Operational Concept Document

D1-1

MALORCA

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MALORCA

MACHINE LEARNING OF SPEECH RECOGNITION MODELS FOR CONTROLLER ASSISTANCE

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Abstract / Executive Summary

This Operational Concept Document focuses on possible implementation of speech recognition systems in air traffic control environment. Prague and Vienna approaches will participate in later verification and, therefore, the document is based on their needs.

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1 Introduction

1.1 Motivation

In an Air Traffic Control working environment, communication between the involved parties is the most important means to control the air traffic. Controlling aircraft in the vicinity of an airport is an example of such a working environment in which two working groups communicate, i.e. pilots and controllers. All pilots in the same sector are supported by a dedicated controller. They use a unique frequency for communication within this sector.

Today ATC communication is still split into two different worlds. One is that controllers communicate via radio links, and another in which machines communicate via computer networks. These two worlds are connected by a human machine interface used by humans to inform the machines and vice versa. Intents and plans of both humans and machines are the basis for these two worlds [1].

The common handicap of these worlds is their connection not in the sense of the human machine interface, but in the sense of how humans inform the machines. Any given clearance to aircraft crew needs to be entered into the system to get at least note of which instruction was given to whom. Eliminate this handicap could be considered as a big step forward to improve the operational environment of air traffic controller. The MALORCA project based on Grant Agreement number 69882 [5] between The Single European Sky ATM (Air Traffic Management) Research Joint Undertaking and MALORCA partners is looking for the solution which aims at taking the knowledge from the laboratory to the operational rooms. The project information is complemented in [4].

1.1.1 Purpose

The purpose of this Operational Concept Description[1] for the MALORCA project is to outline the ATC environment for all the stakeholders to be able put themselves into the role of controller. The last

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

but not least purpose is to describe major attributes of speech recognition systems so the next unit will know what to focus on.

1.1.2 Structure

This Operational Concept Description is structured to adequately capture those characteristics of a situation, and a proposed change, to permit assessment and engineering development.

- **Current system**
  Describes the characteristics of the current system and its environment in both workplaces Prague APP and Vienna APP
- **Justification of changes**
  States the change to the environment that necessitates the system changes and details what these changes are and their priorities
- **Concept of new system**
  Describes the characteristics of the proposed new system including personnel involved
- **Use-cases**
  Documents several operational use-cases and one technical use-case that illustrate the role of the new system and its interaction with users.
- **Analysis of the proposed system**
  Analyses the benefits and detriments of the new proposed system to aid in making an objective decision about implementation

1.2 Air Traffic Control Environment

The task of ensuring safe operations of both commercial and private aircraft falls on air traffic controllers. Air traffic controllers provide service called air traffic control which primary purpose is to prevent collisions, organize and expedite the flow of air traffic, and provide information for pilots. They guide aircraft through controlled airspace, provide advisory service in non-controlled airspace and direct aircraft from runway to the apron on the ground at the aerodrome. The image of air traffic controller is much more complex than only a man sitting in the tower of an aerodrome. Air traffic controllers can be divided into three groups based on in which phase of flight they are involved. Those three groups are:

- **Area Control Centre, ACC**
  It is a facility responsible for controlling aircraft en-route at their area of responsibility at high altitudes between airport approaches and departures.
- **Approach Control Unit, APP**
  The controlled airspace boundaries and altitudes create TMA, terminal control area, where air traffic controllers mostly control aircraft for landing or after departure. This unit stands in the middle between ACC and TWR.
- **Aerodrome Control Tower, TWR**
  The unit is responsible for guiding aircraft and vehicles on the taxiways and runways of the airport itself, and aircraft in the air near the airport.

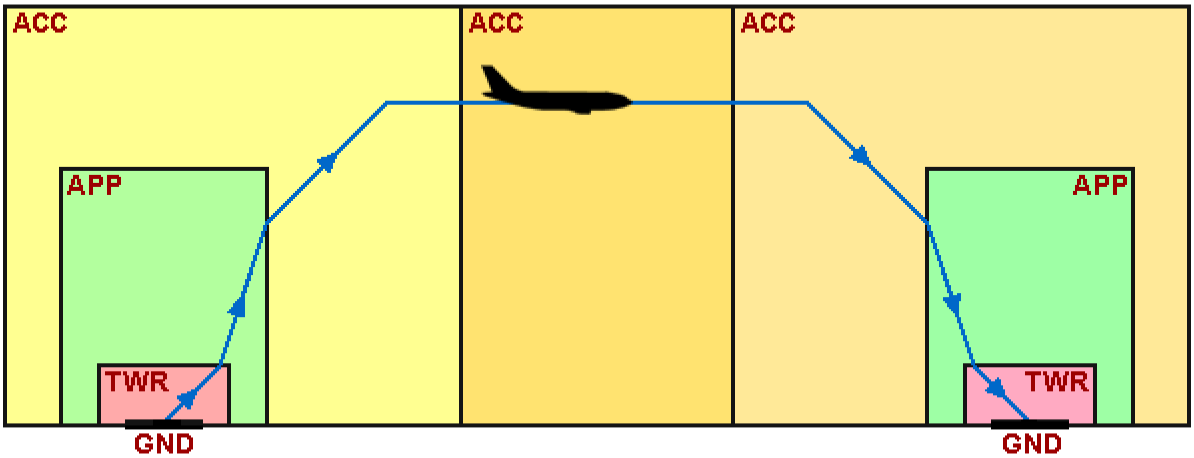


Figure 1: The distribution of Air Traffic Control

It could be found handy to look at each commercial flight phases to get detailed view of different responsibilities of respective control units.

- **Taxi**
  When aircraft is ready to leave terminal gate, flight crew contact the ground controller who is responsible for all ground traffic and ask for push-back from gate. When it is safe controller directs the aircraft to push and then gives a clearance to taxi to holding point of runway for departures.
- **Take-off**
  Tower controller watches the skies above airfield and is responsible for maintaining safe distance between landing and departing traffic and also between planes located at airports circle.

- **Departure**
  Departure controller is located in the TMA and uses radar to monitor the aircraft and maintain safe distances between ascending aircraft on ascent corridors.
- **Climb**
  Once the aircraft has left TMA airspace and continue climbs to its cruising level it enters an ACC sector, which can be split not only horizontally but vertically as well.
- **Cruise**
  When cruising level is reached air traffic controllers monitor to keep safe and expedite flow and pass the aircraft gradually to next controllers as it reaches another and another sectors.
- **Descend**
  At this point the aircraft approaches its destination and starts descent. Controller directs all aircraft flying to same destination to move from high altitudes to low altitudes and merges the descending aircraft into a single file line toward the airport.
- **Approach**
  While back in the APP sector an approach controller directs pilot to adjust the aircrafts heading, speed and altitude to prepare to land along standard approach corridors.
- **Landing**
  When aircraft is in particular distance from runway and it is established on specified type of approach, controller passes the plane to the tower controller, which determines that it is safe and gives a clearance to land.
- **Taxi**
  Once the aircraft has landed the tower controller passes aircraft off to the ground controller which directs the plane to the appropriate terminal gate.

At every point mentioned above and sometimes during duration of each phase (due to split area of responsibility), controllers provide flight crew with the new radio frequency for next sector so it is constantly guaranteed that only one controller can control the aircraft at the same time.

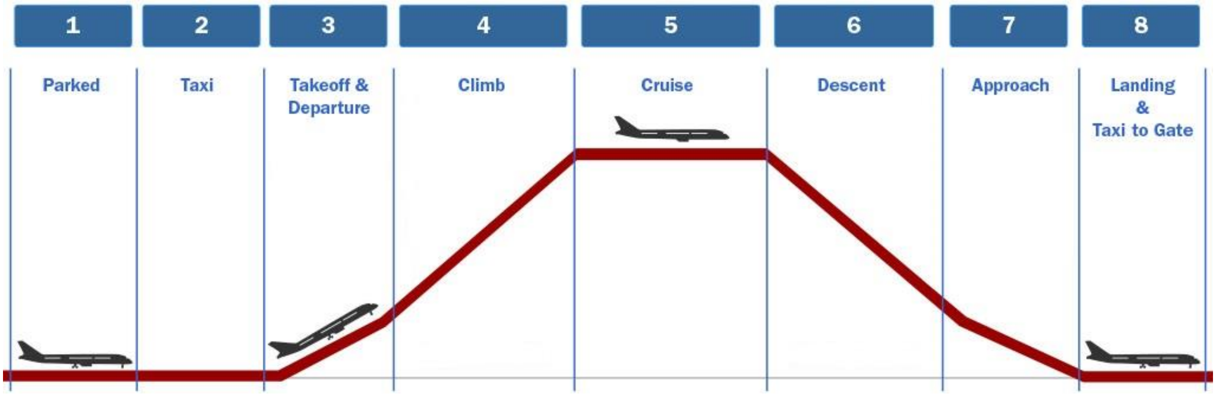


Figure 2: Phases of the flight

2 Current System and Situation

This section shall describe the current system or situation in sufficient detail to permit new concepts to be evaluated against the current system or situation, not just against other new concepts.

2.1 General Overview of ATM systems

At current level of traffic in the airspace, the ATM (Air Traffic Management) systems for the provision of air traffic services are necessary. ATM system is a general name for any device that is used by the air traffic controllers to control the traffic in the airspace.

