Ref. Ares(2018)557748 - 30/01/2018

Operational Concepts Description Update

D4.2

RETINA

Grant:	699370
Call:	H2020-SESAR-2015-1
Topic:	Sesar-06-2015
Consortium coordinator:	UNIBO
Edition date:	15 January 2018
Edition:	00.00.02

Authoring & Approval

Authors of the document

Name/Beneficiary	Position/Title	Date
Cristian Nativi/ENAV	Project Member	17 December 2017
Sara Bagassi/UNIBO	Project Coordinator	17 December 2017

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
Gilda Bruno/TECHNOSKY	Project Member	26 January 2018
Steven Bancroft/EUROCONTROL	Project Member	26 January 2018
Tom Nuydens/LUCIAD	Project Member	26 January 2018
Sergio Piastra/UNIBO	Project Member	26 January 2018
Alan Groskreutz/CRIDA	Project Member	29 January 2018

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

Name/Beneficiary	Position/Title	Date
Sara Bagassi/UNIBO	Project Coordinator	30 January 2018
Antonio Nuzzo/ENAV	Project Member	30 January 2018
Alan Groskreutz/CRIDA	Project Member	30 January 2018
Mohamed Ellejmi/EUROCONTROL	Project Member	30 January 2018
Tom Nuydens/LUCIAD	Project Member	30 January 2018

Document History

Edition	Date	Status	Author	Justification
00.00.01	15/01/2018	Initial Draft	UNIBO, ENAV	Contribution from partners
00.00.02	29/01/2018	Final Version	UNIBO, ENAV	Update after Project Partners Review

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

RETINA

Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision

This project has received funding from the SESAR JU under grant agreement No 699370.

Executive Summary

This document is the update of the operational concepts described in deliverable [1]. It reviews both the SRK taxonomy and the operational concepts according to the results obtained in WP4 Validation. The comprehensive solutions defined in the RETINA Project are analysed and updated in order to meet the recommendations collected during the validation.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

Table of Contents

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

1. Introduction

1.1 RETINA project overview

The RETINA project consists of a research and innovation action that deals with the development of innovative tools for the airport control tower and, as such, relates to ER-06-2015 – High Performing Airport Operations – Improved Visualisation and Awareness.

The RETINA project takes the idea of augmented vision and investigates its application to on-site control towers. It investigates the placement of additional information such as flight tags, runway layout, and warning detection over the actual out the window view that the controller has. Therefore, RETINA builds upon the technology previously developed in SESAR and provide new overlays as well.

From a technological perspective, RETINA investigates two different conceptual solutions based on the following augmented reality (AR) systems: Spatial Displays (SD) which are Conformal Head-Up Displays that, in the future, could be made to coincide with the tower windows and See-Through Head-Mounted Displays (HMD) which are wearable see through devices that can provide conformal augmented reality overlays.

RETINA deals with application-oriented research and encourage innovative and visionary ideas, effectively contributing to the SESAR 2020 Research and Innovation (R&I) cycle.

1.2 Document Scope

This document is the update of the operational concepts described in [1]. It reviews both the SRK taxonomy and the operational concepts according to the results obtained in WP4 Validation. The comprehensive solutions defined in the RETINA Project are analysed and updated in order to meet the recommendations collected during the validation.

1.3 Intended Audience

This document was developed as an output of the RETINA project describing comprehensive solutions that will exploit the concept of using selected Augmented Reality tools in the control tower.

Beneficiaries include all potential stakeholders identified in [2] such as airports interested in implementing these types of tools, air navigation service providers, and airport IT systems providers.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

1.4 Acronym List

Acronym	Definition
ADS-B	Automatic Dependent Surveillance – Broadcast
AH	Abstraction Hierarchy
AOIS	Aeronautical Operational Information system
AR	Augmented Reality
A-SMGCS	Advanced Surface Movement Guidance and Control System
ATC	Air Traffic Control
ATCO	Air Traffic Control Operator
ATCR	Air Traffic Control RADAR
ATM	Air Traffic Management
COO	Coordinator
CTOT	Calculated Take Off Time
CWP	Controller Working Position
DEL	Delivery
DTD	Distance to Touch-Down
EID	Ecological Interface Design
EOBT	Estimated off Blocks Time
ER	Exploratory Research
ETOT	Estimated Take Off Time
FDP	Flight Data Processing
FOV	Field of View
GGV	Gaze, Gesture, Voice
GND	Ground
HDE	Head Down Equipment
HMD	Head Mounted Display
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
IHP	Intermediate Holding Point
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
JU	Joint Undertaking
LOC	Localizer
LVP	Low Visibility Procedure
OOT	Out Of the Tower
PP	Pseudo Pilot
PSR	Primary Surveillance RADAR
RADAR	Radio Detection and Ranging

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

RETINA	Resilient Synthetic Vision for Advanced Control Tower Air Navigation Service Provision
RVR	Runway Visual Range
RWY	Runway
SD	Spatial Display
SESAR	Single European Sky ATM Research Programme
SJU	SESAR Joint Undertaking
SMR	Surface Movement RADAR
SRK	Skill-Rule-Knowledge
SSR	Secondary Surveillance RADAR
TDZ	Touch-Down Zone
TRL	Technology Readiness Level
TWR	Tower
TWY	Taxiway
UCD	User-Centred Design
VALR	Validation Report
V/ARTT	Virtual/Augmented Reality Tower Tool
VFR	Visual Flight Rules
VMC	Visual Meteorological Condition
VR	Virtual Reality
WCAT	Wake Turbulence Category

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

2 Selection of Sensing Technologies and Data Provision standards

2.1 Introduction

A survey of the sensing technologies and data provisioning standards on which the V/ARTT could be built was provided in [1] and [3].

