Operational Concept Document

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Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Hörður ARILÍUSSON(Isavia)	ATM Expert, ATCo	26.06.2020
Teodor SIMIGANOSCHI(Isavia)	WP1 Leader	19.08.2020
Hartmut HELMKE (DLR)	Project Lead	19.08.2020
Julia HARFMANN (NATS)	WP5 Leader	27.07.2020

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Hartmut HELMKE (DLR)	Project Lead	19.08.2020

Approved for submission to the SJU By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date
Hartmut HELMKE	Project Lead	19.08.2020
Pavel SMRZ (BUT)	WP4 Leader	17.08.2020, see minutes of webex
Petr MOTLICEK (Idiap)	WP3 Leader	17.08.2020, see minutes of webex
Christian WINDISCH (ACG)	D6.4 Leader	19.08.2020
Teodor S. SIMIGANOSCHI (Isavia)	WP1 Leader	17.08.2020
Julia HARFMANN (NATS)	WP5 Leader	19.08.2020 (Sine MYEZWA on behalf of Julia)
Martina ERCEG (CCL)	Contact Point CCL	By silent approval

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

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Copyright Statement

HAAWAII

HIGHLY ADVANCED AIR TRAFFIC CONTROLLER WORKSTATION WITH ARTIFICIAL INTELLIGENCE INTEGRATION

This General document is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 884287 under European Union's Horizon 2020 research and innovation programme.

Abstract

Advanced automation support developed in Wave 1 of SESAR IR includes using of automatic speech recognition (ASR) to reduce the amount of manual data inputs by air-traffic controllers. Evaluation of controllers' feedback has been subdued due to the limited recognition performance of the commercial of the shelf ASR engines that were used, even in laboratory conditions. HAAWAII project aims to research and develop a reliable, error resilient and adaptable solution to automatically transcribe voice commands issued by both air-traffic controllers and pilots. The project will build on very large collection of data, organized with a minimum expert effort to develop a new set of models for complex environments of Icelandic en-route and London TMA. HAAWAII aims to perform proof-of-concept trials in challenging environments, i.e. to be directly connected with real-life data from ops room. HAAWAII aims to significantly enhance the validity of the speech recognition models to even enable pilot readback error detection.

This document contains the operational concept of the HAAWAII project. It addresses the high level Automatic Speech Recognition use cases read-back error detection, human workload assessment, callsign highlighting, and integration of speech recognition with CPDLC, radar label prefilling, and consistency checking of manual versus verbal input.

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1 Executive Summary

This Operational Concept Document focuses on possible implementation of speech recognition systems in air traffic control environment. Verifications and testing will be performed with NATS UK and Isavia Iceland.

The operational concept addresses the high level Automatic Speech Recognition use cases read-back error detection, human workload assessment, callsign highlighting, integration of speech recognition with CPDLC, radar label prefilling, and consistency checking of manual versus verbal input.

The operational environments of the Reykjavik Control Area and the London TMA are described. The high level use cases are subdivided into detailed use cases.

The high level use cases, i.e. different instances of “Usage of Speech Information” of ABSR:

- Readback error detection, see use cases described in section 4.1,
- Call sign Highlighting, see use cases described in section 4.2,
- Prefilling Radar Labels and integration of Speech Recognition and CPDLC, see use cases described in section 4.3,
- Human Performance Metric Extraction, see use cases described in section 4.4,
- Checking manual against verbal input, see use cases described in section 4.5.

They will be detailed by requirements in the following deliverable D1.2.

2 Introduction

2.1 Purpose of the document

The purpose of this Operational Concept Description[1] for the HAAWAII project is to outline the ATC environment for all the participating stakeholders to be able to understand the operational environment and the pilot-controller communication details.

2.2 Intended readership

This document is mainly intended for:

- **SESAR JOINT UNDERTAKING (SJU)** as Horizon 2020 Programme coordinator.
- **HAAWAII** consortium project members to have a common view about the existing operational environment. It is the input document for the Requirement document D1.2 and will influence the Architecture Design in D1.3 and also the Validation Concept detailed in work package 5.

2.3 Background

The HAAWAII project addresses both Automatic Speech Recognition for ATM applications and Machine Learning for training the needed Speech Recognition Models. The following Figure 1 shows the roadmap of both.

[1] The opinions expressed herein reflect the author's view only. Under no circumstances shall the SESAR Joint Undertaking be responsible for any use that may be made of the information contained herein.

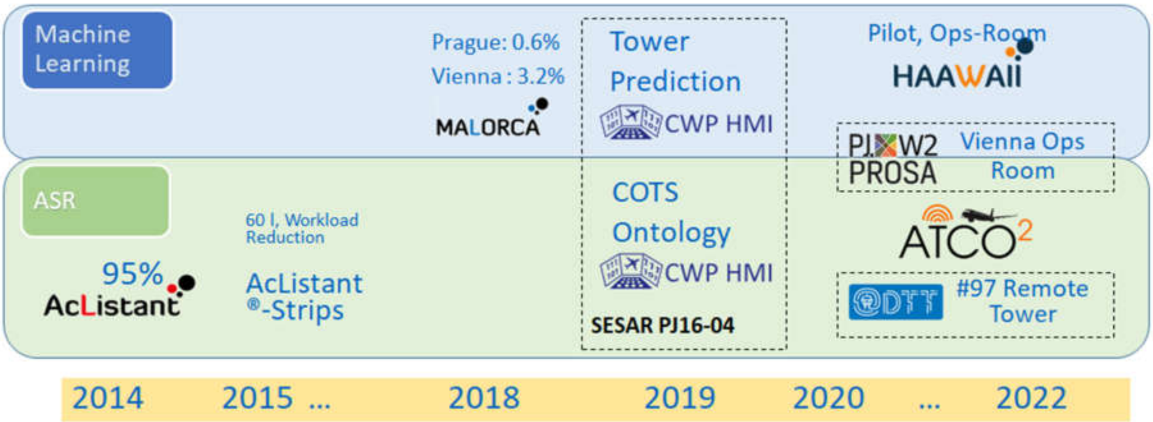

Figure 1 Speech Recognition and Machine Learning Roadmap for Speech Recognition Applications in ATM

The AcListant®[2]-Project conducted by DLR and Saarland University from 2013 to 2015 showed that a sufficient recognition performance is possible to support controllers, if Assistant Based Speech Recognition is used [2]. Command Recognition Rates of 95% were achieved for Dusseldorf Approach area. The project AcListant®-Strips[3] quantified the benefits of Assistant Based Speech Recognition. Fuel Reductions of 60 litres per flight and up to two landings more per hour were possible [3], [4]. The MALORCA project (Machine Learning of Recognition Models for Controller Assistance)[4], conducted by DLR, Saarland University, Idiap Research Institute, and the ANSPs from Austria and Czech Republic, have shown that a baseline speech recognizer can be trained by learning from surveillance data and the voice recordings. Command Recognition Errors Rates below 0.6% and 3.2% were achieved for Prague and Vienna approach area, respectively [5].

The solution PJ.16-04 of SESAR2020's wave-1[5] showed that command prediction is also possible in the tower environment and Commercial off-the-shelf tools (COTS) can be connected to Assistant Based Speech Recognition Approaches. Command Recognition Errors Rates were acceptable, whereas Command Recognition Rates were only moderate [6].

In parallel to HAAWAII other SESAR and CleanSky funded Speech Recognition projects are conducted. The ATCO2 project [6] aims at developing a unique platform allowing the collection and pre-processing of air traffic control (voice communication) data from air space. Preliminarily the project will consider

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[2] Funded by Helmholtz Validation Funds and Technology Marketing of DLR

[3] Funded by Helmholtz Validation Funds and Technology Marketing of DLR and controllers from DFS and Austro Control

[4] MALORCA was supported by SJU under grant number 698824.

[5] PJ.16-04 was supported by SJU under grant number 734141.

[6] *ATCO2 has received funding from the Clean Sky 2 Joint Undertaking (JU) under grant agreement No 864702.*

the real-time voice communication between air-traffic controllers and pilots [7]. PROSA (PJ.10-96-ASR) and DTT (PJ.05-97-ASR) are both supported by SJU in wave-2. PROSA aims to bring Speech Recognition Applications in ATM from TRL 4 to TRL 6. DTT demonstrates for the first time that Automatic Speech Recognition is also possible to support tower controllers. It aims to achieve TRL 4. Both DTT and PROSA can benefit from the results of HAAWAII. The HAAWAII members DLR, NATS, Austro Control, and CCL are also partners in PROSA and DTT. Idiap and BUT are also members of the ATCO2 project.

The data formats of dynamic and static data can also be reused by the above mentioned projects running in parallel to HAAWAII.

2.4 Structure of the document

The structure of this document is based on the Horizon 2020 template for project deliverables. It is organized as follows:

- **Chapter 1: Executive Summary**. Provides a summary of the key information and elements contained in the Technical Validation Report document.
- **Chapter 2: Introduction** (this chapter). Introduces the document.
- **Chapter 3: Description of existing ATC systems and operational environment of Isavia Control Area and NATS London TMA**. Provides a description about the existing ATC systems and the existing operational environment.
- **Chapter 4:** Details the high-level use cases by detailed use cases
- **Appendix A** contains phraseology examples of Iceland en-route traffic and NATS London TMA traffic. The phraseology examples are transformed into the ontology drafted by PJ.16.04 solution. It already shows the deficiencies of that ontology and where HAAWAII will need to improve it.

Figure 2 shows the general integration of an ABSR application into the ATM environment as defined within the European Air Traffic Management Architecture (EATMA). The ABSR receives both surveillance data (e.g. radar and sometimes also weather information) and voice utterances from the pilot and/or air traffic controller from the outside world. The main ABSR building blocks are “Command Prediction” and “Concept Extraction”, which output their result to the “Usage of Speech Information” function.

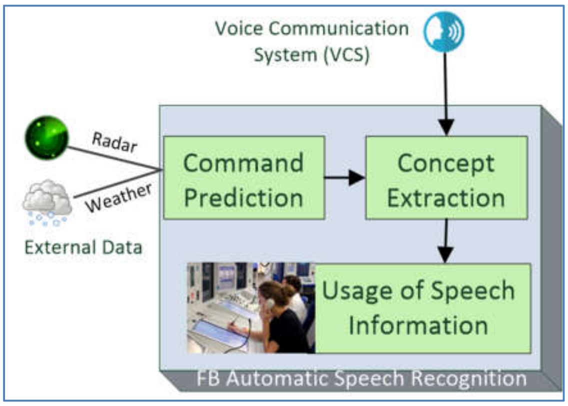

Figure 2 Integration of Automatic Speech Recognition into EATMA

In the HAAWAII project the following applications, i.e. different instances of "Usage of Speech Information" of ABSR are foreseen:

- Readback error detection, see use cases described in section 4.1,
- Call sign Highlighting, see use cases described in section 4.2,
- Prefilling Radar Labels and integration of Speech Recognition and CPDLC, see use cases described in section 4.3,
- Human Performance Metric Extraction, see use cases described in section 4.4,
- Checking manual against verbal input, see use cases described in section 4.5.

2.5 Glossary of terms

HAAWAII project has more than 20 different deliverables. Therefore, HAAWAII project decides to have one separate document containing the glossary of terms, so that maintenance of the terms is eased and errors or misunderstandings only need to be changed in one place.

In order to ease reading the glossary of terms is just added to the end of this document.

2.6 Acronyms and terminology

HAAWAII project has more than 20 different deliverables. Therefore, HAAWAII project decides to have one separate document containing the acronyms, so that maintenance of the acronyms is eased and errors or misunderstandings only need to be changed in one place.

In order to ease reading, the acronyms are just added to the end of this document.

3 Description of existing ATC systems and operational environment

Air traffic control services are provided by ground-based air traffic controllers that are directing the aircraft on the ground and through the controlled airspace, the controllers can provide advisory services also to aircrafts in a non-controlled airspace. The main purpose of ATC is to organize the air traffic and ensure safe operations of both commercial and private aircrafts. Air traffic controllers monitor the location of aircraft in their assigned airspace by radar and communicate with the pilots by radio.

3.1 Description of Reykjavik Control Area

3.1.1 Oceanic Control Area

Also known by the ICAO identifier “BIRD CTA”, the Reykjavik CTA covers an area extending from latitude of 61°N to the North Pole and from a longitude of 76°W to the Greenwich meridian. Its lower vertical limit varies from ground level to 20,000 feet above sea level. It has no upper vertical limit. The adjacent control areas are the Scottish-controlled Shanwick (EGGX) and Prestwick (EGPX), the Canadian-controlled Gander (CZQX) and Edmonton (CZEG), the Russian-controlled Murmansk (ULMM) and the Norwegian-controlled Bodö (ENOB) and Norway (ENOR).

The Reykjavik CTA’s main airports are at Keflavík, Akureyri, Vågar in the Faroe Islands and Söndreström and Thule in Greenland.

The Reykjavik CTA’s air traffic control uses data from seven radar stations located in Iceland, Faroe Islands and in Shetland Islands. The radar coverage thus provided includes all of Iceland and extends east of the Faroe Islands. The radar network facilitates air traffic control in the area and enables a better and more flexible service.