From the perspective of air traffic controllers it is possible to divide ATM systems into two categories mentioned below.

- **The radar information**
  It is necessary to be able determinate the position of aircraft in the airspace. For this purpose there shall be reliable and accurate surveillance radar.
- **The voice communication**
  Once the exact position of the particular aircraft is known it is essential for both air traffic controllers and flight crew to establish communication. The voice communication systems are based on radio communication which consists of a pair of receivers and a pair of transmitters for VHF/UHF frequencies and together form radio channel.

Radar and voice communication together create ATM system which allows air traffic controllers control aircraft in his area of responsibility. In ATM environment there are more systems without which controlling the airspace would be very complicated, but they are not considered as general ones and their omission won't make any harm for the purpose of this document.

2.2 Description of Current Situation in Prague

Area of responsibility of APP controllers goes further then only inside of TMA. Its dimensions have been changed recently due to optimization of using of airspace. Area of responsibility can be divided as follows:

- TMA Praha
    - It consists of 9 parts
    - Coordinates – Appendix B or AIP ENR 2.1-24 – 2.1-28
    - Lower and upper limits – Appendix B or AIP ENR 2.1-24 – 2.1-28
- Other Sectors
    - CTA I Praha
        - Coordinates – Appendix B or AIP ENR 2.1-4
        - Lower and upper limits – Appendix B or AIP ENR 2.1-4
        - With the exception of TMA/CTR
    - CTR Ruzyně
        - Coordinates – Appendix B or AIP LKPR AD 2.17
        - Lower and upper limits – Appendix B or AIP LKPR AD 2.17
    - HDO BOX
        - It is not an official airspace, so it cannot be found in AIP. It is part of airspace belonging to CTA Ostrava but fully delegated for Prague controllers.
        - Coordinates – Appendix B
        - Lower and upper limits – FL 95-FL125

Air traffic controller usually controls aircraft far beyond described boundaries. Once the aircraft is released for further descent, and is transferred to approach sector, the APP controllers can control the plane according to the established rules. It means that responsible area consists of two parts. One part is TMA/CTA I/CTR/HDO box and the second part is indescribable because it has no officially boundaries and depends on coordination between neighbouring sectors.

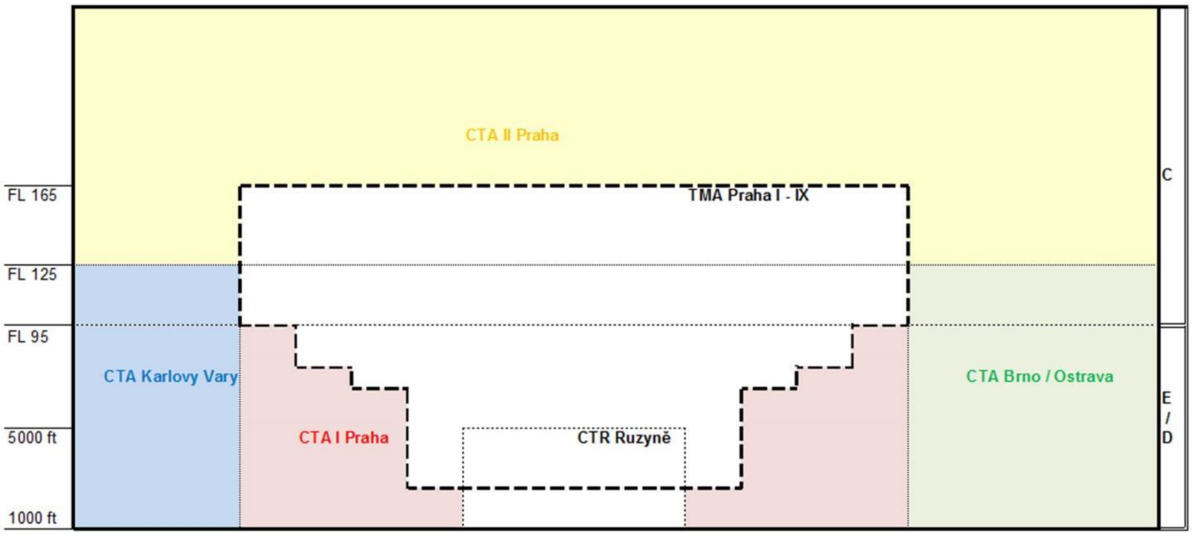


Figure 3, Area of Responsibility of APP controllers in PRG

2.2.1 Nearby Aerodromes

Inside of horizontal boundaries and around of TMA there are several aerodromes. They may be divided according to their position to the TMA or in accordance with flight rules of aircraft landing and departing from them.

- Inside of TMA horizontal boundaries
    - Vodochody, LKVO
    - Kbely, LKKB
- Adjacent to the TMA
    - Karlovy Vary, LKKV
    - Čáslav, LKCV
    - Pardubice, LKPD
- Domestic civil aerodromes
    - Kladno, LKKL
    - Bubovice, LKBU
    - Letňany, LKLT, international AD
    - Sazená, LKSZ
    - Slaný, LKSN
    - Panenský Týnec, LKPC

- ○ Hořovice, LKHV
- ○ Příbram, LKPM
- ○ Roudnice, LKRO, international AD
- ○ Mladá Boleslav, LKMB
- ○ Mnichovo Hradiště, LKMH international AD
- ○ Kolín, LKKO
- ○ Benešov, LKBE, international AD

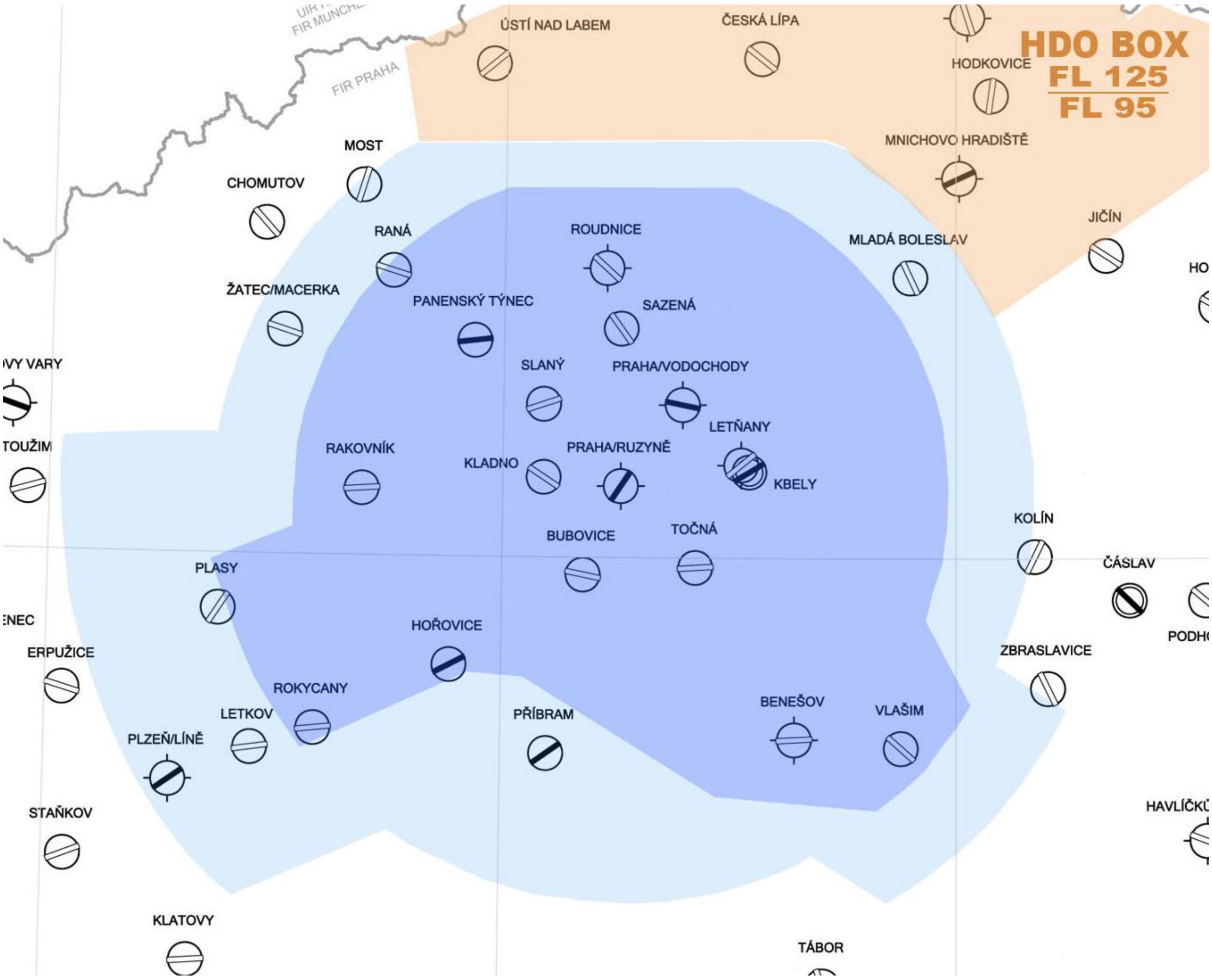


Figure 4, Nearby aerodromes

2.2.2 Working Positions

Approach Praha consists of 7 working positions. They are:

- Approach Senior Controller SC APP
- Approach Watch Supervisor WS APP

• Departure Executive Controller	DEC
• Arrival Planning Controller	APC
• Arrival Executive Controller	AEC
• Director Executive Controller	PEC
• Information Executive Controller	IEC

AEC is the position which is open 24/7. On the contrary DEC, PEC and IEC are open only during rush hour traffic. While IEC is closed responsibility passes to PEC (flights inside CTR Ruzyně) and to AEC, respectively DEC. Area of responsibility differs according to runway in use.