Note that since the RETINA validation was based on a simulated environment, the availability of real data was overcome by the use of simulated data to some extent. Nevertheless, the consortium put every effort into considering real data. This will facilitate further development of the concept, such as the validation in a real control tower.

2.2 Basic requirements for implementation phase

In order to take advantage of the concept, an airport shall meet some basic requirements useful for applications of V/ARTT. These requirements are related to the equipment, airport layout, traffic and ATC procedures and have at least the following features:

- Primary Surveillance RADAR and Secondary Surveillance RADAR (PSR/SSR) equipped;
- Surface Movement RADAR (SMR) equipped;
- Low Visibility Procedures able to manage more than one aircraft at the same time implemented;
- ILS CAT 3B equipped;
- Moderate complexity (one runway, several taxiway, more than one apron);
- Moderate traffic: volume of 200/300 movement per day;
- Apron Management Procedures available;
- Meteorological sensing systems (winds, temperature, pressure, visibility, RVR – Runway Visual Range, cloud base).

2.3 Data sources for operational application

Data sources were classified in [1] in the following three categories:

- Operational Data
- User Data
- Auxiliary Data

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

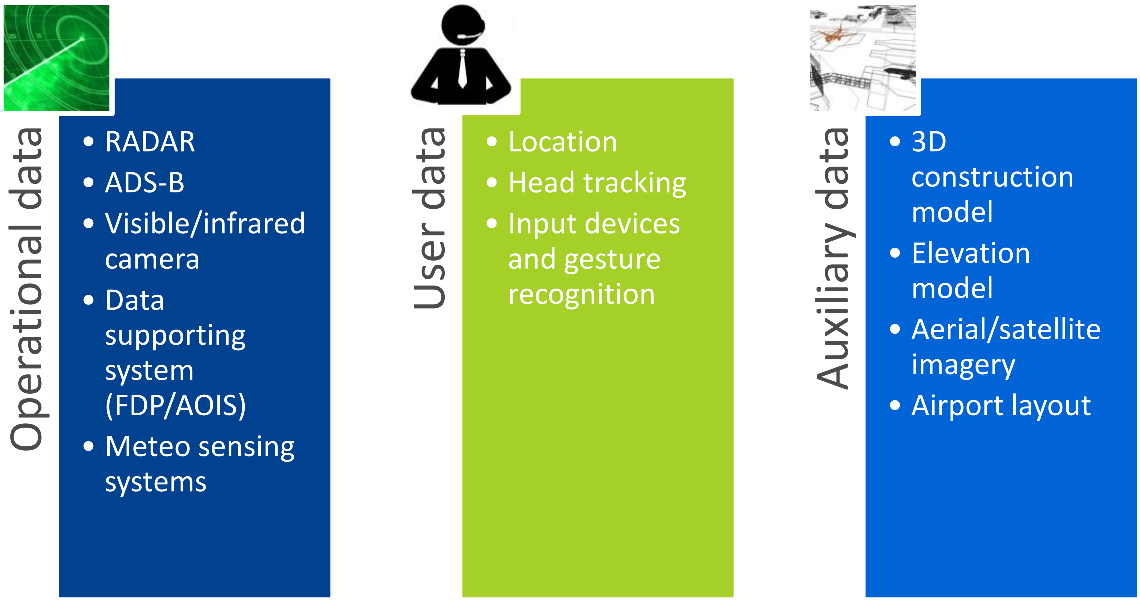


Figure 1 Data sources classified into three categories: Operational data, User data, Auxiliary data.

Based on the scheme reported in Fig. 2, those data are used to create the 4D model which provide data to the applications used to run the RETINA validation platform.

The validation was based on a simulated environment where all user data and auxiliary data were the real ones. As far as operational data is concerned, it was possible to include real meteorological data, whilst the other operational data were simulated. As a result, the user is immersed in a simulated environment where all operational conditions (including different visibility conditions) can be tested (Figg. 3 and 4) .

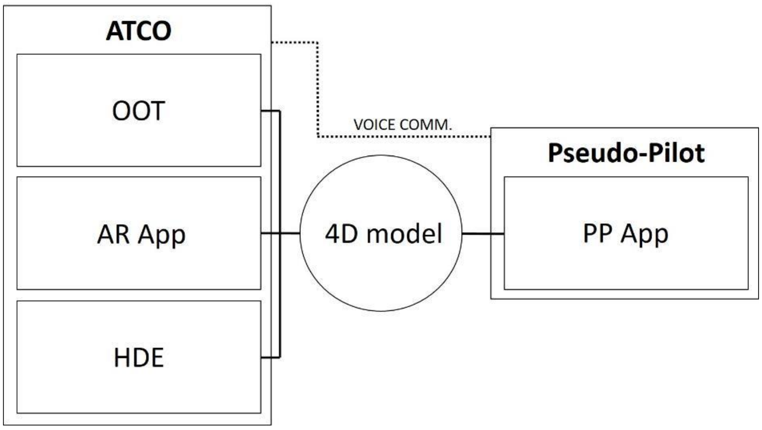


Figure 2 Validation Platform Architecture. The core system is the 4D model of the reference scenario which communicates through data exchange protocols with Out-of-the-Tower View Generator (OOT), Augmented Reality Overlay Application (AR App), Head Down Equipment (HDE) and Pseudo-pilot application (PP App).

