Performance Framework (2019) (edition 01.00.01)
- [15] D110: C.02-D110 Updated D02 after MP Campaign (edition 00.01.01)
- [16] D4.1: PJ19-W2: Validation Targets – Wave 2 (edition 00.01.00)

Validation

- [17] 03.00 D16 WP3 Engineering methodology
- [18] D2.6: PJ19: VALS (2019) (edition 00.01.00)

[19]EUROCONTROL. *E-OCVM Version 3.0 – Volume I - European Operational Concept Validation Methodology*. 2010.

[20]EUROCONTROL. *E-OCVM Version 3.0 – Volume II Annexes - European Operational Concept Validation Methodology*. 2010.

System Engineering

[21]SESAR 2020 Requirements and Validation Guidelines Wave 2 (edition 00.02.02)

Safety

[22] D4.0.060: SESAR Safety Reference Material (edition 00.04.01)

[23] D4.0.050: Guidance to Apply SESAR Safety Reference Material (edition 00.03.01)

[24] D04: Resilience Engineering Guidance Final Deliverable (edition 00.00.12)

Human Performance

[25]D4.0.070: SESAR Human Performance Assessment Process V1 to V3 – including VLD (edition 00.03.01)

Environment Assessment

[26].D4.0.080 SESAR Environment Assessment Process (edition 04.00.00)

Security

[27] SecRAM 2.0 Security Risk Assessment methodology for SESAR 2020 (edition 02.00.00)

7.2 Reference Documents

- [28] ED-78A GUIDELINES FOR APPROVAL OF THE PROVISION AND USE OF AIR TRAFFIC SERVICES SUPPORTED BY DATA COMMUNICATIONS.
- [29] B. Juang, L. Rabiner, *Automatic Speech Recognition – A Brief History of the Technology Development*. 2005.
- [30] T. Trikas, *Automated Speech Recognition in Air Traffic Control*. Cambridge, MA: Transportation Laboratory, Massachusetts Institute of Technology, 1987.
- [31] MALORCA project official webpage (Available at <https://www.malorca-project.de/wp/>)
- [32] SESAR Solution PJ.16-04 datapack
- [33] EUROCAE ED-137: Interoperability Standards for VoIP ATM Components
- [34] D1-1: MALORCA Operational Concept Document (edition 3.00)

Appendix A Service Description Document (SDD)

Not applicable, as no new services have been developed within this solution.

Appendix B Ontology

Legend:

y	will be recognized and displayed to ATCO
r	will be recognized, but not displayed to ATCO in Radar Label, but shown in SpeechLog
n	will not be recognized as out of scope

Note: EXE-005 is not displayed in this table, as it did not address commands from the defined Ontology.

optional parts are displayed in orange					Considered by PJ.10-W2-96 ASR		
Command-Name	2nd part of cmd	Value	Unit	Qualifier	EXE-001	EXE-002a,c,d	EXE-003
CLEARED	TAKEOFF	runway			n	n	n
CLEARED	TOUCH_GO	runway			n	n	n
CLEARED	LOW_APPROACH	runway			n	n	n
CLEARED	LANDING	runway			n	n	n
CLEARED	Approach_Type	runway			n	y	n
CLEARED	MISS_APP_PROC				n	n	n
CLEARED	Approach_Leg	runway			n	n	n
CONTINUE	APPROACH	runway			n	n	n
GO_AROUND					n	n	n
INTERCEPT_GLIDEPATH		runway			n	n	n
INTERCEPT_LOCALIZER		runway			n	y	n
CLEARED	TO	destination			n	n	n
CLEARED	VIA	SIDs /STARs			n	n	n
ABORT	TAKEOFF	runway			n	n	n
CANCEL	TAKEOFF	runway			n	n	n
CANCEL	TOUCH_GO	runway			n	n	n
CANCEL	LOW_APPROACH	runway			n	n	n
CANCEL	LANDING	runway			n	n	n
CANCEL	Approach_Type	runway			n	y	n
CANCEL	CLEARANCE				n	n	n
PUSHBACK		BREAK_AREAS		GND_DIRECTION / APTR_COLOR	n	n	n
STARTUP					n	n	n
HOLDING		Holding-Name / track		Dir-Qualifier	n	r	n
LEAVE_HOLDING		Holding-Name			n	r	n
ORBIT		waypoint / none		Dir-Qualifier	n	r	n
HOLD_AT		TX-Point		Hold-At-Conditional-Keywords	n	n	n
HOLD_BEHIND		Gnd-Acft			n	n	n
HOLD_POSITION					n	n	n
HOLD_SHORT		runway/TX-Point/Alphabet-Letter			n	n	n
CONTACT		ATSU/none/"ME"			n	y	n
CONTACT_FREQUENCY	ME	Frequency			n	y	y
LEAVE_FREQUENCY		Frequency			n	n	n
SQUAWK		4-digit-squawk-value, spec-squawk-values			n	n	y
CPDLC		destination			y	n	n
CONTINUE	PRESENT_HEADING				n	y	y
DIRECT_TO		waypoint(s) / coordinates / radial		Dir-Qualifier	n	y	y
FOLLOW_ROUTE		Route-Name			n	n	n
HEADING		Head-Value-3		Dir-Qualifier	y	y	y
HEADING		RUNWAY_DIR		CROSS	n	n	n
MAGNETIC_TRACK		Heading-value			n	n	n
MAINTAIN	HEADING	Heading-value			y	y	y
NAVIGATION_OWN					n	r	n
TRANSITION		Transition-Name			n	y	n
TURN				Dir-Qualifier	y	r	y
TURN_BY		Head-Value-2		Dir-Qualifier	n	y	y