3.1.2 Terminal Manoeuvring Area

Approach services for Reykjavik Airport and Keflavik Airport are provided by the Reykjavik Area Control Centre (“Reykjavik ACC”). The terminal manoeuvring area (Faxi TMA) reaches up to 24,500 feet, like the domestic area and has a horizontal radius of approximately 40 nautical miles from Keflavik Airport.

3.1.3 Traffic pattern

The Reykjavik Control Area’s traffic pattern can be divided into five main traffic flows:

- International flights from Iceland to Europe and North America
- Traffic between Europe and North America. Most of this traffic follows routes requested by pilots and airlines with regards to favourable high-altitude winds, which means that the traffic volume and routing can vary from day to day.
- Traffic between the Middle East and North America

- Traffic between North America and the Far East
- Traffic within the domestic area and between Iceland, Greenland and the Faroe Islands.

The largest traffic flow segment is between Europe and North America. Daytime traffic consists of flights from Europe to the United States, with opposite traffic at night-time. This creates two main peak periods for the Reykjavik Area Control Centre at around 14:00 and 04:00 hrs.

3.1.4 North Atlantic Organized Track System (NAT OTS)

As is the norm in most of the NAT Region, the Reykjavik CTA is free of fixed routes, the only constraints on routing being the use of anchor points at whole degrees of latitude at every whole degrees of longitude for tracks trending West/East and at 5° intervals of latitude for North/South oriented tracks.

A significant portion of the NAT traffic operates on tracks (NAT OTS), which vary from day to day dependent on meteorological conditions.

The designation of an OTS facilitates a high throughput of traffic by ensuring that aircraft on adjacent tracks are separated for the entire oceanic crossing - at the expense of some restriction in the operator's choice of track. In effect, where the preferred track lies within the geographical limits of the OTS, the operator is obliged to choose an OTS track or fly above or below the system. Where the preferred track lies clear of the OTS, the operator is free to fly it by nominating a random track. Trans-Atlantic tracks, therefore, fall into three categories: OTS, Random or Fixed.

The location of the NAT tracks depends on the meteorological conditions and varies from day to day. The majority of the traffic in the Reykjavik CTA is on random tracks.

3.1.5 ATC Systems

The air traffic control systems employed in the Reykjavik control centre are:

Flight Data Processing System (FDPS) providing:

- General flight data processing.
- Electronic flight progress strips.
- Automatic internal and external coordination.
- Conflict probing.
- Flight progress calculation based on a weather model.
- FANS1/A ADS-C and CPDLC.
- ARINC 623 Oceanic clearance delivery.

Surveillance Data Distribution (SDDS-NG) and Processing Systems (ARTAS)

- SDDS-NG converts radar data to ASTERIX standards and distributes to ARTAS
- ARTAS processes data from several ADS-B ground stations and radar antennas

Integrated Situation Display System and radar data processing system providing:

- Multi Radar data processing.

- Air situation picture showing both radar and CPL tracks.
- Short Term Conflict Alerting (STCA).
- Lateral- and vertical conformance monitoring against the cleared oceanic flight profile.
- Functionality to graphically display flight profiles, estimates, crossing times etc.

Voice Communication System for both internal and external voice communication.

3.1.6 Air/Ground Communications

Communications with aircraft transiting the North Atlantic are an important part of Isavia's international air services. The service area consists primarily of the Reykjavik Air Traffic Control Area. Our services ensure effective and secure communications between aircraft, area control centres, aircraft operators, meteorological offices and other parties involved in air traffic.

The communications are conducted in English and mainly involve the receipt and transmission of messages relating to aviation safety, such as position fixing, various changes in altitude, speed or route, weather messages, information on landing conditions at airports, etc. Messages from aircraft are transmitted, as the case may be, to area control centres, meteorological offices and aircraft operators.

3.1.7 Control Towers

Our Air Navigation Division provides air traffic control (ATC) services at Keflavik, Reykjavik and Akureyri Airports. Only aerodrome flight information service (AFIS) is provided at other scheduled airports, whose control tower personnel come under the Airports and Infrastructure Division, although the Air Navigation Division is responsible for the service.

Air traffic services are provided at the following airports in Iceland:

Location	Service	ICAO Code
Keflavik International Airport	ATC TSWR /APP	BIKF
Reykjavik International Airport	ATC TSWR /APP	BIRK
Akureyri International Airport	ATC TSWR /APP	BIAR
Egilsstaðir International Airport	AFIS	BIEG
Bíldudalur Airport	AFIS	BIBD
Gjögur Airport	AFIS	BIGJ
Grímsey Airport	AFIS	BIGR
Hornafjörður Airport	AFIS	BIHN
Ísafjörður Airport	AFIS	BIIS
Siglufjörður Airport	AFIS	BISI

Vestmannaeyjar Airport	AFIS	BIVM
Vopnafjörður Airport	AFIS	BIVO
Þingeyri Airport	AFIS	BITE
Þórshöfn Airport	AFIS	BITN

Table 1 Airports in Iceland that provide air traffic services

3.1.8 ADS-B

Isavia has implemented ADS-B for air navigation services in the southern part of the Reykjavik Control Area, i.e. Iceland, the Faroe Islands and Greenland south of the 70th parallel north (70°N). ADS-B (Automatic Dependent Surveillance – Broadcast) is an advanced system that enables ADS-B equipped aircraft to transmit their GPS position and other data at a very frequent rate, including identification, altitude and velocity. The signal is received by ground stations, which relay it to the Reykjavik Area Control Centre where the information is displayed to air traffic controllers in a form similar to radar data and the aircraft is eligible for surveillance service.

3.1.9 Sectors within Reykjavik CTA

To spread the air traffic control load between several air traffic controllers, the Reykjavik CTA is divided into four base sectors named North, West, South and East. Those base sectors can then be further divided vertically up to sub sectors.

South Sector is the busiest of the four base sectors in Reykjavík CTA. The sector is located over Iceland so all traffic to and from Iceland route through the Sector (see picture below). The landing and departing flights within in the South Sector are approximately 20% of the overall traffic in the sector. Rest of the traffic are overflights mostly flights between Europe and North America.

The rest of the traffic are overflights mostly flights between Europe and North America.

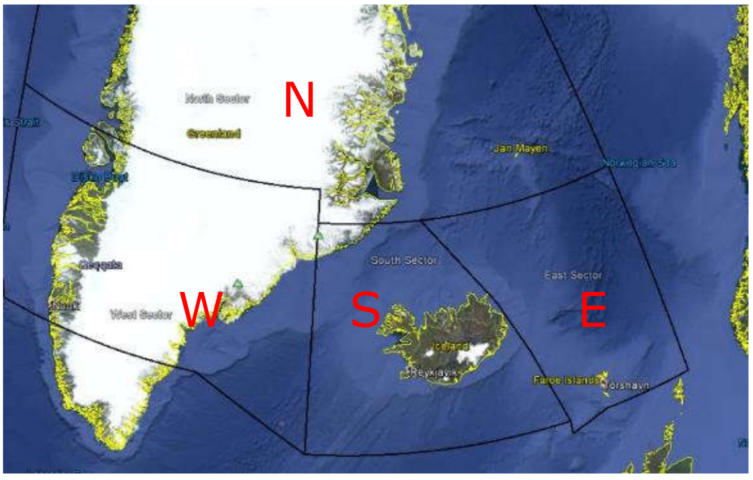

Figure 3 The four base sectors (North, South, East and West) within Reykjavík CTA (only part of North Sector shown).

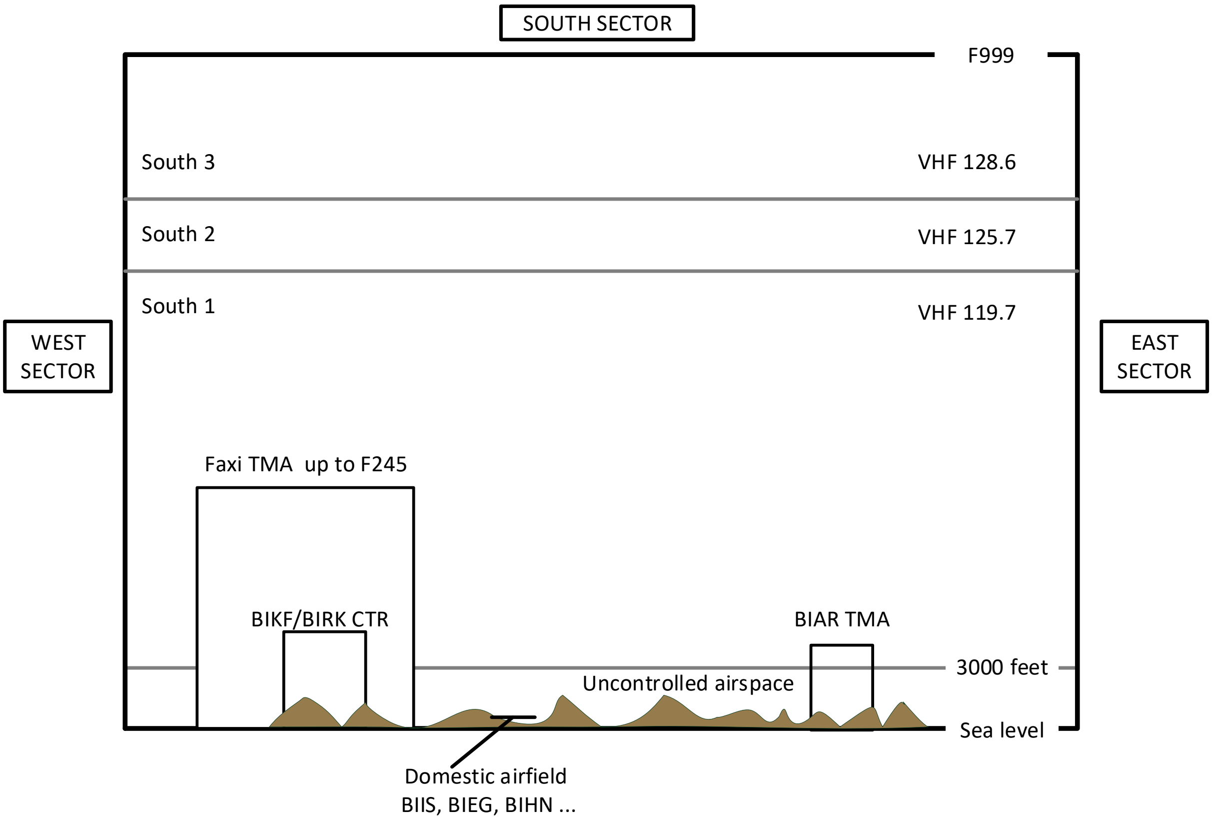

Figure 4 Horizontal cut of South Sector over Iceland

Traffic landing and taking off in Iceland can be sorted in three categories:

1. Traffic to and from Keflavik (BIKF) and Reykjavík (BIRK). Communication transfer between South Sector and Faxi TMA takes place prior to the flights crossing their boundary.
2. Traffic to and from Akureyri (BIAR). Communication transfer between South Sector and Akureyri prior to crossing the boundary.
3. Traffic to/from other domestic airfields are given clearance to exit/enter controlled airspace and then transferred to the appropriate frequency when leaving/entering South Sector.

When the traffic load in the South sector increases, it is common practice to split the sector vertically, i.e., more than one Air Traffic Controller is responsible. Then the lowest sector is defined as South 1 and subsequent sectors above South 2, South 3 etc. The VHF frequency 119.7 MHz remains with South 1 but new sectors, S2 etc. are assigned with new working frequencies.

3.1.10 Communication categories

The voice communication within the South Sector can be categorised into three main categories.

1. Communication transfer.

   a. Accepting new flights on the frequency and informing that surveillance service is established (identified).
   b. Sending flights off the frequency and in some cases terminating surveillance service.
2. ATC clearances.
   a. Climb or descend clearances
   b. Route clearance
   c. Vectoring
   d. Speed change clearance
3. Other
   a. Traffic information. Mainly between two flights when using minimum surveillance separation.
   b. Significant weather information (SIGMETS) or forwarding reports of turbulence and/or icing.
   c. Status of navigation equipment (for example NOTAMS)
   d. Other

3.2 Description of the London TMA and Approach operation

3.2.1 High level description

The London Terminal Control Centre (LTCC) handles traffic below 24,500 feet flying to or from London's airports. This area, one of the busiest in Europe, extends south and east to the borders of France and the Netherlands, west towards Bristol and north to near Birmingham.

3.2.2 Three general ATC functions

NATS controllers provide three different ATC functions:

- **Transition sectors:** operating between En-Route and LTMA operations. LTCC Midlands (4 sectors), TC Capital (2 sectors) and TC East (4 sectors, including 2 bordered by the London FIR boundary) facilitate the interface between some LTMA and London Area Control (LAC) / Prestwick Centre (PC) Sectors.