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

Figure 3 The user is immersed in a simulated environment where normal visibility conditions are reproduced

Figure 4 The user is immersed in a simulated environment where low visibility conditions (CONDIVIS2) are reproduced

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

3 Virtual/Augmented Reality tools

The Operational Concepts deliverable [1] describes the selection of Virtual/Augmented Reality Tools for the provision of the Air Traffic Control (ATC) service by the airport control tower. The state of the art on existing synthetic vision and augmented reality technologies is described in [3] where the following technologies are considered (Fig.5):

- Head Mounted Displays
- Spatial Displays
- Hand Held Displays
- Object-Projected Displays
- Volumetric Displays

Figure 5 Augmented Reality Technologies identified for the airport control tower

Based on the analysis performed in [1] for the use of the above mentioned technologies in the RETINA concept, the following ranking is determined (Fig. 6).

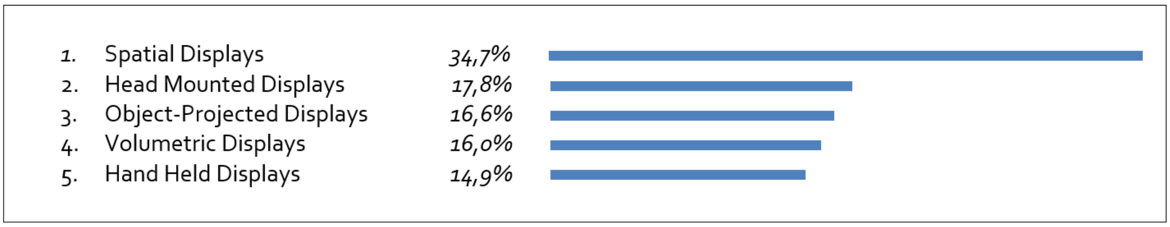


Figure 6 Final ranking of the Augmented Reality Technology

According to the ranking obtained, the two top ranked technologies, namely Spatial Display (SD) and Head Mounted Display (HMD), were considered as input to develop two different RETINA conceptual solutions to be validated within the project.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

Generally speaking, the see-through HMD system includes an image generator, a head tracker, video cameras, depth sensors, audio and voice input devices.

The device selected to develop RETINA validation platform for HMD conceptual solution is Microsoft™ Hololens™, an optical see-through head mounted display developed and manufactured by Microsoft™.

The HoloLens™ is equipped with:

- an inertial measurement unit (composed by an accelerometer, a gyroscope and a magnetometer);
- four grey scale “environment understanding" cameras (two on each side);
- a depth camera with a 120°×120° FOV;
- a 2.4-megapixel video camera;
- a four-microphone array;
- an ambient light sensor.

A "light engine" projects images into a pair of combiner lenses enclosed in a visor piece. The display projected occupies a limited portion of the user's FOV which is about 30°×17.5°. Near the user's ears, there is a pair of small 3D audio speaker. Compared against typical headsets these speakers do not obstruct external sounds, allowing the user to hear computer-generated sounds or other environmental sounds.

The device comes bundled with a thumb-sized input device named “the Clicker” that can be used for selecting and scrolling, via tilting and panning or clicking. For further interaction, Natural User Interface commands such as gaze, gesture and voice commands can be used. These are sometimes referred to as GGV (Gaze, Gesture, and Voice) inputs.

Figure 7 Microsoft Hololens HMD: the hardware

As far as Spatial Displays are concerned, it is worth remembering that the Augmented Reality technology for this solution is not yet available, thus this solution was targeting TRL2 and, from a technical perspective, it is not feasible so far with real embedded hardware. The main limitations for this technology are screen size, costs, and the possibility to provide AR holograms to multiple users looking at the same device. While the first two issues will be likely overcome in the next decade, the latter might take more time to get over.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

Based on this assumption, the conceptual solution based on see-through SD was implemented in a simulated environment that replicates the AR technology for SD as it is expected to be in the next decades.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

4 Virtual/Augmented Reality Overlays and Control Tower Procedures

4.1 Ecological Interface Design

4.1.1 Introduction

Ecological Interface Design is a theoretical framework for designing human-machine interfaces in complex, real-time and dynamic environments. EID differs from User-Centred Design (UCD) insofar it focuses on the work domain rather than on the end user requests, “ecological” is referred to an interface that has been designed to reflect the constraints of the work environment in a way that is perceptually available to the people who use it. Simply put, the users are able to take effective actions with the interface, understanding how those actions will move them towards their interface.