The following working positions shall be supported by the proposed system:

- **Arrival Executive Controller** is responsible for air traffic control in the arrival sector in and above FL 90 and in the area of separation in and above FL 130.
- **Director Executive Controller** is responsible for air traffic control in the arrival sector up to FL 85 inclusive.
- **Departure Executive Controller** is responsible for air traffic control in the arrival sector up to FL 85 inclusive.
- **Information Executive Controller** is responsible for VFR and special VFR flights in CTR Ruzyně. He is also responsible for combined flights in the CTA Praha 1 under TMA Praha.

The MALORCA project will concentrate on Arrival Executive Controller and Director Executive Controller to gather as much data of similar character as possible.

Figure 5, Arrival Executive working position at LKPR

2.2.3 TMA Praha

- Minimum radar vectoring altitude
  - Values of altitudes are corrected for low temperatures during winter season. It applies always for period from 15th November until 15th March.
  - Chart within CTR Ruzyně and TMA Praha can be found in the Appendix as well as minimum radar vectoring altitude within FIR Praha.
- Type of Approaches
  - Visual approach is prohibited with exceptions that are found in AIP AD 2.21.3
  - ILS approach is available for all RWY´s (06/24, 12/30)
  - RNAV approach is available for all RWY´s (06/24, 12/30)
  - VOR approach is available for RWY 12/30
  - NDB approach is available for RWY 06/24
- Handover
  - Departing aircraft from LKPR, LKKB, LKVO are cleared to FL 140 (PROP) or FL 160 (JET) or to cruising level if it is less than FL 140 respectively FL 160.
  - Departing aircraft from aerodromes below TMA are cleared to FL 160 or to cruising level if it is less then FL 160.
  - Arriving aircraft are cleared to descent to FL 150 (JET), respectively FL 130 (PROP), depending on which RWY is in use and what type of aircraft it is.

- Once the aircraft is transferred to the next sector it is released for further climb/descent and turn.

2.3 Description of Current System in Prague

The major system, air traffic controller works with, is called Eurocat 2000 developed by Thales Air Systems. Eurocat 2000 cooperates with other systems such are ESUP and IDP. ESUP allocates appropriate flight plans to target visible on E2000 to establish its correlation. IDP is another back up system of E2000 used on both positions, executive and planning, mainly for the planning purpose and quick overview of displayed situation. Secondary outcome is to provide basic information to be able provide flight information service and to display ESUP data.

Basic functions of Eurocat 2000 are:

- Acquisition and processing of primary and secondary tracks from several radars
- Processing of flight plan data
- Allocation of SSR codes
- Simulation of tracks and flight plans for training purpose
- Communication with essential electronic strip system environment
- Detection of STCA (short-term conflict alert), MSAW (minimum safe altitude warning) and DAIW (danger area infringement warning)
- Enable to filtrate tracks and distribute them over positions

Figure 6, APP Prague workplace

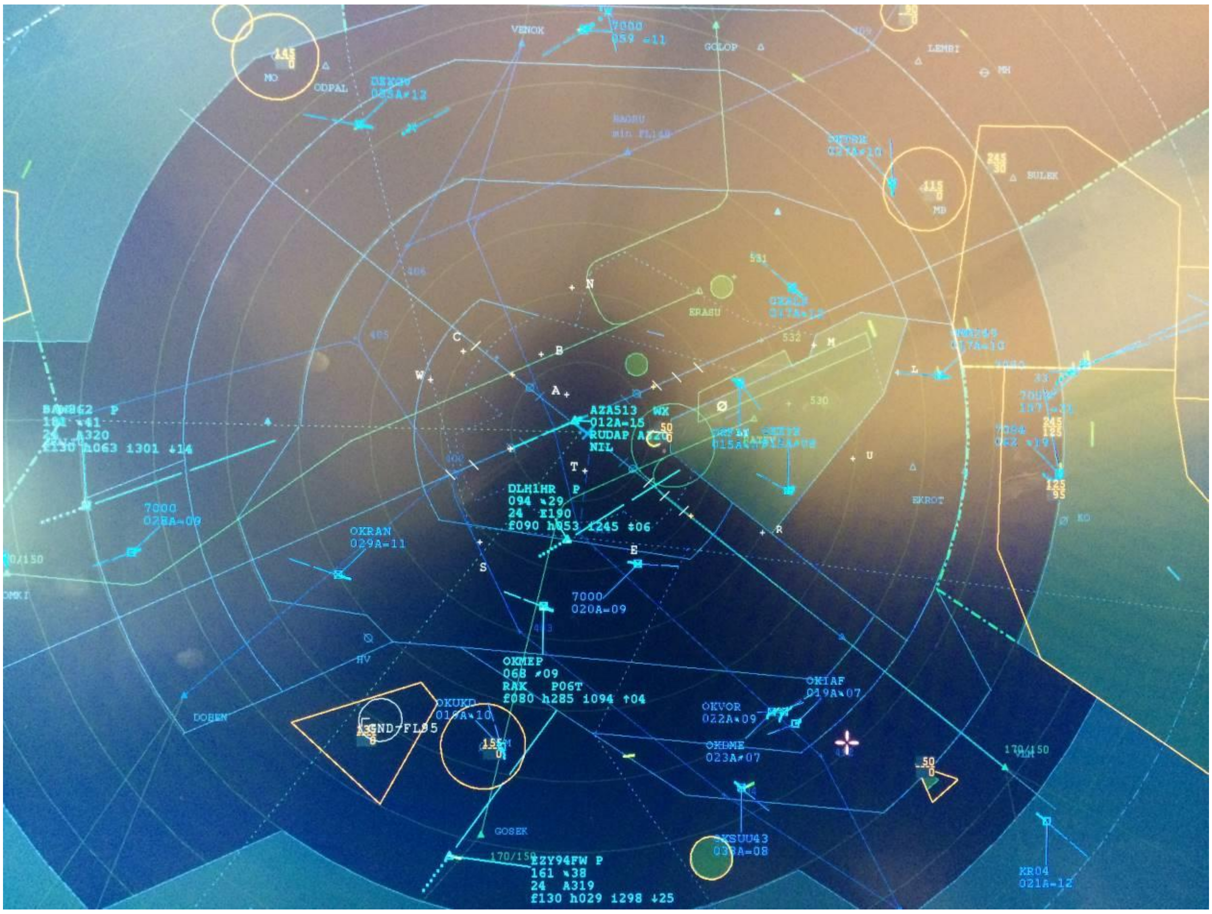


Figure 7, Eurocat 2000 HMI

Other components of controller workplace are:

- VCS Garex, provides standardised package of communications facilities
- By Pass, backup system in case of E2000 failure

There are more, but for the purpose of this document it is not necessary to list all of them.

2.4 Description of Current Situation in Vienna

Austro Control had used a conventional paper strip system to control the Austrian airspace for over 25 years before embarking on the multi-year design and implementation of Topsky, a latest generation air traffic management system designed by Thales, in 2005. Topsky provides air traffic control operators with a stripless environment managed to a significant extent through system coordination.

The implementation of Topsky was conducted in two major steps. On February 27th 2013 the Area Control Center seamlessly migrated to the new system overnight. On November 28th 2016 all remaining Austrian air traffic control units followed suit. A continuous development of Topsky is presently conducted with four Austro Control's ANSP partners (Croatia, Denmark, Ireland and Sweden) within the so-called COOPANS framework, which is in line with the goals of the Single European Sky project.

The implementation of Topsky has enabled Austro Control to boost capacity as well as productivity by a noteworthy margin in the upper airspace. At present Austro Control handles about 1.1 million flight movements per year in Austrian airspace. Vienna airport handles on average between 600-800 controlled flights movements per day.

2.4.1 Area of Responsibility

The area of responsibility of Vienna APP is relatively limited due to the proximity of the state boundaries with the Czech Republic to the north, Slovakia to the east, and Hungary to the south-east. There are some small pieces of airspace that have been delegated from Hungary to Austria to enable better sequencing of arrival traffic to LOWW. To the west and to the south the area of responsibility ranges further (approximately 50nm). Vienna APP is responsible for this airspace between ground and flight level 245. Within this area of responsibility, Vienna APP manages four major holding areas. APP controllers usually manage all the holding traffic for LOWW themselves, with Vienna ACC only playing a supporting role by providing buffer holdings outside the TMA in exceptional circumstances.