- **TC LTMA sectors** whose primary role involves tactical traffic deconfliction of arrivals and departures before transfer to approach control or transition / en-route sectors. TC LTMA sectors are divided into two groups along an east-west axis through Heathrow (TC North (6 Sectors) and TC South (6 sectors)). LTMA inbound sectors share responsibility for the holding stacks with Approach controllers.

- **Approach Control (APC)**: Heathrow (5 positions), Gatwick (3 positions), Stansted (3 positions), Thames Radar (4 positions including SVFR – Special Visual Flight Rule, is a VFR flight cleared by air traffic control to operate within a control zone in meteorological conditions below visual meteorological conditions) and Luton (2 positions).

See sectorisation in Figure 4 below. South sectors are highlighted/shaded in yellow, North sectors are shaded in grey, East sectors are outlined by a purple line, Midlands sectors are outlined by an orange line, Capital sectors are outlined/shaded in pink.

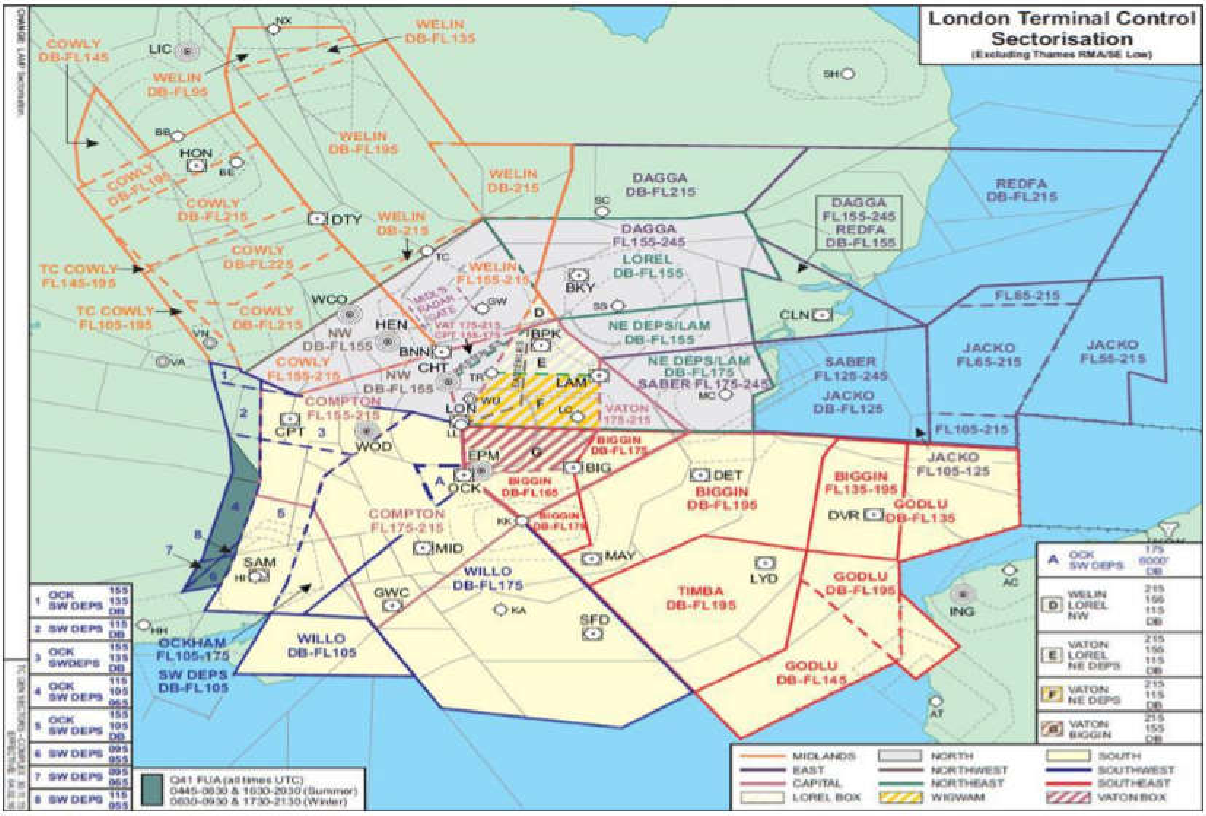

Figure 5 Map of the LTCC

3.2.3 Arriving Aircraft

Arrivals are normally presented to TC controllers from adjacent sectors from multiple directions into their sector. TC controllers dictate the order aircraft arrive at the terminal holding stacks and ensure vertical separation at the holding stacks prior to transfer of control to Approach. Arrivals are normally directed to one of ten holding stacks, each of which is designated to a particular airfield or groups of airfield, by the appropriate tactical controller.

The use of holding stacks is a key feature of today's operation, which sees aircraft fly tiered orbital tracks when the demand on arrival runways exceeds capacity.

At Heathrow, Gatwick, Stansted and Luton, aircraft are instructed to enter the holds at the lowest available level (the lowest level in these holding stacks is usually FL70 or FL80 depending on runway orientation and atmospheric pressure) as this maximises the efficiency of the operation.

The terminal holding stacks are located close to the airfield enabling Approach controllers to manage traffic efficiently enough to maintain runway capacity during peak times and accommodate requests for variable spacing at short notice from the Tower controller. However, the proximity of these holding stacks to the airfield is the primary reason for departures being vertically constrained.

On being cleared to leave the holding stacks, Approach controllers are required to issue heading instructions (vector) for all aircraft into a radar vectoring pattern to establish a sequence for landing. All aircraft require vectors onto the ILS for landing. TC Approach controllers provide an efficient operation delivering high movement rates to single or dual runway operations. To deliver this level of traffic, there is a reliance on a near continuous R/T workload.

3.2.4 Departing Aircraft

Departures from Heathrow, Gatwick, Stansted and Luton are initially restricted to 6000ft or below (co-incident with the LTMA Transition Altitude) on the standard departure routes (SIDs) to remain below traffic in the holding stacks or on the initial/ intermediate approach. Once the departure is clear of the inbound conflicting aircraft the pilots are issued further clearances dependant on prevailing traffic conditions and agreements with adjacent sectors.

Heathrow departures all climb continuously to 6000ft. Departures from adjacent airfields climb to lower, intermediate levels underneath Heathrow SIDs, often containing step-climbs i.e. aircraft are required to level off for periods during their climb rather than benefit from a continuous climb profile. SIDs from Heathrow, Gatwick, Stansted, Luton and London City are all separated from each other for the initial portion of their route. However, tactical intervention is ultimately required by controllers to ensure separation against the other SIDs, routes, Radar Manoeuvring Areas (RMAs), sectors and also in order to present the aircraft to the next sector in the manner required.

When above the Noise Preferential Route (NPR), controllers have the flexibility to vector aircraft off their SID in order to facilitate climb earlier than would be possible if left to follow the SID profile. This is common practice and is indeed what TC controllers are trained to do until their workload becomes too high, at which point aircraft are left to follow the SID. However, as detailed above, aircraft cannot be left on all SID routes for their entirety due to other traffic interactions therefore even during busy periods, tactical intervention is needed.

3.2.5 Main traffic flows

London TMA: Main traffic flows are traffic into and outbound from London TMA and underlying/adjacent airfields and overflights below FL245. Generally, traffic arrives and goes out to all directions (domestic/oceanic to the north, medium/short haul to the south and east).

London Approach: LTC Swanwick provides approach services to London's five main airports and manages the low-level traffic flows with associated VFR tasks.

4 Use cases

4.1 Readback error Detection

The pilot-controller communication loop supports the safety and redundancy of pilot-controller communications, as described in Figure 6 .

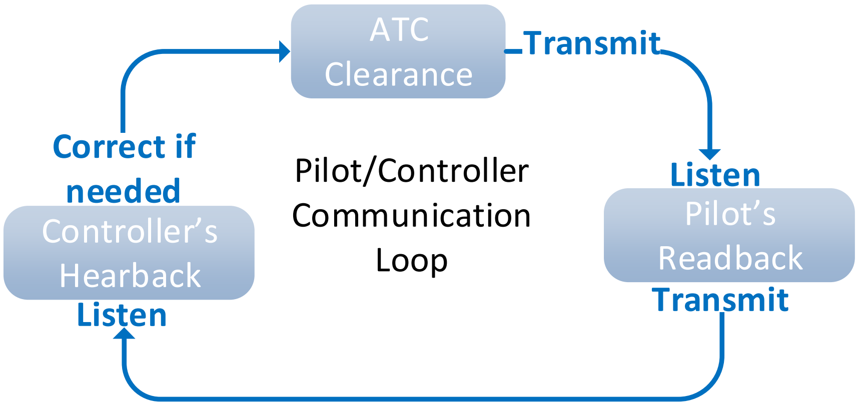

Figure 6 Pilot/Controller communication loop [11]

The readback error can occur at different stages in the communication, some stages are described in the image below using pilot-controller communication timeline view. The Pilot can initiate the call (dotted line in the figure below) but usually the ATCO is the first who initiates the call.

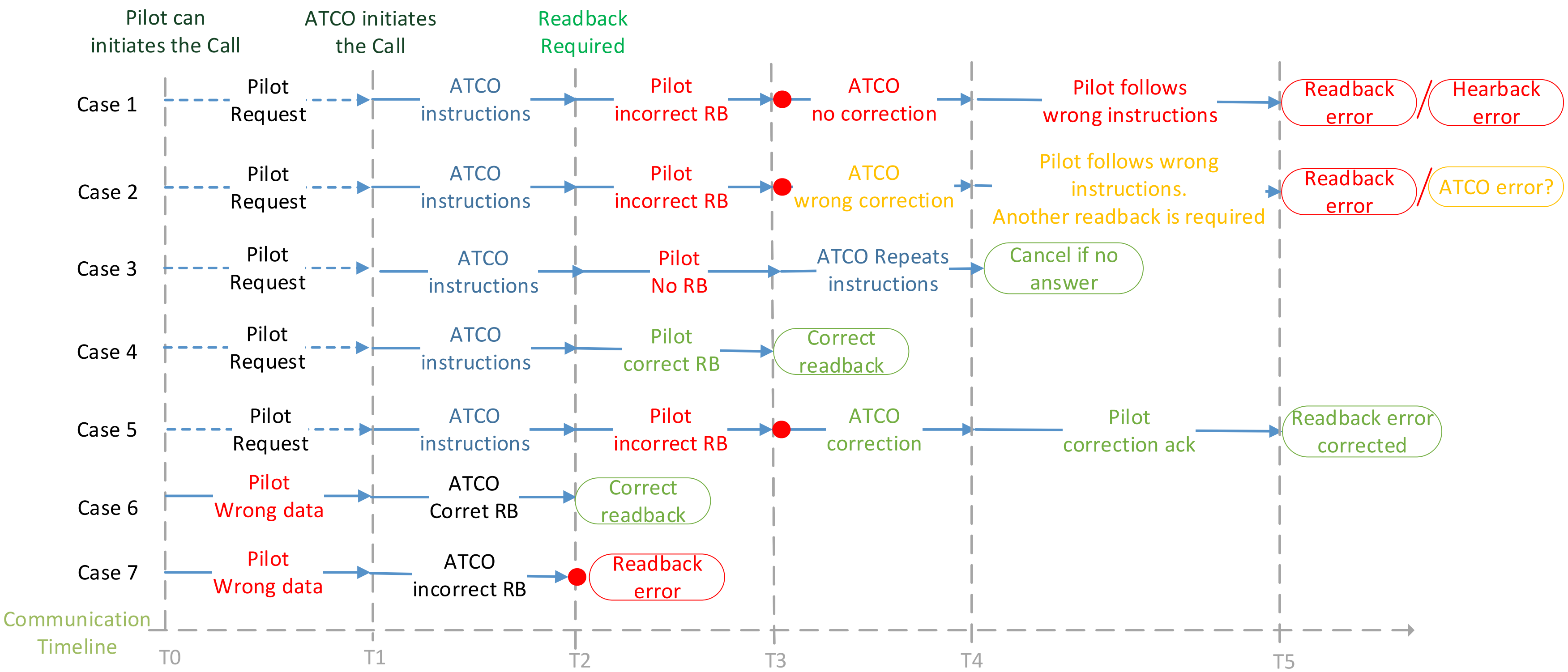

Figure 7 Pilot and controller communication displayed in timeline view

legend:

- T2, T3 – Represents the ABSR measurement point for readback errors
- - Marks readback error found by ASBR resp. the application (here Readback Error Detection)
- - Represents a consequence indication in timeline view

To clarify the meaning of readback and hearback, SKYbrary has two definitions with explanations:

- "An uncorrected erroneous readback is known as a hearback error "[7]
- "Failure to correct an erroneous readback is also known as hearback error"[8]

From the Pilot/Controller communication the ABSR will have to identify and extract the important information from the controller's or pilot's utterance, respectively. We call important information the ATC concept of the ontology defined within solution PJ.16-04 of SESAR wave-1. The important concepts are the call sign, the command main and second type, the value(s), the qualifier, the unit and the condition. Figure 8 shows the ATC concepts. Yellow elements are optional respectively type dependent.