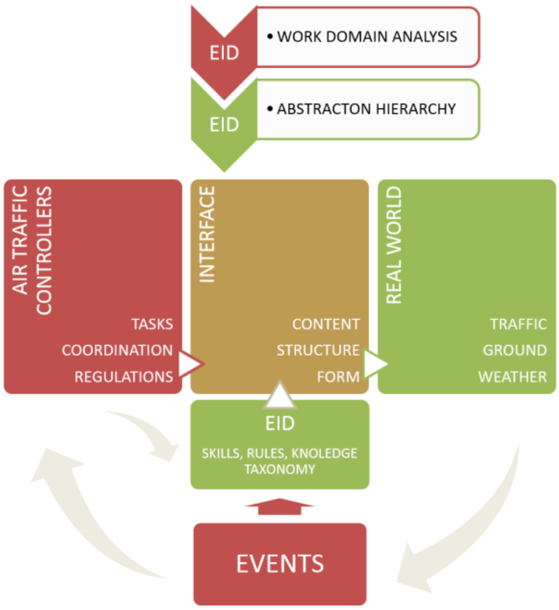


Figure 8 EID framework

The goal of EID is to make constraints and complex relationships in the work environment perceptually evident (e.g. visible, audible) to the user. This allows more of users' cognitive resources to be devoted

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

to higher cognitive processes such as problem solving and decision making. EID is based on three key concepts from cognitive engineering research:

- the Work Domain Analysis,
- the Abstraction Hierarchy (AH) and
- the Skills, Rules, Knowledge (SRK) framework.

By reducing mental workload and supporting knowledge-based reasoning, EID aims to improve user performance and overall system reliability for both anticipated and unanticipated events in a complex system.

4.1.2 The Skill, Rule And Knowledge Based Taxonomy

The Skills, Rules, Knowledge (SRK) framework or SRK taxonomy defines three types of behaviour or psychological processes present in operator information processing**Errore. L'origine riferimento non stata trovata.**. The framework is described in details in [1].

4.1.2.1 Skill-Based Behaviour

At the skill-based level, the behaviour is regulated by the lowest level of conscious involvement and is characterized by highly routinized and automated activities. In fact, skill-based mode refers to "the smooth execution of highly practiced, largely physical actions in which there is virtually no conscious monitoring".

- High Automated processes involving long term memory (procedural)
- Low Executive control (i.e. low attention and working memory)
- No Decision-making (resolution of conflicts and error detection)
- No Problem solving

4.1.2.2 Rule-Based Behaviour

Rule-based behaviour is also activated in familiar work situations, but it is distinguished from skill-based behaviour, as "it requires some degrees of conscious involvement and attention. Situation assessment leads to recognition of which procedures apply to particular familiar situations".

- Less automated processes and long term memory (procedural) than Skill level
- More executive control (i.e. more attention and working memory) than Skill level
- No Decision-making (resolution of conflicts and error detection)
- No Problem solving

Founding Members

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

4.1.2.3 Knowledge-Based Behaviour

When faced with unfamiliar situations, where no solutions are already available, it is necessary to move to the knowledge-based level of behaviour. At this level, the user "carries out a task in an almost completely conscious manner. This would occur in a situation where a beginner is performing the task (e.g. a trainee at the beginning of its training) or where an expert is facing with a completely novel situation. In either such cases, the User would have to exert considerable mental effort to assess the situation, and his or her responses are likely to be slow. Also, after each control action, the user would need to review its effect before taking further action, which would probably further slow-down the responses to the situation".

- No automated processes and long term (procedural) memory
- Executive control (high attention and working memory)
- Decision-making (resolution of conflicts and error detection)
- Problem solving

4.1.3 The use of Constraints

EID is also about exposing "constraints" in order to facilitate the operator job and move complex cognitive behaviours toward simpler cognitive behaviours (K –> R –> S)

4.1.4 EID application in RETINA domain project

4.1.4.1 Assumption

Using the SRK taxonomy we should:

- Expose/move relevant information onto the outside of the window view
- Make constraints visually perceivable
- Increase controllers' situation awareness

This should result in:

- Fewer limitations, therefore:
    - Increased capacity
    - Increased efficiency
- Increased safety

4.1.4.2 RETINA EID – Workflow

The SRK taxonomy applied to the control tower tasks should provide different results according to the current working condition (visibility, traffic), tower equipment (SMR, A-SMGCS, PSR/SSR) and procedures.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

Figure 9 SRK to Control Tower Task

4.2 Operational Context

4.2.1 Operational Context Analysis

All requirements related to the equipment, to the airport layout, to the traffic, and to the ATC procedure explained in [1]are confirmed.

Resuming, in order to be eligible for the RETINA implementation phase, an airport shall have at least the following features:

- Primary Surveillance RADAR and Secondary Surveillance RADAR (PSR/SSR) equipped;
- Surface Movement RADAR (SMR) equipped;
- Low Visibility Procedures able to manage more than one aircraft at the same time implemented;
- ILS CAT 3B equipped;
- Moderate complexity (one runway, several taxiway, more than one apron)
- Moderate traffic: volume of 200/300 movement per day;
- Apron Management Procedures available;

Guglielmo Marconi International Airport in Bologna (LIPE) has been chosen as a reference scenario for the implementation phase. Bologna Airport meets all the requirements mentioned above. Moreover, the Control Tower is quite large in order to easily host future real time experiments.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

4.2.1.1 Aerodrome Layout

Bologna is a single Runway (12 and 30) airport with a main taxiway T and several taxiway and aircraft stand taxilanes. The runway has a 12/30 orientation with an asphalt strip of 2803x45 m.