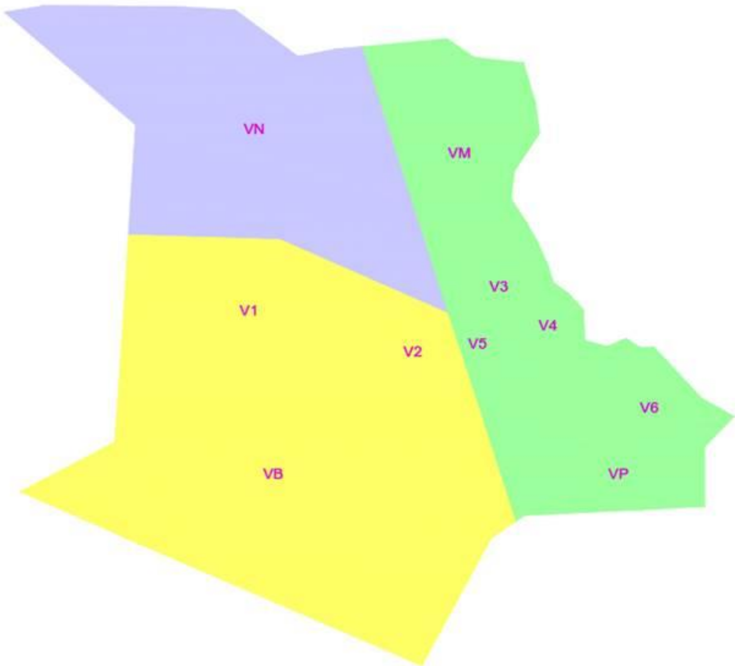


Figure 8, TMA Vienna

2.4.2 Working Positions

Vienna TMA consists of a total of 3 main control sectors (shaded in blue, green, and yellow in Figure 8). Depending on traffic flows and capacity requirements these 3 main control sectors can be merged as well as reconfigured in their dimensions.

Additionally there is feeder position in operation from 0600lcl until 2300lcl time. In case of simultaneous approaches to runways 11 and 16, as permitted under certain circumstances, a second feeder position is opened to serve the arrival traffic to the second runway.

In terms of capacity Vienna APP accepts up to 48 arrivals per hour during rush hours if conditions are favourable. If simultaneous landings to two runways are possible this limit does not apply and no capacity restrictions are enforced for arrival traffic.

Hence, under maximum traffic load, Vienna APP operates 3 sectors (pick-up) and 2 feeder positions. The pick-up sectors are staffed by an executive and a planning controller each, while the feeder positions are staffed by an executive controller only.

Besides traffic arriving to or departing from LOWW, APP controllers also control a significant amount of traffic going to or leaving from Stefanik airport at Bratislava, Turany airport at Brno, as well as Graz and Linz airport. Due to the relatively high vertical reach of Vienna TMA, there is also a considerable amount of enroute traffic passing through the approach sectors.

Within the TMA there is lots of skydiving activity at three airfields within the immediate proximity of LOWW. Two of those airfields also receive IFR traffic thanks to established GNSS procedures, respectively are the source of flights requesting to join IFR after departing following visual flight rules. There is also glider activity in several locations close to LOWW which need to be considered by the ATCOs. VFR traffic outside sensitive airspace within the TMA is usually managed by a dedicated Terminal Flight Information work position.

Figure 9, Vienna APP Center

2.5 Description of Current System in Vienna

The Topsky system is presently one of the most advanced of its kind. It is designed and continuously developed to meet the ever increasing demands to safety, capacity, efficiency, punctuality, and environment. It incorporates critical safety enhancing features such as medium-term-conflict-detection as well as a range of advanced safety nets and monitoring aids to support the controllers in their work. System coordination (SYSCO) ensures the automation of processes which in the past resulted in a relative loss of capacity. Comprehensive monitoring functions such as Downlink Airborne Parameters (DAPs) provide additional benefits. In the foreseeable future arrival manager functionality will be incorporated to further improve traffic management at Vienna International Airport.

The Tower units use Topsky Actual Situation Display (ASD) for the visualization of traffic, but predominately make inputs in an electronic flight strip system (DIFLIS) which is connected to Topsky through a dedicated software gateway.

Vienna APP uses the complete functionalities provided by its Topsky ASD with the exception of very few specifically excluded features such as medium-term-conflict-alert, which has been determined as unsuitable for the approach environment. Additional information is provided to the controllers through a number of features displayed on two additional support screens which are not directly connected to the Topsky system (e.g. chart window, weather radar, etc.)

Figure 10, Working position in Vienna

3 Justification of Changes

3.1 Description of Needed Changes

While stripless work environments have undoubtedly provided controllers in all air traffic control units with numerous much appreciated benefits, it has proven to be especially useful in upper airspace (ACC) where the systems' benefits have become most apparent. However, in busy terminal airspaces such as Vienna the system has so far failed to affect the originally desired gains in productivity. This is mostly due to inherent system limitations as well as the relatively larger number of system inputs that have to be made by the approach controllers when compared to their ACC peers.

With regard to system inputs, for the individual controller documenting multiple instructions to flight crews given in rapid succession has proven to be more time-consuming in a stripless work environment than it had been with a paper strip system, as it may involve several mouse clicks in labels or lists on the ASD. Due to the nature of those inputs a relative reduction of cognitive capacity may result, especially if done inputs are initially faulty and need to be corrected.

It is in the best interest of any air traffic controller working in a dense traffic environment to affect all desired and necessary system inputs with the least possible delay and greatest possible accuracy and expediency. This is particularly relevant for control sectors and work positions with considerable speech efforts, such as final directors during arrival rush hour traffic, or any control sector faced with adverse weather conditions. Any methodology or technological aid that could assist air traffic controllers in making system inputs is therefore of utmost interest. It holds potential for increasing control sector capacity and landing capacity, as well as provide various safety benefits related to reducing operators' cognitive loads. Furthermore, it could significantly assist ab-initio air traffic control trainees in their learning process, allowing them to focus a greater share of their attention to traffic analysis, planning, and data presentation.

3.2 Priorities among the Changes

Priority should first and foremost be given to the introduction of technology that reduces the effort of manually inputting spoken instructions to flight crews into air traffic control systems. Reducing the need for time-consuming manual inputs with their corresponding error potential, a system supporting automated speech recognition and system integration could be a relevant factor in decreasing operators' workload with respect to label (or flight strip) maintenance and thus increasing his cognitive capacity for his actual work and thus increasing the overall efficiency. This in turn has potential to increase a control unit's overall productivity.

3.3 Assumptions and Constraints

Automatic Speech Recognition (ASR) functionality would present air traffic controllers with a major modification in their working methods.

Assumption 1: It is generally assumed that **well-working ASR** functionality would be readily accepted by air traffic controllers as it has solid potential of drastically cutting the number of manual system inputs they have to make during a standard work shift. This is especially true for work positions where speech efforts are generally very high while issued instructions are generally standardized, such as final directors at major airports.

Assumption 2: Furthermore, **consistent reliability** has to be guaranteed in situations where the system is undergoing steps of reconfiguration, such as during the splitting or merging of control sectors, when individual flights may not immediately be in the correct sector state.

Constraint 1: As with any feature or function, its success and acceptance hinges to a large degree on consistent operability. Hence, constraints and limitations could arise for work positions where traffic management doesn't strictly follow a standardized pattern, and regular air traffic control instructions are mixed with a larger amount of "**plain language"** or **"irregular" instructions**. This could be the case in airspaces where air traffic controllers deal with both IFR and VFR traffic, or when clearances are frequently issued for **non-standard procedures** and routines.

4 Concept for a New System

4.1 Background, Objectives and Scope

One of the main causes hampering the introduction of higher levels of automation in the Air Traffic Management (ATM) world is the intensive use of spoken language as the natural way of communication. More particularly, higher level automation would require human-machine interaction systems to bridge the gap between the human/machine agents processing the same type of situational information. For instance, human operator reaches a common understanding of the situation and the intentions of other operators through direct communication and/or listening to the communication, whereas automated systems understand the situation based only on sensor information without any knowledge about the intentions. [2]

The main objectives of this project are:

- Develop a multi-modal, state-of-the-art, automatic learning system based on Assistance Based Speech Recognition (ABSR)
- Provide a cheap, efficient and automatic adaptation system which exploits the large amount of data, available on a daily basis.
- Replace the manual effort required by current procedures
- Analyze advantages, disadvantages and alternatives of proposed system
- To be able to put into operation in OPS room once

4.2 Description of the New System

4.2.1 The Operational Environment

Implementation of the new system should not be observed by Air traffic controllers in the sense of change their operational environment. The only change is that controller would not need to put given clearances into the strips or track labels any more. These clearances will be added automatically by the system. Output of the system consists of two parts. One part is the change of appropriate value in the label and second part is an indication of last given clearances. The HMI example that has been used for the validation trials during AcListant project is in Figure 11.