Fig. 10: commands (I)

Command-Name	2nd part of cmd	Value	Unit	Qualifier	EXE-001	EXE-002a,c,d	EXE-003
EXPECT	Approach_Type_plus	runway			n	r	n
EXPECT_ROUTE		Route-Name			n	n	n
INFORMATION	Approach_Type	runway			n	r	n
INFORMATION	WINDDIRECTION	wp-angle-value			n	n	n
INFORMATION	WINDSPEED	wp-speed-value	kt		n	n	n
INFORMATION	ACTIVE_RWY	runway_without_none			n	r	n
INFORMATION	QNH	qnh-value			n	r	n
INFORMATION	ATIS	Alphabet-Letter			n	r	n
INFORMATION	TRAFFIC	Gnd-Acft-none			n	r	n
INFORMATION	MISCELLANEOUS				n	r	n
CALL_YOU_BACK					n	r	n
CAUTION	WINDSHEAR	wp-speed-value	kt		n	n	n
CAUTION	WAKE_TURBULANCE				n	n	n
CORRECTION					n	r	n
DISREGARD					n	r	n
SAY_AGAIN					n	r	n
AFFIRM					n	r	n
NEGATIVE					n	r	n
GREETING					n	r	n
INIT_RESPONSE					n	r	n
STATION		ATSU			n	r	n
NO_CONCEPT					n	r	n
READY	FOR_DEPARTURE				n	n	n
VFR_CLEARANCE					n	n	n
ENTER_CTR	VIA	waypoint(s)			n	n	n
LEAVE_CTR	VIA	waypoint(s)			n	n	n
ENTER_CA	VIA	waypoint(s)			n	n	n
LEAVE_CA	VIA	waypoint(s)			n	n	n
JOIN_TRAFFIC_CIRCUIT		runway		Dir-Qualifier	n	n	n
DIRECT	Approach_Leg				n	n	n
REPORT					n	r	n
REPORT_NOW	Report-Now-2nd-Parameter				n	r	n
REPORT_NOW	ALTITUDE	flight level / altitude	FL/ft/none		n	n	n
REPORT_NOW	FLIGHT_LEVEL	flight level / altitude	FL/ft/none		n	n	n
REPORT_NOW	MAXIMUM_LEVEL_OV	waypoint			n	n	n
CONFIRM_ACCEPT	Approach_Type	runway			n	n	n
REPORT_MISCELLANEOUS					n	r	n

Fig. 11: commands (II)