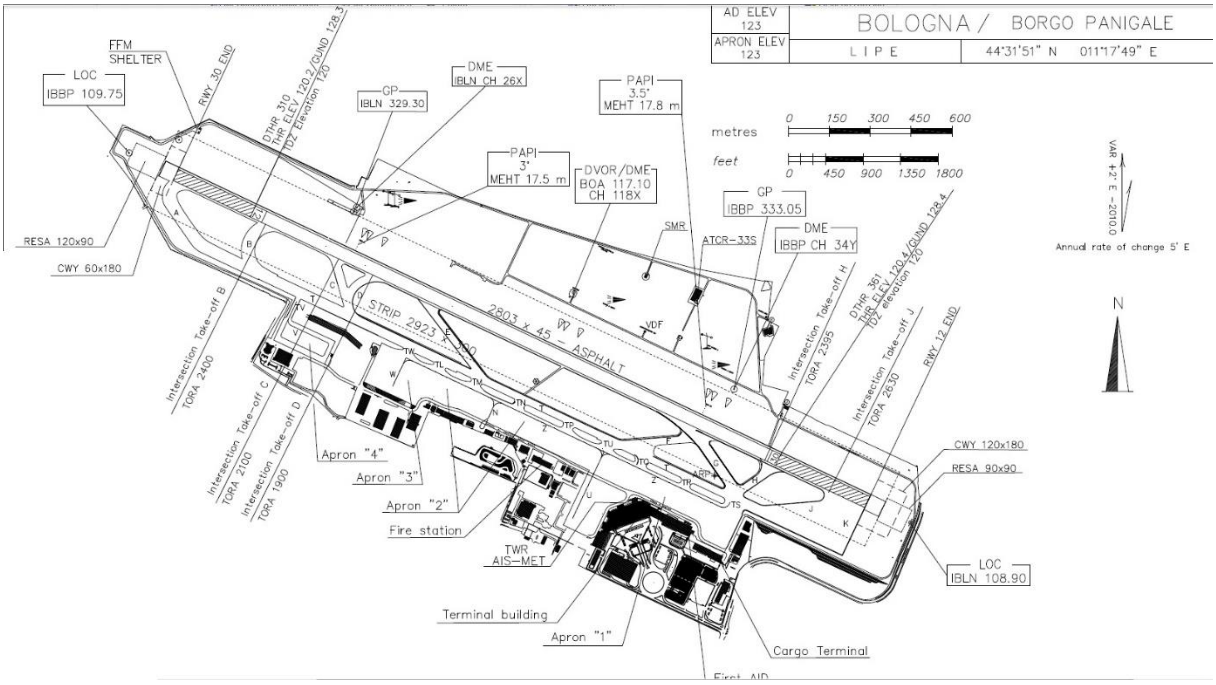


Figure 10 Bologna airport layout

Figure 10 reports Bologna Airport layout. The main taxiway T is parallel to the runway and it links all the aprons with the runway. Four aprons are available; Apron 1 in front of the terminal and the Control Tower, Apron 2 on left in front of the fire fighting area and hangars, Apron 3 is the cargo area and Apron 4 for general aviation. Aprons 1, 2 and 3 are linked to taxiway T with a short taxiway TW, TL, TN, TM,TP, TU, TQ, TR, and TS; Apron 4 is separated from the other aprons and is linked to the main taxiway T with taxiway TV.

The Runway and the main taxiway T are linked via the taxiways A, B, C, D, E, F, G, H, J and K.

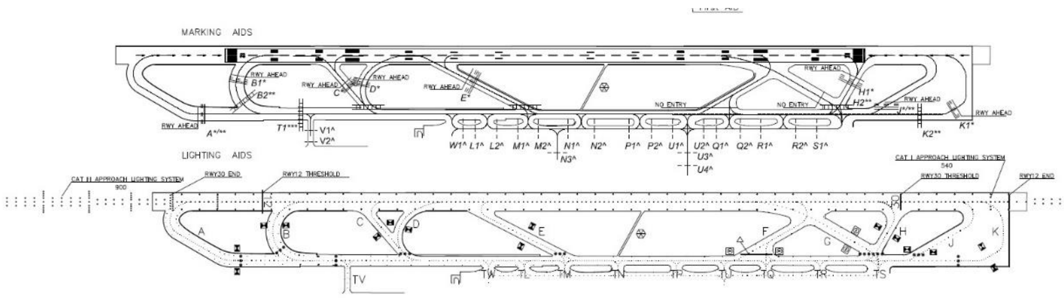


Figure 11 Bologna airport layout, runway, taxiways

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

4.2.1.2 Radio aids and surveillance systems

Bologna Airport is equipped with Primary and Secondary Surveillance RADAR and with Surface Movement RADAR (SMR). The PSR/SSR version is ATCR 33/S and it is Mode-S equipped. The range of the PSR covers about 65NM and the range of the SSR is about 110NM; the antennas are located together with a rotation every 4 seconds. Mode S information is displayed in a specific window of the CWP (controller working position) and includes several pieces of information such as aircraft call-sign, Indicated Air Speed, Heading, Level, etc. The SMR provides aircraft and vehicle positions on the manoeuvring area. Specific labelling is available on the CWP for identification. The SMR has a range of 3.5NM and also provides raw video information. The SMR is also able to detect foreign objects and flocks of birds on the runway.