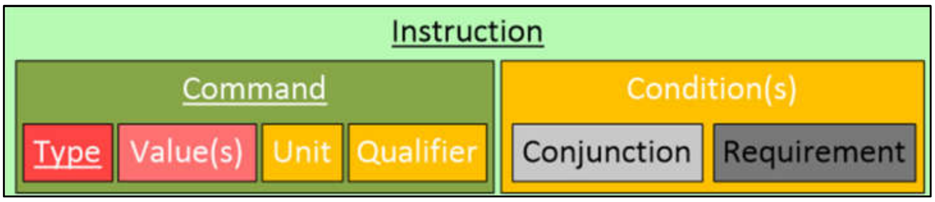

Figure 8 Elements (without call sign) of an instruction of a clearance (figure taken from [1])

The ATCO utterance "lufthansa two alfa four turn left heading three two zero descend flight level one two zero or below when passing gunpa contact approach nineteen three" is transformed into the following instructions each consisting of the specified ATC concepts:

1. DLH2A4 HEADING 320 LEFT
2. DLH2A4 DESCEND 120 FL OR_BELOW WHEN PASSING GUNPA
3. DLH2A4 CONTACT REYK_APPROACH
4. DLH2D4 CONTACT_FREQUENCY 119.300

[7] https://www.skybrary.aero/index.php/Read-back_or_Hear-back

[8] https://www.skybrary.aero/index.php/Pilot-Controller_Communications_(OGHFA_BN) Chapter 6.9

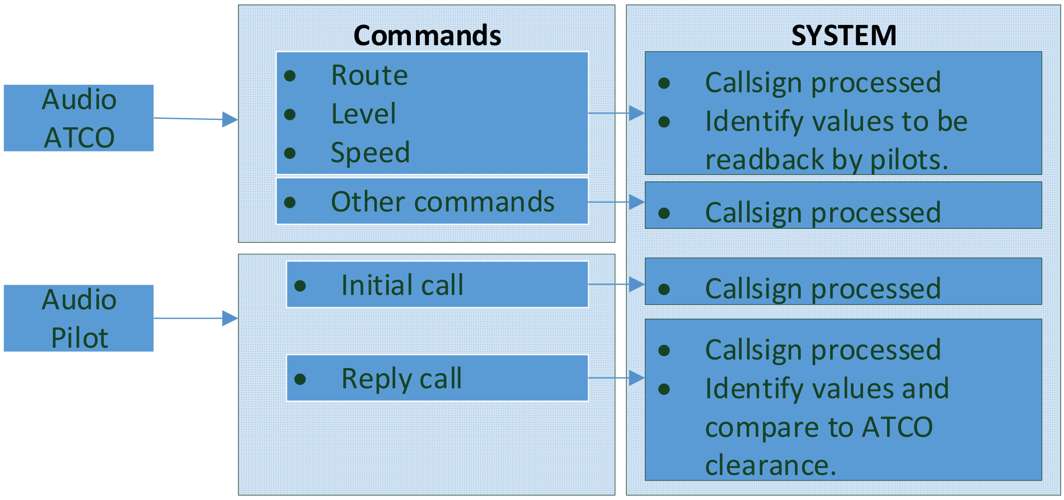

Figure 9 High level diagram with SYSTEM actions

In the following subsections we detail the case of by use cases.

4.1.1 Operational Use Case "Correct Readback"

We assume the following ATCO pilot communication (containing no readback error):

ATCO: lufthansa two alfa four turn left heading three two zero descend flight level one two zero or below when passing gunpa be careful airbus three two zero at two o'clock position
Pilot: descending two alfa four descending one two zero or below after gunpa and turning left three two zero

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: DLH2A4 HEADING 320 LEFT
DLH2A4 DESCEND 120 FL OR_BELOW WHEN PASSING GUNPA
DLH2A4 INFORMATION TRAFFIC
PILOT: DLH2A4 DESCEND 120 none OR_BELOW WHEN PASSING GUNPA
DLH2A4 HEADING 320 LEFT
SYSTEM: no output resp. a green light[9]

Note:

- The words used by pilot and ATCO can be very different. Nevertheless, the readback is correct.
- Not all command types require a readback (here INFORMATION TRAFFIC).
- The sequence of the command types could be different in ATCO's utterance and in the pilot's read (here ATCO first HEADING and the DESCEND, whereas the pilot starts with DESCEND).

---

[9] The terms, green, yellow and red light are detailed in the requirements document and in the user interface description. In this document we just want to highlight, that there is a reaction of the system. Green, everything O.K., yellow, first warning, red: error

- Not all elements need to be repeated. Here the ATCO provides the unit (flight level) in his DESCEND command, whereas the pilot just repeats the number and not the unit.

4.1.2 Operational Use Case "Incorrect Readback with ATCO correction"

We assume the following ATCO pilot communication (containing a readback error):

ATCO: lufthansa two alfa four turn left heading three two zero descend flight level one two zero or below when passing gunpa be careful airbus three two zero at two o'clock position
PILOT: two alfa four descending one three zero or below after gunpa and turning left three two zero
ATCO: lufthansa two alfa four negative sir descend flight level one two zero or below
PILOT: thank you and sorry descending one two zero or below

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: DLH2A4 HEADING 320 LEFT
DLH2A4 DESCEND 120 FL OR_BELOW WHEN PASSING GUNPA
DLH2A4 INFORMATION TRAFFIC
PILOT: DLH2A4 DESCEND 130 none OR_BELOW WHEN PASSING GUNPA
DLH2A4 HEADING 320 LEFT
SYSTEM: detects the wrong readback and shows a yellow light for the callsign
ATCO: DLH2A4 DESCEND 120 FL OR_BELOW
PILOT: DLH2A4 DESCEND 120 none OR_BELOW
SYSTEM: The yellow light disappears and is transformed into a green light.

Note:
- The words used by pilot and ATCO can be very different. Here the value of DESCEND command was wrong. The controller then corrected the descend value and the pilot later read it back correctly.
- ATCO and pilot should always provide the callsign, but this does not always happen, here the ATCO always uses the callsigns, but the pilot does not provide the callsign in the corrected readback.
- Not all command types require a readback (here INFORMATION TRAFFIC).
- The sequence of the command types could be different in ATCO's utterance and in the pilot's read back (here ATCO first HEADING and the DESCEND, whereas the pilot starts with DESCEND).
- Not all elements need to be repeated. Here the ATCO provides the unit (flight level) in his DESCEND command, whereas the pilot just repeats the number and not the unit.

4.1.3 Operational Use Case "Incorrect Readback without ATCO correction"

We assume the following ATCO pilot communication (containing a readback error):

ATCO: lufthansa two alfa four turn left heading three two zero
PILOT1: two alfa four turning right three two zero
ATCO: speedbird one one descend flight level one two zero
PILOT2: descending level one two zero speedbird one one

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: DLH2A4 HEADING 320 LEFT
PILOT1: DLH2A4 HEADING 320 RIGHT
SYSTEM: detects the wrong readback and shows a yellow light for the callsign
ATCO: BWA11 DESCEND 120 FL
PILOT2: BWA11 DESCEND 120 FL
SYSTEM: The yellow light gets red.

4.1.4 Operational Use Case "Incorrect Readback with late ATCO correction"

The use case could, however, also be

ATCO: lufthansa two alfa four turn left heading three two zero
PILOT1: two alfa four turning right three two zero
ATCO: speedbird one one descend flight level one two zero
PILOT2: descending level one two zero speedbird one one
ATCO: lufthansa two alfa four negative turn left heading three two zero I say again turn left
PILOT1: two alfa four turning left three two zero

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: DLH2A4 HEADING 320 LEFT
PILOT1: DLH2A4 HEADING 320 RIGHT
SYSTEM: detects the wrong readback and shows a yellow light for the callsign
ATCO: BWA11 DESCEND 120 FL
PILOT2: BWA11 DESCEND 120 FL
SYSTEM: The yellow light gets red.
ATCO: DLH2A4 NEGATIVE[10]
DLH2A4 HEADING 320 LEFT
DLH2A4 TURN LEFT
PILOT1: DLH2A4 HEADING 320 LEFT
SYSTEM: The red light gets green again

4.1.5 Simultaneous readbacks on multiple cross coupled frequencies ATCO hears only one frequency, SYSTEM connected only to CWP voice, no readback error detected

The ATCO is responsible for multiple bandboxed sectors with multiple cross-coupled frequencies. As they are cross coupled all pilots can hear all the communication within this particular sector. The ATCO of course also can listen to all the communication, but sometimes the crosses coupled frequencies, when simultaneously used, are not send both to the ATCO.

ATCO: qantas eight one eight four descend flight level three five zero.

[10] Currently NEGATIVE is not a command type in the ontology, but just for this cases the ontology needs to be updated.

PILOT1 on frequency A: descend flight level three five zero qantas eight one eight four
PILOT2 on frequency B: descend flight level three five zero Qantas eight one four four

At workstation ATCO can only hear readback of Quantas 8184 on frequency A and thinks the readback is correct but in fact, both aircraft will descend which the ATCO would need to pick up from their visual scan when Quantas 8144 descends without instruction.

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: QFA8184 DESCEND 350 FL
PILOT1, FREQUENCY A: QFA8184 DESCEND 350 FL
PILOT2, FREQUENCY B: QFA8144 DESCEND 350 FL
SYSTEM: Green light no readback error if the SYSTEM is connected to the voice stream from the controllers working position.

Notes: This use case it is a readback error in real life scenario because the ATCO heard only PILOT1 on frequency A and has not heard PILOT2 on frequency B and both but the voice of PILOT2 is not send towards the SYSTEM and it cannot identify it as a readback error. This is considered a limitation of the SYSTEM if it is solely connected to the controller's position.

4.1.6 Simultaneous readbacks on multiple cross coupled frequencies ATCO hears only one frequency, SYSTEM connected to the CWP voice stream and Frequency voice stream, readback error detected

The ATCO is responsible for multiple bandboxed sectors with multiple cross-coupled frequencies. As they are cross coupled all pilots can hear all the communication within this particular sector. The ATCO of course also can listen to all the communication, but sometimes the crosses coupled frequencies, when simultaneously used, are not send both to the ATCO.

ATCO: qantas eight one eight four descend flight level three five zero.
PILOT1 on frequency A: descend flight level three five zero qantas eight one eight four
PILOT2 on frequency B: descend flight level three five zero Qantas eight one four four

At workstation ATCO can only hear readback of Quantas 8184 on frequency A and thinks the readback is correct but in fact, both aircraft will descend which the ATCO would need to pick up from their visual scan when Quantas 8144 descends without instruction.

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: QFA8184 DESCEND 350 FL
PILOT1, FREQUENCY A: QFA8184 DESCEND 350 FL
PILOT2, FREQUENCY B: QFA8144 DESCEND 350 FL
SYSTEM: Detects the wrong readback and shows a yellow light for the callsign

Notes: In this scenario the SYSTEM can be connected to the actual receivers units (before the cross coupling happens) and it could detect the different readbacks directly from the receivers.

4.1.7 Simultaneous readbacks on multiple cross coupled frequencies ATCO hears only one frequency, readback error

The ATCO is responsible for multiple bandboxed sectors with multiple cross-coupled frequencies. As they are cross coupled all pilots can hear all the communication within this particular sector. The ATCO of course also can listen to all the communication, but sometimes the crosses coupled frequencies, when simultaneously used, are not send both to the ATCO.

ATCO: qantas eight one eight four descend flight level three five zero.
PILOT1 on frequency A: descend flight level three five zero qantas eight one eight four
PILOT2 on frequency B: descend flight level three five zero Qantas eight one four four

At Workstation ATCO can only hear readback of Quantas 8144 and is required to pick up the incorrect callsign to become aware of the incorrect readback.

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: QFA8184 DESCEND 350 FL
PILOT1, FREQUENCY A: QFA8184 DESCEND 350 FL
PILOT2, FREQUENCY B: QFA8144 DESCEND 350 FL
SYSTEM: detects the wrong readback and shows a yellow light for the callsign

4.1.8 Pilot instigates transmission resulting in correct controller readback

PILOT: uhh approach can we just check that the QNH is one zero zero one at the moment
ATCO: negative QNH one zero one zero hecto pascals information zulu.

According to the ontology, this is transformed into the corresponding ATC concepts:
PILOT: NO_CALLSIGN CHECK INFORMATION QNH 1001
ATCO: NO_CALLSIGN NEGATIVE
NO_CALLSIGN INFORMATION QNH 1010
NO_CALLSIGN INFORMATION ATIS Z
SYSTEM: no output resp. a green light, i.e. this case should be flagged as correct readback by the controller.
Notes:

- Current implementation of annotation ontology does not cover a pilot request/check.
- Current implementation of annotation ontology does not cover the command type NEGATIVE, but this use case in comparison with the next one shows the necessity for an addition.

4.1.9 Pilot instigates transmission resulting in wrong controller readback

PILOT: uhh approach can we just check that the QNH is one zero zero one at the moment
ATCO: affirm QNH one zero one zero hecto pascals information zulu.