Command-Name	2nd part of cmd	Value	Unit	Qualifier	EXE-001	EXE-002a,c,d	EXE-003
MAINTAIN	PRESENT_SPEED			LessGr-Qualifier2	y	r	y
HIGH_SPEED_APPROVED					n	r	n
INCREASE		Speed-Value, none	kt/MA/none	LessGr-Qualifier	n	y	y
INCREASE_BY		Speed-Value-2	kt/MA/none	OR_GREATER	n	n	n
MAINTAIN	SPEED	Speed-Value	kt/MA/none	LessGr-Qualifier	y	y	y
NO_SPEED_RESTRICTIONS					y	r	n
REDUCE		Speed-Value, none	kt/MA/none	LessGr-Qualifier	n	y	y
REDUCE_BY		Speed-Value-2	kt/MA/none	OR_GREATER	n	n	n
REDUCE_FINAL_APPROACH_SPEED					n	r	n
REDUCE_MIN_APPROACH_SPEED					n	r	n
REDUCE_MIN_CLEAN_SPEED					n	r	n
RESUME_NORMAL_SPEED					n	r	n
SPEED		Speed-Value, none	kt/MA/none	LessGr-Qualifier	n	y	y
TIME_CMD	BETWEEN	time (s)		Time-Qualifier	n	n	n
CONTINUE	TAXI				n	n	n
CROSS		runway		EXPEDITE	n	n	n
FOLLOW		Gnd-Acft			n	n	n
LINEUP		runway			n	n	n
LINEUP_BEHIND		runway		Gnd-Acft	n	n	n
TAXI	Preposition	TX-Point(s)		EXPEDITE / APTR_COLOR	n	n	n
GIVE_WAY		Gnd-Acft		LEFT / RIGHT	n		
BACKTRACK		runway			n	n	n
VACATE	Preposition	runway / TX-Point(s)		LEFT / RIGHT / EXPEDITE	n	n	n
ALTITUDE	BETWEEN (then multiple values)	flight level / altitude / CA	FL/ft/none	Alt-Qualifier	n	y	y
CLIMB	BETWEEN (then multiple values)	flight level / altitude / CA	FL/ft/none	Alt-Qualifier	y	y	y
DESCEND	BETWEEN (then multiple values)	flight level / altitude / CA	FL/ft/none	Alt-Qualifier	y	y	y
MAINTAIN	PRESENT_ALTITUDE			Alt-Qualifier2	y	r	y
MAINTAIN	ALTITUDE	flight level / altitude	FL/ft/none	Alt-Qualifier	y	y	y
NO_ALTI_RESTRICTIONS					n	n	n
STOP_ALTITUDE		flight level / altitude / CA	FL/ft/none	Alt-Qualifier	n	y	y
STOP_CLIMB		flight level / altitude / CA	FL/ft/none	Alt-Qualifier	n	y	y
STOP_DESCEND		flight level / altitude / CA	FL/ft/none	Alt-Qualifier	n	y	y
RATE_OF_CLIMB		vertical_rate	ft_min, none	LessGr-Qualifier	n		n
RATE_OF_CLIMB	OWN, EXPEDITE, MAX				n	n	n
RATE_OF_DESCENT		vertical_rate	ft_min, none	LessGr-Qualifier	n	y	n
RATE_OF_DESCENT	OWN, EXPEDITE, MAX				n	n	n
VERTICAL_RATE		vertical_rate	ft_min, none	LessGr-Qualifier	n	y	n
VERTICAL_RATE	OWN, EXPEDITE, MAX				n	n	n
EXPEDITE_PASSING		flight level / altitude	FL/ft/none		n	n	n

Fig. 12: commands (III)

Parameter Type	Parameter Value(s)	Comments and examples
4-digit-squawk-value		
Alphabet-Letter(s)	A;B;C;D;E;F;G;H;I;J;K;L;M; N;O;P;Q;R;S;T;U;V;W;X;Y;Z	All of them can be used as ATIS-letters for example
altitude	or none	
Alt-Qualfier	ABOVE, OR_ABOVE, BELOW, OR_BELOW	
Alt-Qualfier2	OR_ABOVE, OR_BELOW	
Approach_Leg	DOWNWIND, BASE, FINAL	
Approach_Type	ILS, VISUAL, GNSS, RNAV, NDB, APPROACH, IFR ...	
Approach_Type_plus_RWY	Approach_Type, RUNWAY	
APTR_COLOR	individually for airports, e.g., RED, BLUE, GREEN	Alternative Parallel Taxi Route as identified by color of painted line on tarmac
ATSU	e.g. Tower, Ground, Radar	
BREAK_AREAS	BA_1, BA_2, etc	
CA		"controlled airspace"
climbDescend-condition-keywords	UNTIL REACHING waypoint	UNTIL REACHING TIGER
CONDITION		Examples: UNTIL DISTANCE 100 NM WHEN SPEED_CONVERSION
Contact-Conditional-keywords	WHEN AIRBORNE, WHEN REACHING ALTITUDE xxxx/xx ft/FL	E.g.: when "after passing one thousand five hundred feet contact approach" is said