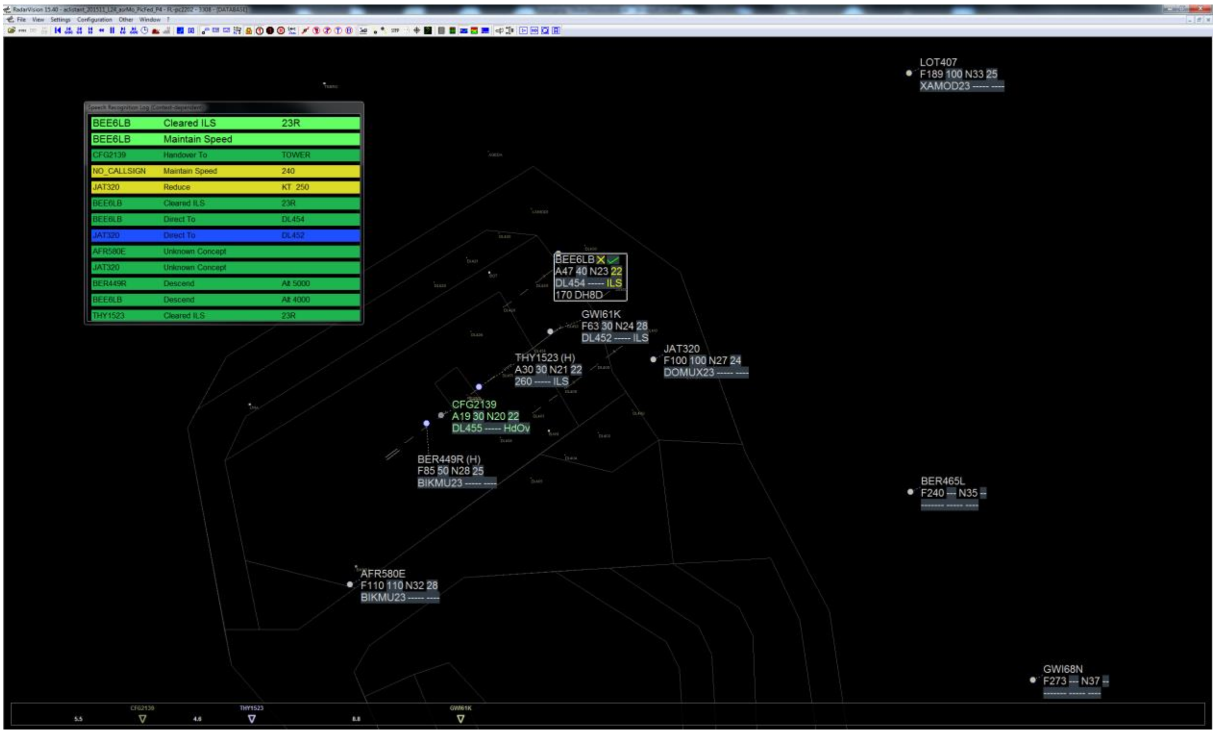


Figure 11, DLR´s RadarVision HMI with Speech Recognition Log

4.2.2 Major System Components

New system should be presented as a black box hidden from view. No systems components are expected.

4.2.3 Capabilities and Functions

Functions of presented system are delineated by following chart which represents usual communication between pilot and air traffic controller.

- ATC contacts flight crew, e.g. “CSA 124, Praha Radar …”
  - system shall recognize which aircraft is called and then highlight its call-sign
- Second part of transmission is clearance, e.g. “… descent to FL 110 and turn right heading 020”
  - given clearance shall be promptly added to particular strip and remains highlighted for some time so that controller can check its value

- If the value is correct ATC shall not need to confirm it. If it is not correct ATC shall change its value as soon as possible.

The one and only function is clearance recognition. These clearances are divided into two groups. Must have and Nice to have.

- **Must have**, clearances which are necessary to be recognizable
  - Heading <Value>
  - Flight level/Altitude <Value>
  - Speed <Value>
  - Assigned STAR <Value> or direct to <Value>
  - Approach clearances <Command>
  - Rate of climb/descent <Value>
  - Handover <Command>
- **Nice to have**, clearances which we would appreciate to be recognizable
  - Holding <Command>
  - Change of flight rule. i.e. IFR/VFR <Command>
  - Assign of different RWY for landing than which is in use <Value>
  - Go Around <Command>
  - Handover <Value>

The whole system shall have an option of changing its parameters. These should be divided also into two groups.

- **Online**, controller shall have an option to turn off/on the entire system
- **Offline**, type of parameters editable by our technicians
  - Turn off/on each of “must have” and “nice to have” instructions
  - Highlight colour
  - Font size
  - Period of highlight

4.3 Users Involved

The main users of the system are certainly air traffic controllers. The attributes of speech recognizing shall be tailored to their needs. To be able to change some minor parameters (described above as “Offline”) it is crucial to consider our technicians as involved users as well.

5 Use Cases

This chapter describes operational and technical use-cases that illustrate the role of the new system and its interaction with users. It shall be highlighted here that the HMI behaviour is out of scope of MALORCA project.

5.1 Operational Use Case No.1, Standard instructions for an arriving flight

The first use-case is focused on rush hour traffic from perspective of final director controller. This controller is supposed to align arriving aircraft behind and it might happen that he/she would speak without a break especially during rush hours.

1-1. Initial contact — *CSA 724, Praha Radar, descend to[2] FL 80*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 80

1-2a) Following instructions — *CSA 724, descend to FL 70, proceed direct to PR 531*

[2] It should be clear, that this clearance is not ICAO phraseology conform (the "to" should be avoided), but real controllers especially in high traffic situation are speaking in this way. In these use cases ICAO phraseology is not used, we concentrate on the contents of the controllers' utterance.

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 70
- Recognize the way point, i.e. PR 532

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 70
- Highlight and change its STAR to point PR 532

Or

1-2b) Following instructions *CSA 724, descend to 4000ft, QNH 1010, turn right heading 150*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared altitude, i.e. FL 4000ft
- Recognize the cleared heading, i.e. HDG 150

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared altitude, i.e. 4000ft
- Highlight and change its cleared heading, i.e. HDG 150

Or

1-2c) Following instructions *CSA 724, turn right heading 210, cleared for ILS approach RWY 24*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80
- Recognize the way point, i.e. PR 532
- Recognized clearance for ILS approach

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change its cleared heading, i.e. HDG 210
- Highlight clearance for ILS approach

1-3.	Final transmission	*CSA 724, contact Ruzyně Tower 118.1*

System shall:

- Recognize the proper call sign
- Recognize the next sector which is Ruzyně Tower

Users HMI will:

- Highlight the label of CSA 724
- Hand aircraft to next sector which is Ruzyně Tower

Effort without ASR: (minimum) 12 Mouse click and 4 Mouse wheel actions (scroll):

Assume; Label, scroll, Level; Label, scroll, Level; Label, scroll, Waypoint; Label, scroll, Heading; Label, C/A (cleared for approach); Label;

Gain with ASR: No single mouse input necessary; ATCO can concentrate on traffic situation; ATCO capacity increases for situational awareness; average spacing decreases therefore landing quantity increases.

5.2 Operational Use Case No.2, delaying of an arriving flight

The following use-case can be expected on any sector and is focused on non-standard instructions in the sense of probability of their occurrence. While emergency situations are generally regarded as indescribable due to the unlimited possible scenarios and their developments and thus cannot be described, there are rush traffic hours, when holding is an indispensable procedure and can be considered as less standard than usual traffic hour.

2-1.	Initial contact	*CSA 724, Praha Radar, descend to*[3] *FL 80*

System shall:

- Recognize the proper call sign

[3] It should be clear, that this clearance is not ICAO phraseology conform (the ”to” should be avoided), but real controllers especially in high traffic situation are speaking in this way.

- Recognize the value of cleared FL, i.e. FL 80

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 80

2-2a) Following instructions *CSA 724, descend to FL 70, hold at ERASU as published*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 70
- Recognize the holding point ERASU

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 70
- Highlight and insert the holding over ERASU

Or

2-2b) Following instructions (The current UTC time is 14:11)

CSA 724, descend to 5000ft, QNH 1010, expect approach clearance at 27, i.e. an approach clearance is expected at 14:27 UTC

System shall:

- Recognize the proper call sign
- Recognize the value of cleared altitude, i.e. 5000ft
- Recognize expected approach clearance time

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared altitude, i.e. 5000ft
- Highlight and insert its expected approach clearance time to 27

Or

2-2c) Following instructions *CSA 724, descend to 4000ft, turn right heading 150*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared altitude, i.e. 4000ft
- Recognize the cleared heading, i.e. HDG 150

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared altitude, i.e. 4000ft
- Highlight and change its cleared heading, i.e. HDG 150

Or

2-2d) Following instructions *CSA 724, turn right heading 210, cleared for ILS approach RWY 24*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80
- Recognize the way point, i.e. PR 532
- Recognized clearance for ILS approach

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change its cleared heading, i.e. HDG 210
- Highlight clearance for ILS approach

4-3. Final transmission *CSA 724, contact Ruzyně Tower 118.1*

System shall:

- Recognize the proper call sign
- Recognize the next sector which is Ruzyně Tower

Users HMI will:

- Highlight the label of CSA 724
- Hand aircraft to next sector which is Ruzyně Tower

Effort without ASR: (minimum) 24 Mouse click and 6 Mouse wheel actions (scroll)

Assume; Label, scroll, Level; Label, scroll, Level; Label, submenu, Hold, Waypoint; Label, scroll, Level; EAT; Label, scroll, Level; Label, scroll, Heading; Label, scroll, Heading; Label, C/A (cleared for approach); Label;

Gain with ASR: No single mouse input necessary; ATCO can concentrate on traffic situation; ATCO capacity increases for situational awareness; average spacing and flying time decreases therefore landing quantity increases.