According to the ontology, this is transformed into the corresponding ATC concepts:
PILOT: NO_CALLSIGN CHECK INFORMATION QNH 1001
ATCO: NO_CALLSIGN AFFIRM
NO_CALLSIGN INFORMATION QNH 1010
NO_CALLSIGN INFORMATION ATIS Z

SYSTEM: no output resp. a red light, i.e. this case should be flagged as incorrect readback by the controller.

Notes:

- Current implementation of annotation ontology does not cover the command type AFFIRM
- If the controller would have just said the correct QNH with "QNH one zero one zero hecto pascals information zulu" without the word "affirm", this should be also flagged as an incorrect readback. The CHECK requires an answer.

4.1.10 Readback corrected halfway through – readback error

ATCO: Easy one four juliet hotel descend flight level one six zero, level by amdut, delay less than twenty minutes.
PILOT: Thanks for that, descending flight level one four zero, I mean one six zero level by amdut, copy the delay easy one four juliet hotel.

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: EZY14JH DESCEND 160 FL AFTER PASSING AMDUT
EZY14JH INFORMATION MISCELLANEOUS
PILOT: EZY14JH CORRECTION
EZY14JH DESCEND 140 FL
EZY14JH 160 FL AFTER PASSING AMDUT
EZY14JH INFORMATION MISCELLANEOUS
SYSTEM: detects the wrong readback and shows a yellow light for the callsign

Note: The readback error is in the fact that there are two different levels in the pilot readback. This scenario requires the whole instruction and readback to be repeated to avoid any potential confusion. The situation should, therefore, be highlighted as readback error.

4.1.11 Missing units

ATCO: american two four descend altitude four thousand feet
Pilot: ok descending down to four thousand american two four

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: AAL24 DESCEND 4000 ft
PILOT: AAL24 DESCEND 4000 none
SYSTEM: yellow for a potential readback error[11]

[11] The checking for units might result in many readback errors. Some ANSPs often do not say the unit especially in high traffic situations. Therefore, it should be configurable, if the SYSTEM should flag unit errors as readback errors. Details will be provided in D1.2 and during the proof-of-concept trials preparation.

Note: The readback of type, callsign and value is correct, but the unit is missing in the pilot's readback.

ATCO: american two four descend altitude four thousand feet QNH nine nine two hector pascals, turn right heading three six zero twenty two miles to touchdown.
Pilot: ok descendin* down to four, nine nine two on the altimeter and turnin* right heading three sixty american twenty four.

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: AAL24 DESCEND 4000 ft
AAL24 INFORMATION QNH 992
AAL24 HEADING 360 RIGHT
AAL24 INFORMATION MISCELLANEOUS
PILOT: AAL24 DESCEND 4000 none
AAL24 INFORMATION QNH 992
AAL24 HEADING 360 RIGHT

Note: Even though the pilot readback the correct QNH, they did not readback the unit (i.e. hectopascal). This should, therefore, be highlighted as readback error. Use case deliberately chosen as American based carriers often mistake QNH in HpA (when below 1000) for QNH in mmHg, these errors can lead to very large altimeter setting issues. This is also pertinent for use of 'Flight Level and Degrees', also pertinent to 'Flight Level & Altitude'

4.1.12 Varying pronunciation/formation of Callsigns

Callsigns that are used infrequently can be called by different 'names' which are all correct. For example, 'VXS' stands for 'Voluxis' which some controllers know and others do not; so they might call them either 'victor x-ray sierra' or 'Voluxis'. A similar case is 'ORT' – callsign 'Skywalker'.

ATCO2: victor x-ray sierra one two three turn right heading zero nine zero degrees.
Pilot: turning right heading zero nine zero, voluxis one two three.

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: VXS123 HEADING 090 RIGHT
PILOT: VXS123 HEADING 090 RIGHT
SYSTEM: *green light*

ATCOs handover

ATCO2: victor x-ray sierra one two three climb flight level one four zero, and by the way what is that callsign again
Pilot: no problem, Its vol-ux-is, climbing flight level one four zero voluxis one two three.

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO2: VXS123 CLIMB 140 FL
PILOT: VXS123 CLIMB 140 FL

SYSTEM: *green light*

Note: the information of how to speak VXS is annotated as NO_CONCEPT, i.e. it cannot be mapped into commands in the ontology.

Additionally, callsigns can be spoken in many varying, inconsistent ways:

QTR4444:

Qatari four four four four

Qatari four triple four

Qatari triple four four

Qatari double four double four

Even qatari four four or four triple four without the Qatari are possible.

Etc. It is entirely possible for aircraft to have multiple exchanges with a ground station and both sides use different verbal formations of the callsign for each and every individual transmission.

All of these **are correct** and should not be highlighted as readback errors. And the situation is even more complicated. We have what the ATCo and pilot say and on the other hand we have what the speech recognizer extracts.

4.1.13 ATCO changes callsign

Exceptionally in cases of callsign confusion, ATC may temporarily amend the callsign of an aircraft. These are usually, but not limited to, the company callsign + the registration of the aircraft.

ATCO: speedbird one two three report your registration
Pilot: speedbird one two three, it's uh, golf echo uniform romeo oscar
ATCO: roger speedbird one two three, due callsign confusion adopt new callsign speedbird golf romeo oscar.
Pilot: roger, speedbird golf romeo oscar.
ATCO: speedbird golf romeo oscar descend flight level three hundred
Pilot: descending flight level three zero zero speedbird golf romeo oscar

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: BAW123 REPORT_MISCELLANEOUS
PILOT: BAW123 INFORMATION MISCELLANEOUS
SYSTEM: *green light*

ATCO: BAW123 CHANGE_CALLSIGN BAWGRO
PILOT: BAWGRO NO_CONCEPT
SYSTEM: *green light*

ATCO: BAWGRO DESCEND 300 FL
PILOT: BAWGRO DESCEND 300 FL
SYSTEM: *green light*

Note: Currently the CHANGE_CALLSIGN command type is not supported by the ontology. This information could be helpful, because the registration code is not exchanged via the surveillance data. It is only available via mode S downlink.

4.2 Call-sign Highlighting

4.2.1 Operational Use Case No. 1, Standard instructions

ATCO: speedbird one two three climb to flight level three two zero

According to the ontology, this is transformed into the corresponding ATC concepts:

ATCO: BAW123 CLIMB 320 FL
SYSTEM: recognize aircraft call-sign and then immediately highlights its call-sign on the radar screen

4.2.2 Operational Use Case No. 2, Pilot initiates the call

PILOT: lufthansa three eight nine, request decent flight level two two zero

According to the ontology, this is transformed into the corresponding ATC concepts:

PILOT: DLH389 DESCEND 220 FL
SYSTEM: recognize aircraft call-sign from the pilot and then immediately highlights its call-sign

4.2.3 Operational Use Case No. 3, Pilot ATCO conversation

PILOT: lufthansa three eight nine, request decent flight level two two zero
ATCO: lufthansa three eight nine, cleared decent flight level two two zero
PILOT: lufthansa three eight nine decending to flight level two two zero, lufthansa three eight nine

According to the ontology, this is transformed into the corresponding ATC concepts:

PILOT: DLH389 DESCEND 220 FL
SYSTEM: recognize aircraft call-sign from the pilot and then immediately highlights its call-sign
ATCO: DLH389 DESCEND 220 FL
SYSTEM: recognize aircraft call-sign from the pilot and then immediately highlights its call-sign. The SYSTEM, however, recognizes that DLH389 also was previously recognized. A flashing of the callsign highlighting needs to be avoided. This will be detailed in the requirements and in the validation concept.
PILOT: DLH389 DESCEND 220 FL
SYSTEM: recognize aircraft call-sign from the pilot and then immediately highlights its call-sign

Note: Call-sign flashing should be avoided when call-sign highlights.

4.2.4 Operational Use Case No. 4, Callsign at the end

ATCO: lufthansa three eight nine, cleared decent flight level two two zero
PILOT: decending to flight level two two zero, lufthansa three eight nine

According to the ontology, this is transformed into the corresponding ATC concepts:

ATCO: DLH389 DESCEND 220 FL
SYSTEM: recognize aircraft call-sign from the pilot and then immediately highlights its call-sign
PILOT: DLH389 DESCEND 220 FL
SYSTEM: recognize aircraft call-sign from the pilot and then highlights its call-sign. This is, however, only possible at the end of the utterance.

Note: Call-sign flashing should be avoided when call-sign highlights.

4.2.5 Operational Use Case No. 5, Missing callsign

ATCO: decent flight level two two zero

According to the ontology, this is transformed into the corresponding ATC concepts:

ATCO: NO_CALLSIGN DESCEND 220 FL
SYSTEM: No callsign is highlighted, because no callsign is said. It might be clear, from the previous conversation, which callsign is meant, but from the utterance itself, nothing could be extracted. This happens sometimes, although ATCO and pilot should avoid it. It could also happen when the ATCO speaks to a callsign, the pilot answers with callsign and the ATCO immediately reacts without repeating the callsign. This should be avoided, but you cannot change reality.

4.3 Pre-filling Radar Labels and CPDLC Messages

4.3.1 Operational Use Case No. 1 Pre-filling electronic strips

ATCO: airfrance one zero hotel descend flight level nine zero on qnh one zero zero four reduce two hundred or below
According to the ontology, this is transformed into the corresponding ATC concepts:

ATCO: AFR01H DESCEND 90 FL AFR01H INFORMATION QNH 1004
AFR01H REDUCE 200 none OR_BELOW
SYSTEM: The system prefills the descend value flight 90 and the speed target of 200 knots into the radar label. The QNH value is also recognized, but a QNH

ATCO: airfrance one zero juliet hotel your hold at ockham is cancelled. Leave ockham heading zero nine zero degrees downwind left hand two seven left twenty eight miles to touchdown
According to the ontology, this is transformed into the corresponding ATC concepts:

ATCO: AFR01JH LEAVE_HOLDING OCKHAM AFR01JH 090 none AFR01JH INFORMATION ACTIVE_RWY 27L AFR01JH INFORMATION TRAFFIC

SYSTEM: should populate the flight strip/radar label with required annotations, i.e. the heading value of 90 degrees the integrated..

Note: It should also be noted that this functionality is ONLY applicable for air traffic units without conflict detection tools linked to the flight data system. ATCOs will always need to probe/visually check whether their intended instruction is safe. Therefore, having the system populated only once the controller gives the instruction might be too late for probing/visual conflict detection.

4.3.2 Operational Use Case No. 2 CPDLC message – correct recognition

ATCO (system input): indicates to the system that they want to send a CPDLC message.
ATCO (verbal input): speedbird one two three contact London on 123 decimal 456.
SYSTEM: presents the CPDLC content to ATCO, which includes "BWA123 CONTACT LNDN_RADAR BWA123 CONTACT_FREQUENCY 123.456"
ATCO accepts content.
ATCO sends message to aircraft.
PILOT acknowledges message.
ATCO indicates to the system that the system should stop populating CPDLC messages after acknowledgement from the pilot is received.

Note: It needs to be specified outside the ontology that "contact London" is mapped to "CONTACT LNDN_RADAR" or "CONTACT LONDON" or "CONTACT TOWER_OF_LONDON. Even "CONTACT OSLO_AIRPORT" could be specified, but this of course makes no sense.

4.3.3 Operational Use Case No. 2 CPDLC message – incorrect recognition

ATCO (system input): indicates to the system that they want to send a CPDLC message.[12]
ATCO (verbal input): speedbird one two three contact London on one two three decimal four five six.
SYSTEM: presents a wrong CPDLC content to ATCO, which could e.g. be "BWA123 CONTACT LNDN_RADAR BWA123 CONTACT_FREQUENCY 124.356".
ATCO rejects content.
ATCO corrects content to 123.456. This could be done again verbally or manually.
ATCO accepts content.
ATCO sends message to aircraft.
PILOT acknowledges message.
ATCO indicates to the system that the system should stop populating CPDLC messages after acknowledgement from the pilot is received.

[12] This could be implemented by pressing a button or a toggle function implemented also by pressing a button.

4.4 Human Performance Metric Extraction

The idea of extracting human performance metrics from voice communication data stems from operational experience and observations around changes in workload. Most supervisors are able to judge the overall workload on their sector groups by noise level, use of particular words or phrases and body language of the controllers operating the sector.

On ANSP level we currently rely on subjective measures around controller workload. Even though data extraction from system input is possible it is not currently used during live operation to support supervisors' decision making. New ways of using voice communication data as a way to better understand controller workload objectively could provide an exciting opportunity for ANSPs to manage workload and support more efficient staffing decisions.

It should be noted that one single variable (i.e. voice communication related human performance metric) is only one puzzle piece in order to accurately measure workload. It should not be analysed in isolation but could be a valuable input for objective human performance metrics.

In the following sections, potential use cases for human performance metrics extraction from voice communication data are illustrated.

4.4.1 Operational Use Case No. 1 Changes in speed of speech

Does the controller change the speed at which syllables are spoken? The speed at which syllables are spoken can indicate varying workload levels. Experienced controllers report slowing down when workload increases to buy themselves thinking time whereas more inexperienced controllers are perceived to speed up when they get busier.