Both runways are equipped with ILS; runway 12 until CAT IIIB and runway 30 until CAT1.

4.2.1.3 Local traffic rules and Low Visibility Procedures

The use of the taxiways is regulated via some restrictions:

1) TWY F and G shall be used only as an exit taxiway
2) TWY B and D shall not be used to enter the runway 12and perform backtrack
3) TWY G is a rapid exit taxiway: max speed 93km/h
4) Minimum thrust requested to pilots on all taxiways/taxilanes.
5) RWY 30 shall be used only if RVR (TDZ, MID and STOP/END) is equal or greater than 550m.

Moreover some restrictions applies depending on the ICAO code of the aircraft:

1) Aircraft with ICAO Code F shall use only taxiway A, J and K to enter the runway: A to enter runway 12, J as preferential to vacate runway 12 and K to enter runway 30.
2) Taxilane Z shall be used by aircraft up to ICAO code C between TQ and TS
3) aircraft with ICAO code letter “D” are allowed to taxi on TWY T and on aircraft stand taxilane Z only simultaneously with aircraft with ICAO code letter “A”
4) aircraft with ICAO code letter “E” shall not taxi on aircraft stand taxilane Z. Taxiing on TWY T and aircraft stand taxilane Z simultaneously with any other aircraft is forbidden
5) aircraft with ICAO code letter “F” shall not taxi on aircraft stand taxilane Z. Taxiing on TWY T and aircraft stand taxilane Z simultaneously with any other aircraft is forbidden
6) aircraft with ICAO code D, E, F parked on stand 114 or 115 shall be pushed-back on TWY T through TWY TS
7) aircraft with ICAO code E, F parked on apron 3 shall be pushed-back on TWY T through TWY TW
8) Use of taxilane N allowed only for aircraft up to ICAO code B included
9) aircraft with ICAO code letter “D” shall not taxi on the aircraft stand taxilane Z between apron holding points Q2 and S1
10) aircraft with ICAO code letter “E” shall use TWY TU/TS/ TW as exit/entry TWY from/to aprons

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

11) aircraft with ICAO code letter “F” shall use TWY “TS” as exit/entry TWY from/to stands 114 and TWY “TW” as exit/entry from/to Apron 3.

4.2.1.3.1 Local traffic regulation in CONDI VIS 2

Runway 12 is used preferentially and it is mandatory if RVR is less than 550m. Arriving aircraft vacate runway 12 only via taxiway G,H and J and runway 30 only via B. Departing aircraft enter runway 12 only via A and runway 30 via J. The stopbar at the Runway Holding point CAT II and III are activated. Minimum spacing between arriving aircraft is 10NM if LVP are not in force, 12NM in case LVP in force, 15NM to permit departure between arrivals and LVP in force. In case of LVP, in order to ensure that the radio path of the ILS is free, the TWR controller will clear for take off a departure only if it will overfly the LOC antenna before the arriving aircraft is 4NM on final.

4.2.1.3.2 Local traffic regulation in CONDI VIS 3

Only runway 12 is used. Intermediate Holding Point (IHP) T1 on main taxiway is activated, the follow-me is positioned on the taxiway T abeam TS on TWR request in case of arrival. Departing aircraft taxi to IHP T1 initially and then to RHP A. Further departures start taxi only once the previous one is between T1 and A RHP. Arriving aircraft vacate the runway only via J and follow the follow-me until the parking. Push back operations are allowed only from stand belonging to not contiguous blocks. Minimum spacing between arriving aircraft is 15NM in case of no departure and 16NM in case of departure. In order to ensure that the radio path of the ILS is free, the TWR controller will clear for take off a departure only if it will overfly the LOC antenna before the arriving aircraft is 4NM on final.

4.2.1.4 Controller Working Position

The TWR controller is responsible to provide the Aerodrome Control Service, the Flight Information Service and the Alert Service to all traffic in the Aerodrome Traffic Zone (portion of airspace with radius of 5NM and 2000ft) and on the Runway. Image below reports the TWR CWP, COO CWP and GND CWP as described in [1] .

Figure 12 Bologna Airport TWR CWP

Figure 13 Bologna airport COO CWP

Figure 14 Bologna airport GND CWP

4.2.2 Scenario definition

The information needed by the controller considering the following 4 scenarios are analysed:

1. VMC scenario: visibility equal or greater than 5km and ceiling equal or greater than 1500ft (VFR flights available).

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

2. IMC visibility CONDITION 1: there are no conditions for the visual flights (only Special VFR) but visibility condition 1 still hold. Visibility condition 1 (CONDI VIS 1) is considered whereas the visibility is sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, and for personnel of control units to exercise control over all traffic on the basis of visual surveillance.

3. IMC visibility CONDITION 2: Visibility condition 2 (CONDI VIS 2) is considered whereas the visibility is sufficient for the pilot to taxi and to avoid collision with other traffic on taxiways and at intersections by visual reference, but insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance.

4. IMC visibility CONDITION 3: Visibility condition 3 (CONDI VIS 3) is considered whereas the visibility is sufficient for the pilot to taxi but insufficient for the pilot to avoid collision with other traffic on taxiways and at intersections by visual reference, and insufficient for personnel of control units to exercise control over all traffic on the basis of visual surveillance. For taxiing, this is normally taken as visibilities equivalent to an RVR of less than 400 m but more than 75 m.