5.3 Operational Use Case No.3, recognition difficulties

It is necessary to take into consideration possible problems with recognizing of given clearance that naturally can be expected on any sector.

5.3.1 Missing Recognition

3.1-1. Initial contact *CSA 724, Praha Radar, descend to FL 80*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 80

3.1-2. Following instructions *CSA 724, descend to FL 70, continue present heading*

System cannot recognize the new value, FL70:

System shall:

- Recognize the proper call sign
- Recognize the cleared heading, i.e. present HDG is output

Users HMI will:

- Highlight the label of CSA 724
- Highlights present value ,FL80, the colour of highlighted value on users HMI is different than in the case of proper recognizing

- Highlight its cleared heading, i.e. present HDG

Controller shall::

Controller can turn off/on the entire system if he is not satisfied with recognition rate

Remark: The same procedure shall be applied for every non-recognized instruction, not only for values, but also for clearances itself. Therefore, no additional use cases are specified.

If the clearance is recognized and value is automatically, but wrongly changed, same procedure shall be applied also. It means that controller must be able to change any value anytime he needs.

5.3.2 Not Relevant Recognition

System recognizes given instruction and callsign but it is not relevant i.e. no aircraft with such a callsign is on the controller screen:

3.2-1. Initial contact *CSA 724, Praha Radar, descend to FL 80*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 80

3.2-2. Following instructions *CSA 742, descent to FL 70, continue present heading*

System should:

- Recognize relevant call sign
- Recognize the current value of cleared FL and HDG

Users HMI will:

- Highlight the label of CSA 724, the colour of highlighted callsign on users HMI is different than in the case of proper recognizing.

It is only an optional feature and system should react like this only if the misspelled call sign is similar (e.g. two digits are draped)

- Highlight the value of current FL
- Highlight the current heading

Remark: Above-mentioned scenario contains controller error in form of misspell of call-sign.

5.4 Operational Use Case No.4, recognition difficulties

Special consideration needs to be given to the possibility that the system completely fails to recognize the callsign causing that a correctly recognized clearance cannot be assigned to an aircraft. Such event can be expected on any sector.

4-1. Initial contact *CSA 899, Praha Radar, descend to FL 80*

If there is no CSA 899 in the list of possible flights or for some other reason the recognized callsign strictly does not match:

System shall:

- Notify the controller about not recognized callsign
- Recognize the value of cleared FL, i.e. FL 80

Controller will:

- Manually enter the right value for the cleared flight value

5.5 Operational Use Case No.5, verbal aircraft selection differences

Operational use case no.5 deals with the fact that it is not necessary to use call sign every time. Especially if communication continues and there is not any other transmission to someone else controllers are not obligated to use call sign. This behaviour can be expected on any sector.

5-1. Initial contact *CSA 724, Praha Radar, descend to FL 80*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 80

5-2. Following instructions *CSA 724, descend to FL 70, proceed direct to PR 531*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 70
- Recognize the way point, i.e. PR 532

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 70
- Highlight and change its STAR to point PR 532

5-3. Following instructions *Descend to 4000ft, QNH 1010, turn right heading 150*

The instruction is given e.g. 10 seconds later than instructions in B1. of this use-case.

System shall:

- Recognize that no call sign was given and use the previous call sign used
- Recognize the value of cleared altitude, i.e. FL 4000ft
- Recognize the cleared heading, i.e. HDG 150

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared altitude, i.e. 4000ft
- Highlight and change its cleared heading, i.e. HDG 150

5-4. Following instructions *CSA 724, turn right heading 210, cleared for ILS approach RWY 24*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared heading, i.e. HDG 210

- Recognized clearance for ILS approach

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change its cleared heading, i.e. HDG 210
- Highlight clearance for ILS approach

5-5. Final transmission *Contact Ruzyně Tower 118.1*

This instruction is given e.g. 10 seconds later than instructions in B2. of this use-case.

System shall:

- Recognize the proper call sign
- Recognize the next sector which is Ruzyně Tower

Users HMI will:

- Highlight the label of CSA 724
- Hand aircraft to next sector which is Ruzyně Tower

5.6 Operational Use Case No.6, verbal aircraft selection differences

Slightly more complicated call signs such as AUI, Air Ukraine International, can be tricky to remember or to pronounce. Therefore the same call sign can be expressed by multiple ways during communication. This additional complexity is applicable on any sector.

6-1. Initial contact *AUI 724, Praha Radar, descend to FL 80*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80

Users HMI will:

- Highlight the label of AUI 724
- Highlight and change the value of cleared FL, i.e. FL 80

8-2a) Following instructions *Air-Ukraine-International 724, descend to FL 70, proceed direct to PR 531*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 70
- Recognize the way point, i.e. PR 532

Users HMI will:

- Highlight the label of AUI 724
- Highlight and change the value of cleared FL, i.e. FL 70
- Highlight and change its STAR to point PR 532

Or

8-2b) Following instructions *Ukraine-International 724 descend to 4000ft, QNH 1010, turn right heading 150*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared altitude, i.e. FL 4000ft
- Recognize the cleared heading, i.e. HDG 150

Users HMI will:

- Highlight the label of AUI 724
- Highlight and change the value of cleared altitude, i.e. 4000ft
- Highlight and change its cleared heading, i.e. HDG 150

Or

8-2c) Following instructions *ALFA-UNIFORM-INDIA 724, turn right heading 210, cleared for ILS approach RWY 24*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80
- Recognize the way point, i.e. PR 532
- Recognized clearance for ILS approach

Users HMI will:

- Highlight the label of AUI 724
- Highlight and change its cleared heading, i.e. HDG 210
- Highlight clearance for ILS approach

6-3. Final transmission *Air Ukraine 724, contact Ruzyně Tower 118.1*

System shall:

- Recognize the proper call sign
- Recognize the next sector which is Ruzyně Tower

Users HMI will:

- Highlight the label of AUI 724
- Hand aircraft to next sector which is Ruzyně Tower

Effort without ASR: (minimum) 16 Mouse click and 6 Mouse wheel actions (scroll)

Assume; Label, scroll, Level; Label, scroll, Level; Label, scroll, Waypoint; Label, scroll, Level; Label, scroll, Heading; Label, scroll, Heading; Label, C/A (cleared for approach); Label;

Gain with ASR: No single mouse input necessary; ATCO can concentrate on traffic situation; ATCO capacity increases for situational awareness; average spacing decreases therefore landing quantity increases.

5.7 Operational Use Case No.7, bad weather situation

Bad weather use-case can be expected on any sector and focused on non-standard instructions and non-standard sector sequences. In terms of ATCO workload and safety issues, bad weather is one of the most challenging situations.

7-1. Initial contact *CSA 724, Praha Radar, descend to*[4] *FL 80*

System shall:

[4] It should be clear, that this clearance is not ICAO phraseology conform (the “to” should be avoided), but real controllers especially in high traffic situation are speaking in this way.

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 80

7-2. Following instructions *CSA 724, descend to FL 70, proceed direct to PR 531*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 70
- Recognize the way point, i.e. PR 531

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared FL, i.e. FL 70
- Highlight and change its STAR to point PR 531

In these situations the pilots very often ask for different routings to avoid bad weather ahead. This often also leads to a changed sector sequence and new sectors to be informed and included in the new sector sequence, which automatically increases the ATCO workload dramatically. The challenge for the assistance based speech recognition system is here that it includes weather information and therefore does not exclude direction commands (e.g. to a holding pattern) which are usually not used in normal weather conditions.

7-3. Following instructions CSA 724, stop descend FL 100, turn right heading 110, reduce speed 220kts

System shall:

- Recognize the proper call sign
- Recognize the value of cleared level, i.e. FL100
- Recognize the cleared heading, i.e. HDG 110
- Recognize the cleared speed, i.e. 220kts

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared level, i.e. FL100
- Highlight and change its cleared heading, i.e. HDG 110
- Highlight and change its cleared speed, i.e. 220kts

7-4. Following instructions *CSA 724, descend to FL70, resume own navigation direct to PR535*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared level, i.e. FL70
- Recognize the way point, i.e. PR 535

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared level, i.e. FL80
- Highlight and change its STAR to point PR 535

7-5. Following instructions *CSA 724, descend to 4000ft, QNH 1010, turn right heading 150*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared altitude, i.e. FL 4000ft
- Recognize the cleared heading, i.e. HDG 150

Users HMI will:

- Highlight the label of CSA 724
- Highlight and change the value of cleared altitude, i.e. 4000ft
- Highlight and change its cleared heading, i.e. HDG 150

7-6. Following instructions *CSA 724, turn right heading 210, cleared for ILS approach RWY 24*

System shall:

- Recognize the proper call sign
- Recognize the value of cleared FL, i.e. FL 80
- Recognize the way point, i.e. PR 532

	Users HMI will: • Highlight the label of CSA 724 • Highlight and change its cleared heading, i.e. HDG 210 • Highlight clearance for ILS approach
7-7. Final transmission	*CSA 724, contact Ruzyně Tower 118.1* System shall: • Recognize the proper call sign • Recognize the next sector which is Ruzyně Tower Users HMI will: • Highlight the label of CSA 724 • Hand aircraft to next sector which is Ruzyně Tower
Effort without ASR:	(minimum) 26 Mouse click and 11 Mouse wheel actions (scroll) Assume; Label, scroll, Level; Label, scroll, Level; Label, scroll, Waypoint; Label, scroll, Level; Label, scroll, Heading; Label, scroll, Speed; Label, scroll, Level; Label, scroll, Waypoint; Label, scroll, Level; Label, scroll, Heading; Label, scroll, Heading; Label, C/A (cleared for approach); Label;
Gain with ASR:	No single mouse input necessary; ATCO can concentrate on traffic situation, which is highly necessary in bad weather situation; ATCO capacity increases for situational awareness in bad weather situation; Safety increases and flying time decreases.