In order to measure varying levels of workload the average speed of speech would need to be measured for an individual to be able to draw valuable conclusions. When they fall outside of their 'usual speed of speech' it could be indicated to the supervisor that workload at the sector is changing (increasing as well decreasing).

4.4.2 Operational Use Case No. 2 Recognition of workload related phrases

Is there a change in amount of use of 'say again', 'stand by', 'avoiding action', 'break', 'correction'?

Does the controller use more filler words (e.g. ahm, hmm, good morning/afternoon, etc.)?

All the phrases above can indicate increased workload. Again, it will be important to measure any changes of the frequency in which these phrases are used to indicate changes in workload rather than absolute scores.

Phraseology indicating high workload:

Note: This is a very extreme example that might not happen like this in the real world, but it should just illustrate the use of the different words listed above.

Example 1
PILOT: London hello, speedbird seven eight echo november.
ATCO: Station calling, say again callsign.
For this purpose the new command type "SAY_AGAIN" is added to the ontology.

Example 2:
PILOT: Lufthansa two eight seven hello, flight level one six zero speed two eight zero knots and we are heading one eight zero degrees.
ATCO: Lufthansa two eight seven stand by, break break, speedbird seven eight echo November turn left heading one seven zero degrees.
The ontology does not cover the "break, break" concept, but the output is here
DLH287 CALL_YOU_BACK BWA78EN HEADING 170 LEFT
We have the command type CALL_YOU_BACK (for standby) and we have two different callsigns in the same utterance. The output of the annotation is independent from the usage of the words sequence "break, break". Therefore the output to the "USAGE OF SPEECH INFORMATION" (human performance metric evaluation") in Figure 2 at page 12 should also include the recognized word sequence, which also includes "break, break".

Example 2 (cont):
PILOT: left turn heading one eight zero degrees speedbird eight echo November.
ATCO: correction. speedbird seven eight echo November turn left heading one seven zero degrees.
PILOT: left one seven zero degrees speedbird seven eight echo November.
The annotation of the ATCO's utterance would be:
BWA78EN CORRECTION
BWA78EN HEADING 070 LEFT
Note: The phraseology used here by the ATCO is not fully correct. Correction is used to correct in the same utterance. Negative would be the correct phraseology.

Example 3:
ATCO: avoiding action speedbird seven eight echo November turn right heading two hundred degrees immediately traffic on your left-hand side.
PILOT: turning right heading two hundred degrees speedbird seven eight echo November.
ATCO: BWA78EN HEADING 200 RIGHT BWA78EN INFORMATION TRAFFIC PILOT: BWA78EN HEADING 200 RIGHT

The "avoiding action" and "immediately" word sequences are not part of the ontology.

Filler words indicating high workload:

PILOT: hello London airfrance one five two flight level one seven zero heading zero nine zero degrees speed is two twenty knots.
ATCO: ahhhm thank you remain present heading airfrance ahhhm one five two.
PILOT: London good morning, Lufthansa one two three.
ATCO: gooooood morning Lufthansa one two three descend flight level one four zero
PILOT: flight level one four zero Lufthansa one two three.

Note: Pilots calling with callsign only can be an indication of a busy frequency. The pilot has been listening to the frequency before calling and assumed that the controller is too busy to take their full message. Additionally, within TC controllers can instruct pilots to only state their callsign upon first call on the next sector to reduce R/T loading for the downstream controller.

Note: The fillers are not part of the ontology. “gooood” and “goood” etc. are all mapped to “good”.

4.4.3 Operational Use Case No. 3 General R/T loading

The percentage of R/T loading in general can provide useful information of the workload experienced at the sector.

4.4.4 Operational Use Case No. 4 Error rates

It will also be interesting to see how many readback errors occur at a sector (regardless of ATM GND or Airborne, errors require correcting and thus additional workload) and how this rate changes depending on different workload levels.

4.4.5 Operational Use Case No. 5 Application of speech recognition for supervisor roles

A challenge will be to present the output of the use cases above in a meaningful way to the supervisor. They will be most interested in changes in workload at the sector as they are responsible for bandboxing/splitting and general staffing level decisions. An early indication of increase or decrease of workload will be extremely useful to this role.

Potential HMI solutions for this should be discussed during Application and Evaluation activities as part of the HAAWAII project.

4.4.6 Operational Use Case No. 6 Number and type of clearance

Generally, the number and type of clearances can give a good indication of workload at the sector. Obviously, the more clearances are given overall the more the busier the controller is. Again, what is important is the rate of change. How sudden is the increase/decrease in overall number of clearances per time interval?

Another interesting indicator is the type of clearance and different combinations of them. The following list of clearances varies in cognitive load from high cognitive demand to lower demand:

- Level
- Heading
- Speed
- Route

Following this, different combinations introduce different levels of cognitive workload. For example, a controller given a level and heading clearance combined in one transmission indicates a higher level of cognitive demand compared to a single speed change in one transmission.

Giving this is a good indication for cognitive workload it should be extracted from speech recognition. The practical application of this information could be twofold. The information will be especially interesting for supervisors in near-real time in the live operation. It could give them a good understanding of workload changes of the sector and support them in decision making around sector splits. The other application would be an offline analysis of this data for longer term workload analysis and incident investigations. However, this second application is not the primary focus from an ANSP perspective as it can already be achieved through system input data analysis.

Note: Many types are already directly inserted into the HMI by the ATCOs (e.g. headings, descend values etc.), but other types of the ontology, which are verbally exchanged between ATCOs and pilots are not inserted into the HMI and therefore lost for workload estimation if not Automatic Speech Recognition Application is available. Examples are INFORMATION TRAFFIC, INFORMATION QNH, INFORMATION ATIS, EXPECT ILS, EXPECT RUNWAY, REPORT etc.

4.4.7 Operational Use Case No. 7 Number of open communications

Normally the ATCO speaks to one pilot and the pilot answers, but it could also happen that another pilot answer in between. The number of open communications could therefore also be a hint with respect to workload.

PILOT1: hello London air_france one five two flight level one seven zero request descend
ATCO: speedbird one eight four one heading one nine zero
The communication to pilot 1 is still open: open comm count is one.

PILOT2: london good morning, passing gunpa hansa one nine alfa
ATCO: air_france one five zero good morning
The communication to pilot 1 is still open, because his request for descend is not answered yet and the answer to Pilot2 is also open, open comm count is two

The situation can even be more complex, if read back errors are considered, see the beginning of this chapter for more details.

4.5 Consistency Check of manual versus verbal input

Checking “mouse versus mouth” input

4.5.1 Use Case “Inadvertent utterance – Level“

Controller inadvertently utters (incorrect) FL80 when intending and electronically clearing the aircraft to FL90:

ATCO enters clearance to FL90

ATCO: Austrian six seven eight descend flight level eight zero, hold at Ockham is cancelled, leave Ockham heading two four five.
PILOT: Descending flight level eight zero, leave Ockham heading two four five Austrian six seven eight.

According to the ontology, this is transformed into the corresponding ATC concepts:

ATCO: AUA678 DESCEND 80 FL
AUA678 HEADING 245 none
PILOT: AUA678 DESCEND 80 FL
AUA678 HEADING 245 none

Note: Even though the instruction and readback are correct, this scenario is erroneous as the controller intended and entered a different level into the system.

4.5.2 Use Case "Inadvertent utterance – Callsign"

Controller inadvertently utters wrong callsign and instructs aircraft A when intending and electronically clearing aircraft B:

ATCO enters clearance Descend FL160 for BAW456 into system.

ATCO: Speedbird one two three descend flight level one six zero.

PILOT: Descending flight level one six zero speedbird one two three.

According to the ontology, this is transformed into the corresponding ATC concepts:
ATCO: BAW123 DESCEND 160 FL
PILOT: BAW123 DESCEND 160 FL

Note: Verbal instruction and readback are correct but system input (and ATCO's mental model) are incorrect. This should be recognised as a readback error.

5 References

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[11] https://flightsafety.org/asw-article/failure-to-communicate/ - Pilot controller communication loop Figure 1 (Source: Flight Safety Foundation Approach-and-Landing Accident Reduction (ALAR) Task Force)

Appendix A En-route Phraseology examples from Isavia's Airspace

The following operational phraseology examples are extracted from Isavia MANOPS and are intended to be used to better understand the operational environment. The ABSR shall recognize callsign of Pilot and ATCO and verify the readback.

Each example consists of the words the controller/pilot uses and also contains the corresponding annotation with respect to the ontology rules.

The annotation also serves as input for D1.2 to identify gaps in the current ontology with respect to en-route phraseology.

A.1 Level Changes

#	Phraseology	Example of frequent phrases
1	Climb/descent to (level)	• Speedbird123 climb to flight level 320 • Delta005 descend flight level 100
		BWA123 CLIMB 320 FL DAL005 DESCEND 100 FL
2	Climb/descend to and maintain block (level) to (level)	• Iceair007 climb to flight level 340 block 360
	Currently the ontology does not cover the phraseology "block 360"	ICE007 CLIMB 340 FL
3	Climb/descend to reach (level) at/by (time or significant point)	• Austrian234 climb to reach flight level 340 at 1200 • American555 climb to reach flight level 390 by 18 west
	The ATCO does not explicitly mention, whether it is a climb or descent rate. It is clear from the context, but the ontology mostly covers, what is said, not what is meant. No unit was specified for the climb rate; therefore, none is used. The second example contains a conditional clearance. The condition is an UNTIL and not a WHEN.	AUA234 CLIMB 340 FL AUA234 VERTICAL_RATE 1200 none AAL555 CLIMB 390 FL UNTIL PASSING 18 WEST
4	Stop climb/descend at (level)	• Faxi56 Stop climb at flight level 090
		FXI56 STOP_CLIMB 90 FL
5	Continue climb/descend at (level)	• Arctic Eagle 202 continue descend flight level 160
	The ontology does not distinguish between descend and continue	FEI202 DESCEND/CLIMB 160 FL

	descend.	
6	Expedite climb/descend until passing (level)	• Volga 20 expedite descend until passing flight level 200
	There is now special expedite for climb or descend	VDA20 EXPEDITE_PASSING 200 FL
7	When ready climb/descend to (level)	• UPS 788 when ready descend flight level 100
	It is not an IF READY, because IF READY would mean, do it now or do not do it. WHEN READY means do it now or later.	UPS788 DESCEND 100 FL WHEN READY
8	After passing (significant point) climb/descend to (level)	• United 400 after passing 2630 west climb flight level 390
		UAL400 CLIMB 390 FL AFTER PASSING W2630
9	At (time or significant point) climb/descend to (level)	• Executive 3 alfa bravo at 1303 climb flight level 450 • Pegasus 002 at mike yankee descend below controlled airspace
	DESCEND below controlled airspace is currently not modelled. We would currently annotate just with NO_CONCEPT	EXT3AB CLIMB 450 FL WHEN TIME 1303 MVM002 DESCEND CA none BELOW WHEN PASSING MY
10	Climb via SID to (level)	• India Fox India climb via sid to flight level 180
	We assume that the hellas lift 234A is the only hellas lift in the air, otherwise NO_CALLSIGN would be provided. "via SID" is not modelled yet, as qualifier for CLIMB, but we have FOLLOW_ROUTE	IFI234A CLIMB 180 FL IF!23CA FOLLOW_ROUTE SID
11	Climb via SID to (level), cancel level/speed restrictions at (point)	• Westjet 666 climb via SID to flight level 340, cancel level restrictions at kilo fox india • Survey 9 bravo climb via SID to flight level 250, cancel speed restrictions at flight level 100.
	CANCEL is modelled, but the second type LEVEL_RESTRICTIONS is currently missing. NO_SPEED_RESTRICTIONS is, however, modelled.	WJA666 CLIMB 340 FL WJA666 FOLLOW SID WJA666 CANCEL LEVEL_RESTRICTIONS WHEN PASSING KFI SUY9B CLIMB 250 FL SUY9B FOLLOW SID SUY9B NO_SPEED_RESTRICTIONS WHEN PASSING 100 FL
12	Descend via STAR to (level), cancel level/speed restrictions at (point)	• Air india 898 descend via star to flight level 100 • Topswiss 1 bravo, descend via STAR to flight level 100, cancel speed restrictions at Victor Mike

		• Romeo Yankee Romeo 122, descend via STAR to flight level 100, cancel level restrictions 120 miles from kilo fox victor.
	The condition with the waypoint and a distance is currently not modelled.	AIC898 DESCEND 100 FL AIC898 FOLLOW_STAR EZS1B DESCEND FL 100 EZS1B FOLLOW STAR EZS1B NO_SPEED_RESTRICTIONS WHEN PASSING VM RYR122 DESCEND 100 FL RYR122 FOLLOW_ROUTE STAR, RYR122 CANCEL LEVEL_RESTRICTIONS WHEN PASSING KFV 120 mi

A.2 Issue of clearance

The ontology has no special type for a reclearance.