It is important to note that scenario 1 and 4 are defined by measured value while the shift from CONDI VIS 1 and 2 is defined by the controller.

4.2.2.1 VMC/Visibility CONDITION 1 scenario

4.2.2.1.1 Task analysis and Flight Phases in VMC/Visibility CONDITION 1 scenario

- GND/DEL: issue ATC clearance, Issue Start Up clearance, Approve Push Back, Issue taxi clearance, monitor taxi route;
- TWR: issue Landing clearance (in case go around), issue take off clearance, monitor take off and landing operations, issue clearance to vehicle for runway inspections/operations.

4.2.2.1.2 ATCO information in VMC/ Visibility CONDITION 1 scenario

- **Information related to arrival aircraft**: identification, altitude, speed, Type/WCAT, Taxi Route assigned, Distance/time from Touch Down, “Animated Bounding Box” to highlight far aircraft position, landing clearance, parking stand (when landed);
- **Information related to departure aircraft**: Identification, EOBT, speed (only when taxing), Type/WCAT, CTOT, Ready message (only departure at stand), taxi route assigned, take-off clearance, parking stand, sequence number;
- **Information related to Ground Vehicles**: Identification, speed, taxi route assigned;
- **Information related to Airport static features:** RWY status (Occupied, closed), Restricted areas (Taxiway closed);

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

- **Environmental Information:** MET REPORT data: Wind, Visibility, Ceiling, QNH, Temperature, dew point, RWY surface condition, NAVAIDS status;
- **Safety Net:** Warning for some RWY incursion (RWY closed, vehicle and aircraft on RWY).

4.2.2.2 IMC Visibility CONDITION 2

4.2.2.2.1 Task analysis and Flight Phases in CONDI VIS 2

- GND/DEL: issue ATC clearance, Issue Start Up clearance, Approve Push Back, Issue taxi clearance, monitor taxi route;
- TWR: issue Landing clearance (in case go around), issue take off clearance, monitor take off and landing operations, issue clearance to vehicle for runway inspections/operations.

4.2.2.2.2 ATCO information in CONDI VIS 2

- **Information related to arrival Aircraft:** Identification, Altitude, Speed, Type/WCAT, Taxi Route assigned, Distance/time from Touch Down, “Animated Bounding Box” to highlight far aircraft position, landing clearance, parking stand (when landed);
- **Information related to departure Aircraft:** Identification, EOBT, Speed (only when taxing), Type/WCAT, CTOT, Ready message (only departure at stand), Taxi Route assigned, take-off clearance, parking stand, sequence number;
- **Information related to Ground Vehicles:** Identification, speed taxi route assigned;
- **Information related to Airport static features:** Aerodrome layout (apron and manoeuvring area), RWY status (Occupied, closed), Restricted areas (Taxiway closed: F), stopbar (holding point A);
- **Environmental Information:** MET REPORT data: Wind, Visibility, RVR, Ceiling, QNH, Temperature, dew point, RWY surface condition, NAVAIDS status;
- **Safety Net:** Warning for some RWY incursion (RWY closed, vehicle and aircraft on RWY).

4.2.2.3 IMC Visibility CONDI VIS 3

4.2.2.3.1 Task analysis and Flight Phases in CONDI VIS 3

- GND/DEL: issue ATC clearance, Issue Start Up clearance, Approve Push Back, Issue taxi clearance, monitor taxi route;
- TWR: issue Landing clearance (in case go around), issue take off clearance, monitor take off and landing operations, issue clearance to vehicle for runway inspections/operations.

4.2.2.3.2 ATCO information in CONDI VIS 3

- **Information related to arrival Aircraft:** Identification, Altitude, Speed, Type/WCAT, Taxi Route assigned, Distance/time from Touch Down, “Animated Bounding Box” to highlight far aircraft position, landing clearance, parking stand (when landed);

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

- **Information related to departure Aircraft:** Identification, EOBT, Speed (only when taxing), Type/WCAT, CTOT, Ready message (only departure at stand), Taxi Route assigned, take-off clearance, parking stand, sequence number;
- **Information related to Ground Vehicles:** Identification, speed, taxi route assigned;
- **Information related to Airport static features:** Aerodrome layout (apron and manoeuvring area), RWY status (Occupied, closed), Restricted areas (Taxiway closed: B,C,D,E,F,G,H), stopbar ((holding point A and T1);
- **Environmental Information:** MET REPORT data: Wind, Visibility, RVR, Ceiling, QNH, Temperature, dew point, RWY surface condition, NAVAIDS status;
- **Safety Net:** Warning for some RWY incursion (RWY closed, vehicle and aircraft on RWY).

4.3 EID Analysis update

4.3.1 SRK Classification

The section 4.3.2 in[1] reports a S-R-K analysis of the controller tasks for each selected condition.

The following graph, represent the SRK analysis for sample exercises simulated during the validation phase. In order to perform the analysis, each controller task is reported in the timeline according to the status of each flight simulated during exercises. This timeline is useful to identify the density of tasks to be performed and graphically represents the relative timing of different tasks.