5.8 Technical Use Case No.8, machine learning

Initial condition	Actual valid arrival route for Vienna Transition "NERDU_4N" is modeled in the system. It is defined via the waypoints "WaypointsOfTransition": ["NERDU", "WW987", "WW985",

"WW983", "WW981", "WW979", "WW977", "WW975", "WW974", "WW973", "WW972", "WW971", "WW970"], with defined pronunciation: "PronouncedAs": "nerdu four november".

8-1. Controller instruction *DLH123, follow NERDU4N transition*

System shall:

- Recognize the instruction: DLH123 TRANSITION NERDU_4N.

8-2a) The arrival routes for Vienna are changed, i.e. a new arrival route is defined: “VALMO5C” but not modeled in the system.

Controller instruction *DLH123, follow VALMO5C transition*

System shall:

- Send the information that the arrival route is not recognized (as it is not automatically learned by the system).

8-2b) The arrival routes for Vienna are changed, i.e. new arrival route is defined:“VALMO5C” and it is modeled in the system.

It is defined via the waypoints "WW987", "WW321", "WW421"WW971", "WW970” “WW971", "WW970" with defined pronunciation.

Controller instruction *DLH123, follow VALMO5C tranition*

System shall:

- Recognize the instruction: DLH123 TRANSITION VALMO_5C.

The system should learn during some hours of training that this arrival route is only used for arrivals from the south and that VALMO is often also pronounced as “valme” or something else.

6 Analysis of the Proposed System

This chapter summaries possible benefits or detriments obtained from the implementation of voice recognition system in air traffic controller´s environment.

6.1 Summary of Advantages

Proposed system is a robust voice recognition system allowing the users to control airspace through voice commands using standard air traffic control phraseology. Every possibility of reducing air traffic controllers workload should be heard for the most limiting part of future development is human itself. Voice recognition system can greatly reduce workload by accepting and implementing controller´s clearances. Saved time and controller´s capacity can serve for increasing the air traffic controller´s situational awareness and greatly reduce the risk of incident. Such an advantage is sufficient for the defence of the proposed system.

Another significant advantage is the possible connection with ATC support tools, e.g. AMAN. Planning of such a system as AMAN is, is better due to the knowledge of information in system immediately after clearance is issued.

6.2 Summary of Disadvantages

Disadvantage that must be taken into account is the performance of proposed system in the way of compliance with parameters such as recognition rate, error rate and rejection rate. One thing is to fulfil stated parameters, but another thing is the actual feeling of controllers. If the system has high recognition rate across every possible instruction but fails with the most frequently used clearances, for example with a “Climb” clearance, the acceptance of controllers would be lower and therefore the proposed system could fail among controllers despite of the reached values written on paper.

Noisy environment condition could also lead to low recognition rates and hereby the system could be refused by air traffic controllers. The essential feature of proposed system, its possibility of turning on and off some parts or the system as a whole, could divide air traffic controller´s community into two groups a satisfied group and a group unsatisfied with a system. This possible division would not allow further system development thus it is crucial to reach as high recognition rates as possible to make air traffic controllers be delighted with proposed system.

Last but not least it is important to mention the possibility of system failure. In such a situation the backup procedure based on manually enter of clearances would be used so the unexpected high load would appear.

Deviation from standard ICAO phraseology could lead to lower recognition rates and therefore the fundamental condition of using such a system is to follow prescribed phraseology. For some users this can be considered as a great disadvantage for different deviation from standards can be heard across air traffic controllers.

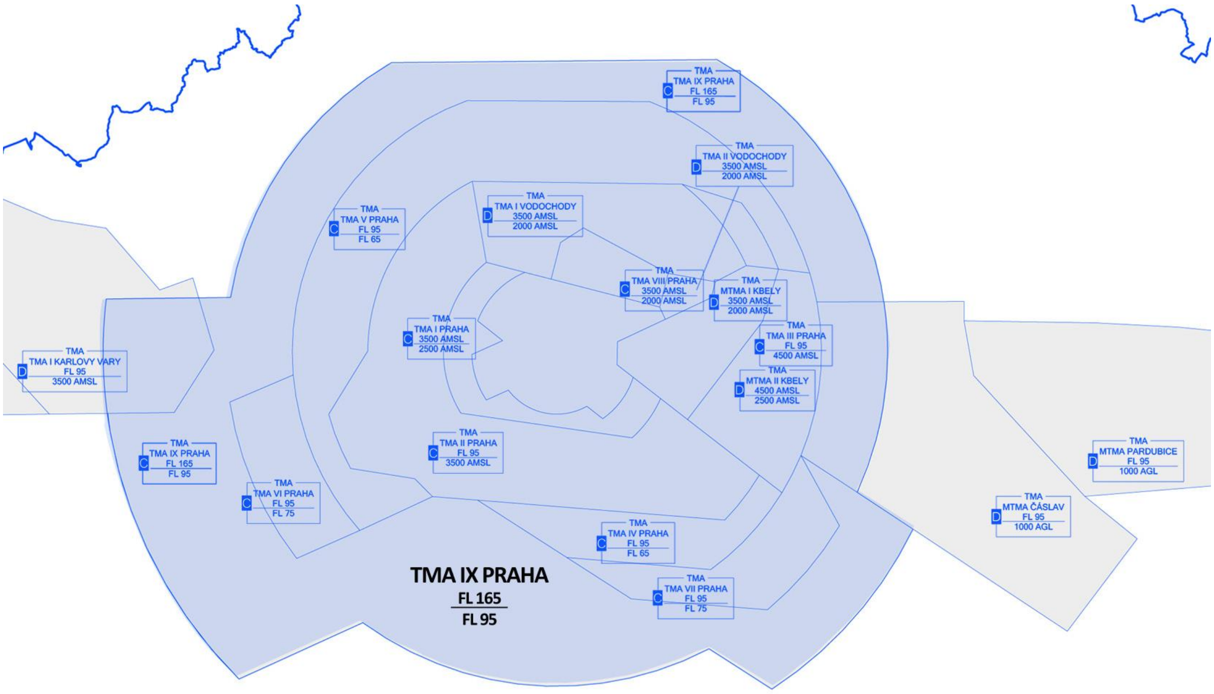
6.3 Summary of Alternatives

If we consider that the limiting aspect of future development is voice communication and a necessity of writing down every given clearance, than we must seek for some option how to eliminate these limits. The possible replacement may be using the data link communication. This would decrease the chances that one pilot accidentally override another, thus requiring the transmission to be repeated. In addition, each exchange between a controller and pilot requires a certain amount of time to complete so even this time would be reduced. Great disadvantage is the loss of awareness of pilots for they will not be able to hear each other's instructions.