coordinates	xxx-xxX_yyy-yyY (or shorter form) where x/y are digits for latitude and longitude degrees with optional hyphen and minutes, X is W/E/none, Y is N/S/none	Examples: 018W 009-34E 03N_033W 17N_032-11none 15-21S_012-09W 62N_000L (zero long neither east nor west)
destination	DESTINATION or 4 letter ICAO code of destination (not three letter IATA code)	DESTINATION or 4-letter code of airport (e.g. LKPR, EDDF), not Frankfurt
Dir-Qualifier	LEFT, RIGHT, none	
Direct_To-Conditional-keywords	AT xx NM XXX	Examples: AT 23 NM AT 15 none DME
flight level	or none	
Frequency	3 digits decimal 3 digits (zeros are added if necessary at the end)	118.300 (as an example; decimal point always used)
GiveWay-Conditional-Keywords	WHEN AT TX-Point	Eg: "at november four number two behind the ..."
GND_DIRECTION	LEFT, RIGHT, STRAIGHT, NORTH, EAST, SOUTH, WEST, etc	There might be very special examples for gnd_direction such as "FACING_A", "NOSE_WEST", etc. BA_1 stands for break away area, these are areas where the pushback vehicle is detached from the aircraft)
Gnd-Acft	Callsign, Callsign part (lufthansa), aircraft type (airbus) or MARSHALLER	
Gnd-Acft-none	Gnd-Acft or none	
Heading-value	Heading with 3 digits or none	
Head-Value-2	Heading with 1 or 2 digits	
Head-Value-3	Heading with 3 digits or SOUTH, EAST, WEST, NORTH	

Heading-Conditional-keywords	WHEN PASSING waypoint, WHEN ALTITUDE 123	"leave xxx heading two seven zero"
Hold-At-Conditional-Keywords	WHEN ABEAM	
Holding-Conditional-keywords	WHEN DURATION x min	
Holding-Name	waypoint or ...	
Intercept-glidepath-conditional-keywords	WHEN ESTABLISHED	"turn left heading two nine five when established descend glide path runway two seven right"
LessGr-Qualifier	LESS, OR_LESS, GREATER, OR_GREATER	
LessGr-Qualifier2	OR_LESS, OR_GREATER	
Preposition	VIA, TO	
Pushback-Conditional-Keywords	WHEN AWAY AIRCRAFT_NAME (CALLSIGN)	WHEN AWAY CCA8330
radial	XXX_RADIAL_xxx where Y is a letter of navigation aid name and x is a digit	Examples: KFV_RADIAL_152 ING_RADIAL_220
Report-Conditional-Keywords	BASE CLEAR_OF_WEATHER CROSSING rad-value ESTABLISHED_ILS ESTABLISHED FINAL FREE_OF_BUILD_UPS LEVEL_PASSING flight level/altitude FL/ft LOCALIZER_ESTABLISHED PASSING waypoint/TX-Point/segment REACHING_PASSING flight level/altitude FL/ft READY_FOR_BASE READY_FOR_DEPARTURE READY_FOR_TAXI TURNING_FINAL VACATED	Examples: REPORT CROSSING 360 REPORT PASSING CTR_BOUNDARY REPORT PASSING HIGHWAY REPORT PASSING HP_A REPORT PASSING SOROK REPORT REACHING_PASSING 110 FL

Report-Now-2nd-Parameter	ALTITUDE ESTABLISHED_ILS ESTABLISHED FLIGHT_LEVEL HEADING LOCALIZER_ESTABLISHED MAXIMUM_FLIGHT_LEVEL MAXIMUM_LEVEL_OVERHEAD MINIMUM_CLEAN_SPEED POSITION READY_FOR_DEPARTURE SPEED SPEED_MACH_NUMBER SQUAWK	Example: UM133 REPORT PRESENT LEVEL
Route-Name		
runway	runway_without_none + "none"	
runway_without_none	e.g. RW01, RW01L, RW29C, RW30R	RW two digits, optional L, C, R
spec-squawk-values	mayday, com-loss, hijacking	
Speed-Value		
Speed-Value-2	speed value with two digits used in REDUCE_BY	
Startup-Conditional-keywords	WHEN TIME time/two digits	Examples: WHEN TIME 27 WHEN TIME 0901
TaxiwayQual	LEFT / RIGHT	Applicable only for TAXI VIA (taxiways)
time	time as four digits (HourHourMinuteMinute) in UTC 24h format	e.g., 0845, 2355; not 08:45
Time-Qualifier	EARLIER, OR_EARLIER, LATER, OR_LATER	
track		Example: TRACK_340
Transition-Name		
TX-Point	Name of defined Taxi-Point (or Taxi-Way, Runway Entry/Exit) such as A (alfa), B1, HP_05R or DEICING-BAY	

vertical_rate	rate of descent, rate of climb	normally four digits such as "2500"
waypoint(s)		e.g., DL455 or XAMOD
wp-angle-value	3 digits or SOUTH, EAST, WEST, NORTH or VARIABLE	If e.g. "SOUTH" it is used for aircraft headings, the aircraft is flying from the NORTH to the SOUTH; in case of wind, the wind is coming from the SOUTH (going northwards)
wp-speed-value	Speed-Value+"none"	Normally one digit; in seldom cases two digits; if wind is calm, then "0 kt"; if direction was said without proper value, then "none"

Table 9: Parameter types and values