#	Phraseology	Example of frequent phrases
1	Recleard (amended clearance details)	• Air France 033 Recleard Mach 080 in Reykjavík Area
	"Reykjavík Area" is not modelled yet. Recleared is not distinguished from a normal speed clearance.	AFR033 SPEED 0.8 MA
2	Recleard (amended route portion) TO (significant point or route) Rest of clearance unchanged.	• Scandinavian946 Recleard after passing 64 north 20 west via 61 north 30 west Rest of clearance unchanged.
	DIRECT_TO is currently followed by a waypoint name, but in en-route communication direct lat/long positions are quite normal. Therefore, the ontology wil be extended. It needs to be decided whether the coordinates are separated by an underscore or by blank. "rest of clearance unchanged" is not annotated.	SCS946 DIRECT_TO 61N_30W AFTER PASSING 64N_20W
3	Enter controlled airspace via/at (Significant point, level or time).	• Greenlandair 246 enter controlled airspace at flight level 190 • Faxi 300 enter controlled airspace at time 1245 or later.
	ENTER_CA is currently not covered by ontology. ENTER_CTR, however, is already available.	GRL246 ENTER_CA WHEN PASSING 190 FL FXI300 ENTER_CA WHEN TIME 1245 OR_LATER

4	Leave controlled airspace via/at (Significant point, level or time).	• November 2 charlie tango, leave controlled airspace at flight level 120 • Danish two rescue, leave controlled airspace at time 1919 or earlier.
	"rescue" is covered in the callsign.	N2CT LEAVE_CA WHEN PASSING 120 FL DTR2 LEAVE_CA WHEN TIME 1919 OR_EARLIER
5	From (location) TO (location) DIRECT/VIA/FLIGHT PLAN ROUTE	• Connie two tango, from yankee delta papa FLIGHT PLAN ROUTE TO 69 north 20 west • Radio five, after sierra fox proceed direct hotel bravo.
	The type FLIGHT_PLAN_ROUTE is currently completely ignored, also in the tower environment.	CKS2T FLIGHT_PLAN_ROUTE WHEN PASSING YDP UNTIL PASSING 69N_20W
6	Maintain (level) TO (significant point).	• Austrian five five, maintain flight level 320 to india november golf • Tango fox fox Oscar x-ray, maintain 3000 feet until ecco sierra.
		AUA55 MAINTAIN 320 FL UNTIL PASSING ING TFFOX MAINTAIN 3000 ft UNTIL PASSING ES
7	Maintain (level) UNTIL PASSING (significant point).	• K L M nine nine,, maintain flight level 390 until passing 6230 north
		KLM99 MAINTAIN 390 FL UNTIL PASSIG 6230N
8	Maintain (level) WHILE IN CONTROLLED AIRSPACE.	• Faxi five six, maintain flight level 190 while in controlled airspace • Tango fox foxtrot tango foxtrot, maintain 9000 feet while in controlled airspace
		FXI56 MAINTAIN 190 FL UNTIL PASSING CA TFFTF MAINTAIN 9000 ft UNTIL PASSING CA
9	Cross (significant point) AT (or ABOVE, or BELOW) (level).	• Pakistan six oh six, climb to cross 19 west at or above flight level 380 • World one one, cross kilo fox victor at or below flight level two five zero.
	It is not clear, whether we have a DESCEND or CLIMB. It is just implicitly said due to "or below". The cross keyword is said before the altitude keyword, therefore, the ALTITUDE is the condition.	PIA606 CLIMB 380 FL OR_ABOVE WHEN PASSING 19W WOA11 DIRECT_TO KFV WHEN ALTITUDE 250 FL OR_BELOW
10	Cross (significant point) AT (time) OR LATER (OR BEFORE) AT (level).	• Iceair four five four, cross rapad at one three one three or later at flight level two nine zero. • Scandinavian two bravo, cross valdi at or before zero

		eight at flight level three nine zero
	We have two conditions.	ICE454 DIRECT_TO RAPAD WHEN TIME 1313 OR_LATER WHEN PASSING 290 FL
11	CRUISE CLIMB BETWEEN (levels) (or ABOVE (level)).	• Air France two two, cruise climb between flight level three five zero and flight level four one zero. • Noaa four three, cruise climb above flight level four one zero
	The ontologoy has no concept for "between".	AFR22 CLIMB 350 FL OR_ABOVE AFR22 CLIMB 410 FL OR_BELOW
12	CROSS (distance) MILES, (GNSS or DME) [(direction)] OF (name of DME station) OR (distance) [(direction)] OF (significant point) AT (or ABOVE or BELOW) (level).	• Arctic air seven zero three, cross two zero miles east of india Romeo kilo DME at flight level one two zero or below. • K L M two two tango, cross twenty miles GNSS west of valdi at flight level three nine zero
	CROSS not covered yet with this semantics. We have multiple qualifiers.	CIR703 DIRECT_TO IRK 23 nm EAST WHEN PASSING 120 FL OR_BELOW Or CIR703 CLIMB 120 FL OR_BELOW WHEN PASSING IRK 23 nm EAST
13	CROSS (significant point) AT (or ABOVE, or BELOW) (level)	• Speedbird two four five, cross one two west at flight level three five zero or below. • Odinn one, cross linda at or above flight level one three zero
		BWA245 DIRECT_TO 12W WHEN PASSING 150 FL OR_BELOW ODI1 DIRECT_TO LINDA WHEN PASSING 130 FL
14	CONFIRM ESTABLISHED ON THE TRACK BETWEEN (significant point) AND (significant point) [WITH ZERO OFFSET	• Dynasty five five, confirm established on the track between ecco sierra and alfa kilo india
	Currently modelled as "REPORT_MISCELLANEOUS", an ontology extension needed. ESTABLISHED_TRACK could have multiple values with different semantics	CAL55 REPORT_NOW ESTABLISHED_TRACK ES AKI

A.3 Holding clearances

#	Phraseology	Example of frequent phrases
1	CLEARED (or PROCEED) TO (significant point, name of facility or fix) [MAINTAIN (or CLIMB or DESCEND TO) (level)] HOLD [(direction)] AS PUBLISHED EXPECT APPROACH CLEARANCE (or FURTHER CLEARANCE) AT (time)	• Iceair two bravo, cleared to nasbu descend flight level nine zero to hold expect further clearance at one two one five • Finnair two two, proceed to kilo fox india zero one climb flight level one eight zero to hold expect further clearance at one four zero zero
	HOLDING value mandatory, so we extract it from words before. "expect further clearance at one two one five" is completely ignored. INFORMATON TRAFFIC is the only concept we have.	ICE2B DIRECT_TO NASBU ICE2B DESCEND 90 FL ICE2B HOLDING NASBU FIN22 DIRECT_TO KKI01 FIN22 CLIMB 180 FL FIN22 HOLDING KKI01
2	CLEARED (or PROCEED) TO (significant point, name of facility or fix) [MAINTAIN (or CLIMB or DESCEND TO) (level)] HOLD [(direction)] [(specified) RADIAL, COURSE, INBOUND TRACK (three digits) DEGREES] [RIGHT (or LEFT) HAND PATTERN] [OUTBOUND TIME (number) MINUTES] EXPECT APPROACH CLEARANCE (or FURTHER CLEARANCE) AT (time) (additional instructions, if necessary)	• Norland zero one, cleared to golf Romeo maintain flight level zero eight zero hold inbound track three four zero right hand pattern outbound time two minutes expect approach clearance at two three five nine
		FNA10 DIRECT_TO GR FNA10 MAINTAIN ALTITUDE 80 FL FN10 HOLDING TRACK_340 RIGHT
3	CLEARED TO THE (three digits) RADIAL OF THE (name) VOR AT (distance) DME FIX [MAINTAIN (or CLIMB or DESCEND TO) (level)] HOLD [(direction)] [RIGHT (or LEFT) HAND PATTERN] [OUTBOUND TIME (number) MINUTES] EXPECT APPROACH CLEARANCE (or FURTHER CLEARANCE) AT (time) (additional instructions, if necessary)	• Scandinavian one seven double eight, cleared to the one five two radial of the kilo fox victor VOR at two three DME fix climb flight level two two zero hold left hand pattern expect further clearance at time two two two two
		SAS1788 DIRECT_TO ? SAS1788 CLIMB 220 SAS1788 HOLDING ??? LEFT
4	CLEARED TO THE (three digits) RADIAL OF THE (name) VOR AT (distance) DME FIX [MAINTAIN (or CLIMB or DESCEND TO) (level)] HOLD BETWEEN (distance) AND (distance) DME [RIGHT (or LEFT) HAND	• Condor six zero, cleared to the two two zero radial of the india November golf vor at one five dme fix maintain flight level three two zero hold between one five and three five dme expect further clearance at one five five

	PATTERN] EXPECT APPROACH CLEARANCE (or FURTHER CLEARANCE) AT (time) (additional instructions, if necessary)	zero.
	The first and third clearance are not covered by ontology yet.	CFG60 DIRECT_TO RADIAL_220_ING 15 DME CFG60 MAINTAIN 320 FL CFG60 HOLDING DME 15 DME 35

A.4 Vectoring instructions

#	Phraseology	Example of frequent phrases
1	LEAVE (significant point) HEADING (three digits)	• Flyme seven, leave atsix heading two two zero • Eva triple seven, leave kilo fox victor heading three five zero
	The leaving of the waypoint is not modelled. LEAVE_HOLDING is the only available command type. None is added, because neither LEFT nor RIGHT is said.	FYE7 HEADING 220 none EVA777 HEADING 350 none
2	CONTINUE PRESENT HEADING	• Wizzair two seven five, continue present heading after passing atsix
	The aircraft is before and after ATSIX using the same heading (the present heading).	WZZ275 CONTINUE PRESENT_HEADING WHEN PASSING ATSIX
3	FLY HEADING (three digits)	• Scandinavia zero zero, fly heading two two five • Volga nine triple nine, fly heading three five five
		SAS00 HEADING 220 none VDA9999 HEADING 355 none
4	TURN LEFT (or RIGHT) HEADING (three digits) [reason]AT (time) (additional instructions, if necessary)	• Iceair four five, turn right heading zero zero five due traffic • Greenland air five alfa, turn left heading two seven zero for delay
	Currently “due traffic” and “for delay” is not annotated. It could added as “INFORMATION TRAFFIC”.	ICE45 HEADING 005 RIGHT GRL5A HEADING LEFT 270
5	TURN LEFT (or RIGHT) (number of degrees) DEGREES[reason]	• November one one, turn right ten degrees report new heading

		• Kilo fox bravo, turn left ten degrees due traffic
	It is not a REPORT_NOW, but a REPORT is reached. All REPORT types are, however, without the conditions keywords "IF, UNTIL, WHEN".	N11 TURN_BY 10 RIGHT N11 REPORT HEADING
6	FLY HEADING (three digits), WHEN ABLE PROCEED DIRECT (name) (significant point)	• Nordland eight eight, fly heading two eight zero when able proceed direct rapax
	This is not an "IF", but a "WHEN" condition.	NWS88 HEADING 280 NWS88 DIRECT_TO RAPAX WHEN ABLE
7	RESUME OWN NAVIGATION (position of aircraft) (specific instructions)	• Golf echo Charlie seven eight, four five miles from kilo fox victor resume own navigation direct gunpa • German cargo seven eight over kilo foxtrox resume own navigation direct valdi
		GEC78 NAVIGATION_OWN WHEN PASSING KFV 45 nm
8	RESUME OWN NAVIGATION [DIRECT] (significant point) [MAGNETIC TRACK (three digits) DISTANCE (number) KILOMETRES (or MILES)	• India Charlie echo four seven, radar vectoring terminated resume own navigation direct November bravo magnetic track one one five distance one hundred miles • P A T three, resume own navigation direct Mykenes magnetic track zero one five distance one two three six miles
	The semantics of "magnetic track one one five distance one hundred miles" is currently no covered and "radar vectoring terminated" is also not modelled.	ICE47 NAVIGATION_OWN ICE47 DIRECT_TO NB PAT3 NAVIGATION_OWN PAT3 DIRECT_TO MYKENES
9	MAKE A THREE SIXTY TURN LEFT (or RIGHT) [reason]	• Rome Oscar uniform triple four, make a three sixty to the right due traffic
	No waypoint for the 360 is specified. Therefore we use none.	ROU444 ORBIT none RIGHT
10	TURN LEFT (or RIGHT) NOW	• Fox fox Charlie zero one. Turn right now
	The "now" is modelled. "now" is always is assumed if no condition is provided.	FFC10 TURN RIGHT