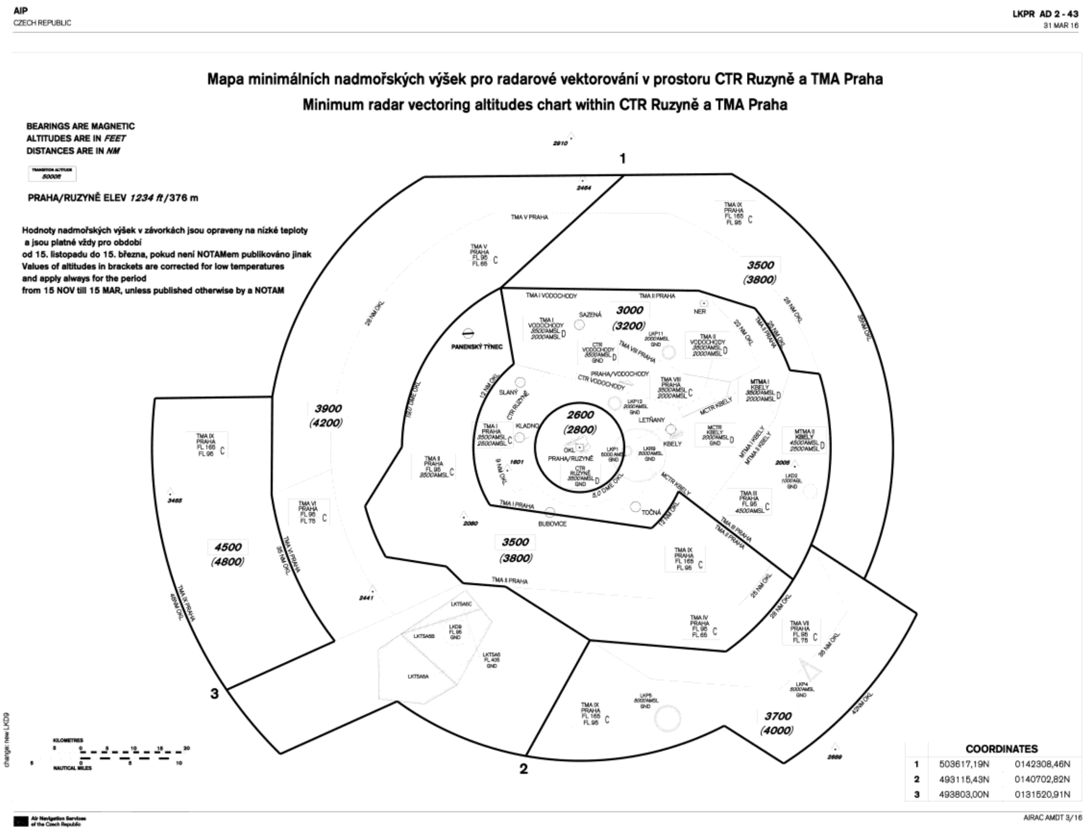
Appendix

Appendix A Maps of Prague TMA

A.1 Individual parts of TMA



A.2 Minimum radar vectoring altitude in TMA



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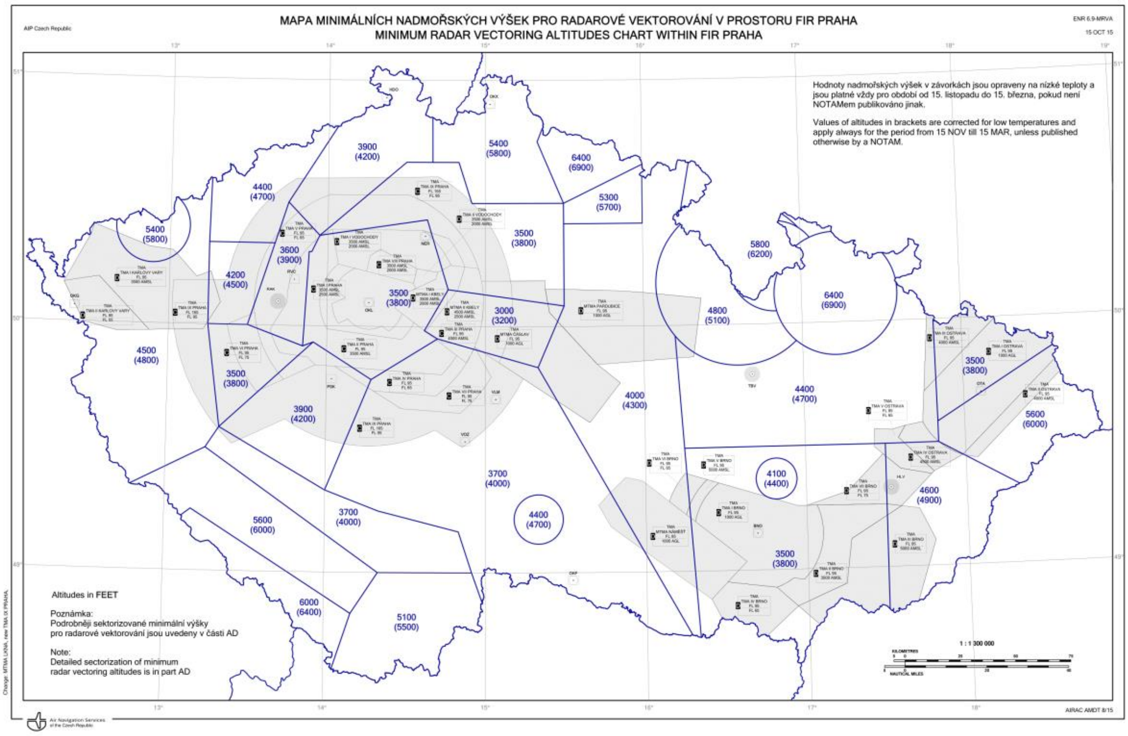
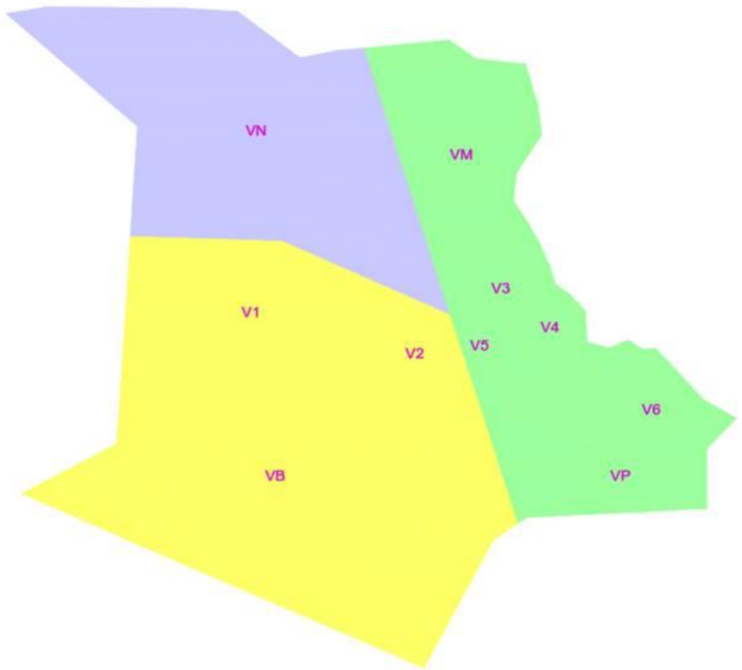
A.3 Minimum radar vectoring altitude in FIR



Appendix B Map of Vienna TMA



Appendix C Abbreviations

Abbreviations used in this document are defined below:

ABSR	Assistant Based Speech Recognition
ACC	Area Control Centre
AD	Aerodrome
AcListant	Active Listing Assistant
AEC	Arrival Executive Controller
ANSP	Air Navigation Service Provider
APC	Arrival Planning Controller
APP	Approach Control Unit
ASD	Actual Situation Display
ASR	Automatic Speech Recognition
ATC	Air Traffic Control
ATCO	Air Traffic Controllers
ATM	Air Traffic Management
CTA	Control Area
CTR	Controlled Traffic Region
DEC	Departure Executive Controller
DLR	German Aerospace Centre
ESUP	Eurocat Support System
FL	Flight Level
HDG	Heading
IDP	Information Data Processing and Presentation (ATM systems)
IFR	Instrument Flight Rules
IED	Information Executive Controller
LKKB	Prague Kbely Airport
LKPR	Prague Vaclav Havel Airport
LKVO	Vodochody Airport
LOWW	Vienna International Airport

PEC	Director Executive Controller
PMP	Project Management Plan
SSR	Secondary Surveillance Radar
SYSCO	System Supported Coordination
TMA	Terminal Manoeuvring Area
TWR	Aerodrome Control Unit
UTC	Coordinated Universal Time
VCS	Voice Communication System
VFR	Visual Flight Rules

Appendix D Glossary of Terms

Terms used in this document are defined below

Recognition rate[5]	The amount of recognized instructions
Error rate	The amount of wrongly recognized instructions
Rejection rate	The amount of unrecognized instructions (not included in error rate)

[5] The derived measurements of terms can be found in the paper from ATM conference in Lisbon 2016 [3], Section A, pg.6.

Appendix E References

The documents listed below become part of this Operational Concept Description to the extent referenced herein:

[1]. Helmke, H.; Rataj. J.; Muhlhausen, Th.; Ohneiser, O.; Ehr, H.; Kleinert, M.; Oualil, Y.; Schulder, M.; Klakow, D., Assistant-Based Speech Recognition for ATM Applications, 23.-26. June 2015, Lisbon, Portugal, 11th FAA/Eurocontrol ATM-Seminar

[2]. Helmke, H.; Muhlhausen, Th.; Ohneiser, O.; Ehr, H.; Kleinert, M.; Muth, K.; Gurluk, H.; Wies, M., Assistant-Based Speech Recognition – Another Pair of Eyes for the Arrival Manager, 13.-17. September 2015, Prague, Czech Republic, 34th Digital Avionics Systems Conference

[3]. Helmke, H.; Rataj, J; Muhlhausen, Th.; Ohneiser, O.; Ehr, H.; Kleinert, M.; Muth, K.; Oualil, Y; Schulder, M.; Assistant-Based Speech Recognition for ATM Applications, 2016, Lisbon, Portugal, ATM Conference

[4]. Helmke, H. et al.: MALORCA project: D6-1; Project Management Plan, 29 April 2016, Edition 1.00

[5]. SESAR Joint Undertaking & DEUTSCHES ZENTRUM FUER LUFT - UND RAUMFAHRT EV; UNIVERSITAET DES SAARLANDES; FONDATION DE L'INSTITUT DE RECHERCHE IDIAP; Řízení letového provozu České republiky; AUSTRO CONTROL OSTERREICHISCHE GESELLSCHAFT FUR ZIVILLUFTFAHRT, Grant Agreement number: 698824 — MALORCA — H2020-SESAR-2015-1/H2020-SESAR-2015-1