A.5 Speed control

#	Phraseology	Example of frequent phrases
1	MAINTAIN (number) KILOMETRES PER HOUR (or KNOTS) [OR GREATER (or OR LESS)] [UNTIL (significant point)]	• Air India seven, maintain two seven zero knots until passing flight level one zero zero • Papa papa victor triple seven, maintain three hundred knots or greater until passing flight level three zero zero
		AIC7 MAINTAIN SPEED 270 kn UNTIL PASSING 100 FL PPV777 MAINTAIN SPEED 300 kn OR_GREATER UNTIL PASSING 300 FL
2	MAINTAIN PRESENT SPEED	• Wizz go five five, maintain present speed
		WUK55 MAINTAIN PRESENT_SPEED
3	INCREASE (or REDUCE) SPEED TO (number) KILOMETRES PER HOUR (or KNOTS) [OR GREATER (or LESS)]	• Faroeline two two, reduce speed to two two zero knots or less
	This phraseology is airport dependent. Many ANSPs avoid the word “TO” before the speed value. Mismatch between “to” and “two” is very likely.	FLI22 REDUCE 220 kn OR_LESS
4	RESUME NORMAL SPEED	• Golf bravo Juliet alfa Juliet, resume normal speed
		GBJAJ RESUME_NORMAL_SPEED
5	REDUCE TO MINIMUM APPROACH SPEED or REDUCE TO MINIMUM CLEAN SPEED	• Aurela one, reduce to minimum approach speed • Tango fox triple tango, reduce to minimum clean speed
		LSK1 REDUCE_MIN_APPROACH_SPEED TFTTT REDUCE_MIN_CLEAN_SPEED
6	NO SPEED RESTRICTION	• Alfa golf tango, no speed restrictions • Sierra alfa sierra nine zero four, no atc speed restrictions
		AGT NO_SPEED_RESTRICTIONS SAS904 NO_SPEED_RESTRICTIONS
7	SPEED UP ON CONVERSION (number) KNOTS	• Iceair two three three, speed upon conversion three zero zero knots

	The semantics of "upon conversion" is not modelled.	ICE233 SPEED 300 kn
8	MAINTAIN MACH (number) [OR GREATER (or OR LESS)] [UNTIL (significant point)]	• Midnight nine nine, maintain mach zero eight zero or greater until twenty west • Netjet eight, maintain mach eight two or less until hotel oscar
		MDT99 MAINTAIN SPEED 0.8 MA OR_GREATER UNTIL PASSING 20W NJT8 MAINTAIN SPEED 0.82 OR_LESS UNTIL PASSING HO

A.6 Traffic information and avoiding action

#	Phraseology	Example of frequent phrases
1	TURN LEFT (or RIGHT) IMMEDIATELY HEADING (three digits) TO AVOID [UNIDENTIFIED] TRAFFIC (bearing by clock reference and distance)	• CSA-LINES triple two, turn right immediately heading two five five to avoid traffic
	"immediately" and "avoid traffic" not modelled. "INFORMATION TRAFFIC" is possible.	CSA222 HEADING 255 RIGHT
2	TURN LEFT (or RIGHT) (number of degrees) DEGREES IMMEDIATELY TO AVOID [UNIDENTIFIED] TRAFFIC AT (bearing by clock-reference and distance)	• Kilo tango kilo two, turn right 30 degrees immediately to avoid unidentified traffic at your twelve o clock two miles
	"turn right by" is of course preferred, otherwise "TURN_BY" could be mixed by HEADING, although the heading value is here just two digits. "twelve o'clock" and "two miles" are not modelled.	KTK2 TURN_BY 30 RIGHT KTK2 INFORMATION TRAFFIC
3	SQUAWK (code)	• Fox fox india, squawk three seven seven five
		FFI SQUAWK 3775
4	(aircraft call sign) LOW ALTITUDE WARNING, CHECK YOUR ALTITUDE IMMEDIATELY, QNH IS (number) [(units)]. [THE MINIMUM FLIGHT ALTITUDE IS (altitude)]	• Lucky air six six, low altitude warning, check your altitude immediately, qnh is low nine seven two at Bildudalur airport, minimum flight altitude is six thousand feet.
	"low altitude warning", "immediately", "Bildudalur airport",	LKE66 REPORT_NOW ALTITUDE LKE INFORMATION

	and "minimum flight altitude is six thousand feet" are not modelled. "INFORMATION MISCELLANEOUS" possible, but also not helpful.	QNH 972

Appendix B Appendix: Acronyms and terminology

Term	Definition
ABSR	Assistant Based Speech Recognition
ACC	Area Control Centre
ACG	Austro Control Österreichische Gesellschaft (Austria ANSP)
ADS-B	Automatic dependent surveillance–broadcast
AEC	Approach executive controller
AFIS	Aerodrome Flight Information Service
AG	Attention Guidance
AI	Artificial Intelligence
ANRIC	Aeronautical Radio Incorporated
ANSP	Air Navigation Service Provider
ANS-CR	Air Navigation Services of the Czech Republic
APC	Approach planning controller
APP	Approach
ARR	Arrival
ARTAS	ATM suRveillance Tracker And Server
ASR	Automatic Speech Recognition
ASTERIX	All Purpose Structured Eurocontrol Surveillance Information Exchange
ASW	Air situation window
ATC	Air Traffic Control
ATCo	Air Traffic Controller
ATM	Air Traffic Management
Avg	Average
BUT	Brno University of Technology
CBA	Cost Benefit Analysis
CER	Context (Prediction) Error Rate
Cmd	Command (files containing annotations)
CmDER	Command Error Rate
CmDRR	Command Recognition Rate

Term	Definition
CoCoLoToCoCo	Controller Command Logging Tool for Context Comparison
Cor	Correct (files containing transcriptions)
COTS	Commercial of the shell
CPP	Context Portion Predicted
CONOPS	Concept of operations
CPDLC	Controller Pilot Data Link Communications
CTA	Control area
CTR	Controlled traffic region
CV	Clearance verification
CWP	Controller Working Position
DASC	Digital Avionics Systems Conference
DEC	Departure executive controller
DEP	Departure
DFS	Deutsche Flugsicherung GmbH (German ANSP)
DLR	German Aerospace Center, Deutsches Zentrum für Luft- und Raumfahrt e.V.
DNN	Deep neural network
DVI	Direct Voice Input
DVO	Direct Voice Output
EATMA	European Air Traffic Management Architecture, An architectural Model of European ATM for each SESAR Concept Story board step containing information relating to Operational activities.
EDR	Event Detection Rate
EML	European Media Laboratory
ENAIRE	Spanish ANSP
ER	En-Route
Err	Error (files containing errors)
EU	European Union
EXE	Exercise
FAA	Federal Aviation Administration
FANS	Future Air Navigation System

Term	Definition
FDPS	Flight Data Processing System
FL	Flight level
FIR	Flight Information Region
ft	Feet
GUI	Graphical User Interface
HF	Human factors
HMI	Human Machine Interface
HUP	Human Performance
ICAO	International Civil Aviation Organization
ICE	Intelligent Communications Environment
ID	Identifier
Idiap	Idiap Research Institute
IEC	Information executive controller
ILS	Instrument landing system
IFR	Instrument Flight Rules
ISA	Instantaneous self assessment
khz	Kilo hertz
KPA	Key Performance Area
kt	Knots
LAC	London Area Control
LTCC	London Terminal Control Centre
LTMA	London Terminal Manouvering Area
MALORCA	Horizon 2020 funded project MACHINE LEARNING OF SPEECH RECOGNITION MODELS FOR CONTROLLER ASSISTANCE
MWM	Mental Workload Model
N/A	Not applicable
NASA TLX	NASA Task load index
NATS	United Kingdom ANSP
NAT OTS	NORTH ATLANTIC ORGANIZED TRACK SYSTEM
Nm	Nautical miles

Term	Definition
No.	Number
NOK	Not Ok
NPR	Noise Preferential Route
Obj	Objective
OSED	Operational services and environment description
OTS	ORGANIZED TRACK SYSTEM
PC	Prestwick Centre
PEC	Director executive controller
PERF	Performance
PJ	Project
POK	Partly Ok
PST	Performance Stability
PSS	Paperless Strip System
PTT	Push to talk
R/T	Radio Telephony
REF	Reference
REQ	Requirement
ReTi	Reaction Time
RMA	Radar Manoeuvring Areas
RNAV	Area navigation
RWY	Runway
(S)VFR	(Special) Visual Flight Rules
SA	Situation Awareness
SAR	Safety assessment report
SASHA	Situation Awareness for SHAPE (Solutions for Human Automation Partnerships in European ATM)
SAF / SAFE	Safety
SC APP	Approach Senior Controller
Scn	Scenario
SDK	Software Development Kit

Term	Definition
SDDS	Surveillance Data Distribution
SESAR	Single European Sky ATM Research
SID	Standard instrument departure
SJU	SESAR Joint Undertaking
SME	Subject Matter Experts
SOL	Solution
STAR	Standard terminal arrival route
STCA	Short Term Conflict Alerting
T2C	Text-to-Concept
T2S	Text-to-Speech
TC	Terminal Control
TMA	Terminal Manoeuvring Area
TRL	Technology Readiness Level
TS	Technical Specification
TSWR	Tower
TTC	Text-to-Concept
TTS	Text-to-Speech
TVALP	Technical Validation Plan
TVALR	Technical Validation Report
V2T	Voice to Text
V&V	Validation & Verification
VFR	Visual flight rules
VieAPP	Vienna Approach
VRR	Voice Recognition and Response
VTT	Voice to Text
WDR	Word Detection Rate
WL	Workload

Appendix C Appendix: Glossary of terms

Term	Definition	Source of the definition
AcListant®	Venture Capital funded project Active Listening Assistant being conducted by DLR and Saarland University from 2013 to 2015.	PJ.16-04
Assistant Based Speech Recognition (ABSR)	Special Instance of Automatic Speech Recognition which needs an assistant system to provide context in order to improve recognition rate and/or reduce error rate	See definition in [1]
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. 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 Prediction Error Rate	The number of controller commands which are given but not predicted (by the Command Hypotheses Predictor) divided by number of total given commands; in other words: the percentage of errors of the Command Hypotheses Predictor.	See definition in [1]
Command Recognition Rate	The number of controller commands which are correctly recognized by ASR and are not rejected before divided by number of total given commands; in other words: the percentage of given commands correctly shown on the controllers' HMI.	See definition in [1]
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.	See definition in [1]
Concept of Operations	**Concept of Operations [ConOps]:** The ConOps is jointly elaborated by all ATM stakeholders, from the civil and military airspace users and service providers, to airports	See definition in [2]

Term	Definition	Source of the definition
[ConOps]:	and the manufacturing industry to gain common understanding of the ATM system. It describes the operational targets, to move ATM towards trajectory-based operations whereby aircraft can fly their preferred trajectories, taking into account the matching between constraints and optimization. The ConOps allows all ATM stakeholders, from the civil and military airspace users and service providers, to airports and the manufacturing industry to gain common understanding of the ATM system. In this context, the ConOps is the operational answer to reach the ATM Performance improvements targeted by the ATM MP. Furthermore the ConOps is an important reference for global interoperability and harmonization, as it has been adapted for Europe from the ICAO Global Air Traffic Management Operational Concept.	
Exploratory Research	The exploratory research investigates relevant scientific subjects (during the ATM Excellent Science & Outreach phase) and conducts feasibility studies looking for potential application areas in ATM (during the ATM application-oriented research phase).	See definition in [2]
Horizon 2020	The EU Framework Programme for Research and Innovation.	SESAR 1, WP14, SESAR 2020
MALORCA		
PMP deliverable	Output produced by the projects that is submitted to the SJU via the SESAR 2020 collaborative platform and that is subject to quality assessment by the SJU. However, these deliverables do not appear in the grant agreement as contractual deliverables. The production of PMP deliverables is done in support of subsequent contractual deliverables and is described in the PMP.	See definition in [2]
Project Management Plan	Formal, approved document, provided by each SESAR 2020 Solution Project, used to manage its execution. It defines how the project is executed, monitored, controlled, and closed.	See definition in [2]
SESAR 2020	The SESAR 2020 (Single European Sky ATM Research) Research and Innovation (R&I) Programme will demonstrate the viability of the technological and operational solutions already developed within the SESAR R&I Programme (2008-2016) in larger and more	SESAR 1, WP14, SESAR 2020, PJ.17-03

Term	Definition	Source of the definition
	operationally-integrated environments. At the same time, SESAR 2020 will prioritise research and innovation in a number of areas, namely integrated aircraft operations, high capacity airport operations, advanced airspace management and services, optimised network service performance and a shared ATM infrastructure of operations systems and services. SESAR 2020 will retain its founding members, the European Union and Eurocontrol.	
TRL 2 (V1)	**Technology concept and/or application formulated:** Applied research. Theory and scientific principles are focused on very specific application area(s) to perform the analysis to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.	See definition in [2]
TRL 3	**Analytical and experimental critical function and/or characteristic proof-of concept:** Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies including verification of technical feasibility using early prototype implementations that are exercised with representative data.	See definition in [2]
TRL 4 (V2)	**Component/subsystem validation in laboratory environment:** Standalone prototyping implementation and test with integration of technology elements and conducting experiments with full-scale problems or data sets.	See definition in [2]

Reference used in Glossary of terms

[1] H. Helmke, J. Rataj, T. Mühlhausen, O. Ohneiser, H. Ehr, M. Kleinert, Y. Oualil, and M. Schulder, "Assistant-Based Speech Recognition for ATM Applications," in 11th USA/ Europe Air Traffic Management Research and Development Seminar (ATM2015), Lisbon, Portugal, 2015.

[2] SESAR 2020 Execution guidance of ER4 projects : https://ec.europa.eu/research/participants/data/ref/h2020/other/guides_for_applicants/jtis/h2020-guide-project-handbook-er4-sesar-ju_en.pdf