When controllers cope with head down systems the cognitive effort required for managing interfaces and retrieving information, implies a higher workload. They are responsible for interpreting information from multiple systems and making decisions.

All the information displayed by RETINA solutions aims to reduce the complexity of operations and allow activities to be accomplished according to “if-then rules”. This allows to shift from a knowledge based behavior to a rule based behavior.

Figg. 15,16, and 17 analyze the duration of tasks for each flight of a sample exercise respectively for CONDIVIS1, CONDIVIS2 and CONDIVIS3.

Based on this analysis and the SRK analysis performed in [1], it is possible to derive charts reported in Figg. 18 to 23 where a representation of the cognitive behavior in use during the single exercise at each minute of the simulation is given. Specifically, each bar represents the number of active sub tasks in the specified minute of simulation, classified as SRK according to [1].

Looking at the single chart, the reader can get a qualitative estimation of both the task load and the associated cognitive behavior along the single exercise. For example, Fig.18 shows that the number of subtasks that are simultaneously managed at minute 37 is very high. This corresponds to a situation where the controller should manage the use of the runway between arriving and departing flights. According to the SRK analysis the controller’s behavior for this task is fully-knowledge-based. That

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

means the controller should identify the situation, interpret, evaluate, select a procedure and act.

Moreover, comparing pairs of charts in the same visibility condition, it is possible to get information about the cognitive shift introduced by RETINA solutions. For instance, weighing Fig. 20 up against Fig. 21 it is possible to qualitatively assess that the introduction of RETINA solutions in CONDIVIS2 elicits a shift in the user's cognitive behavior towards more simple manners of performing tasks.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

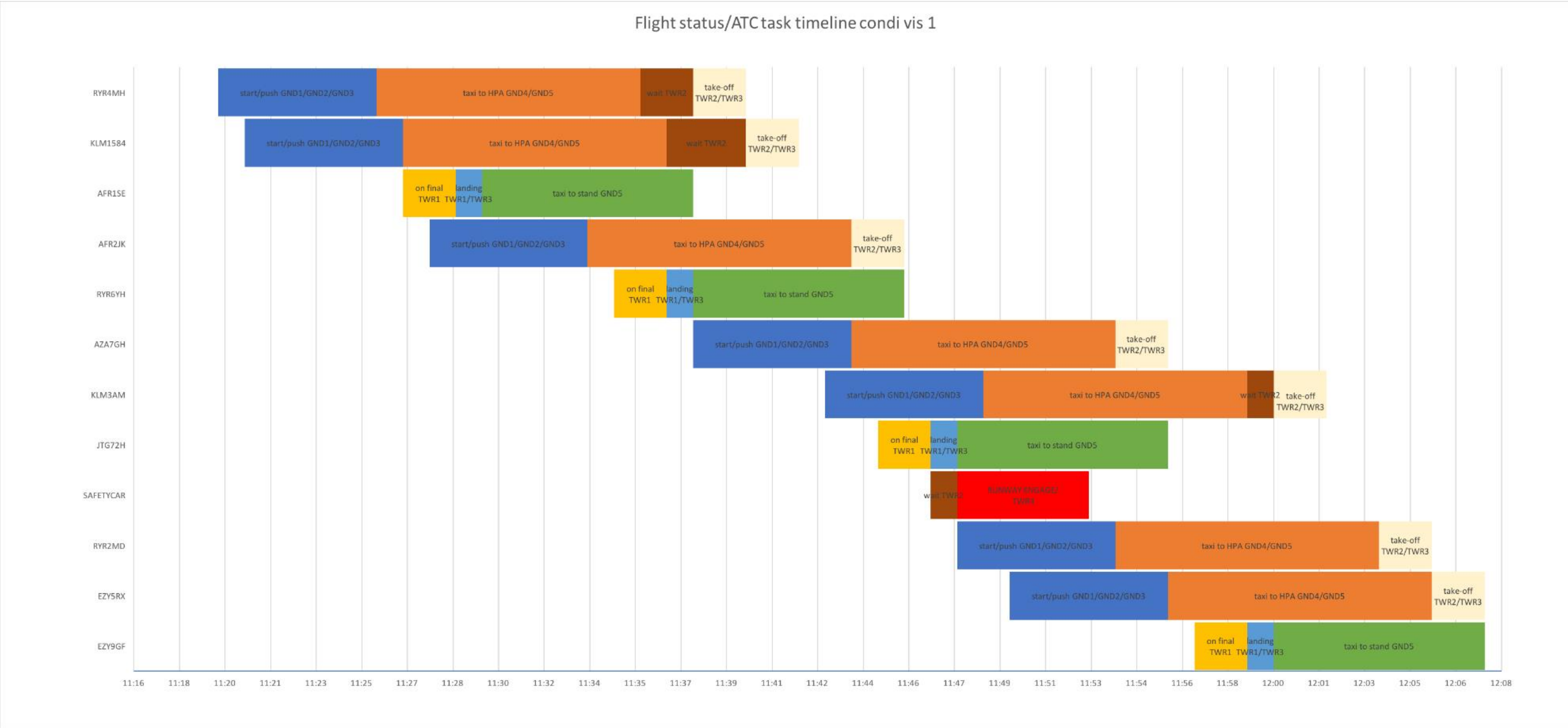


Figure 15 Duration of tasks for each flight of a sample exercise in CONDIVIS1

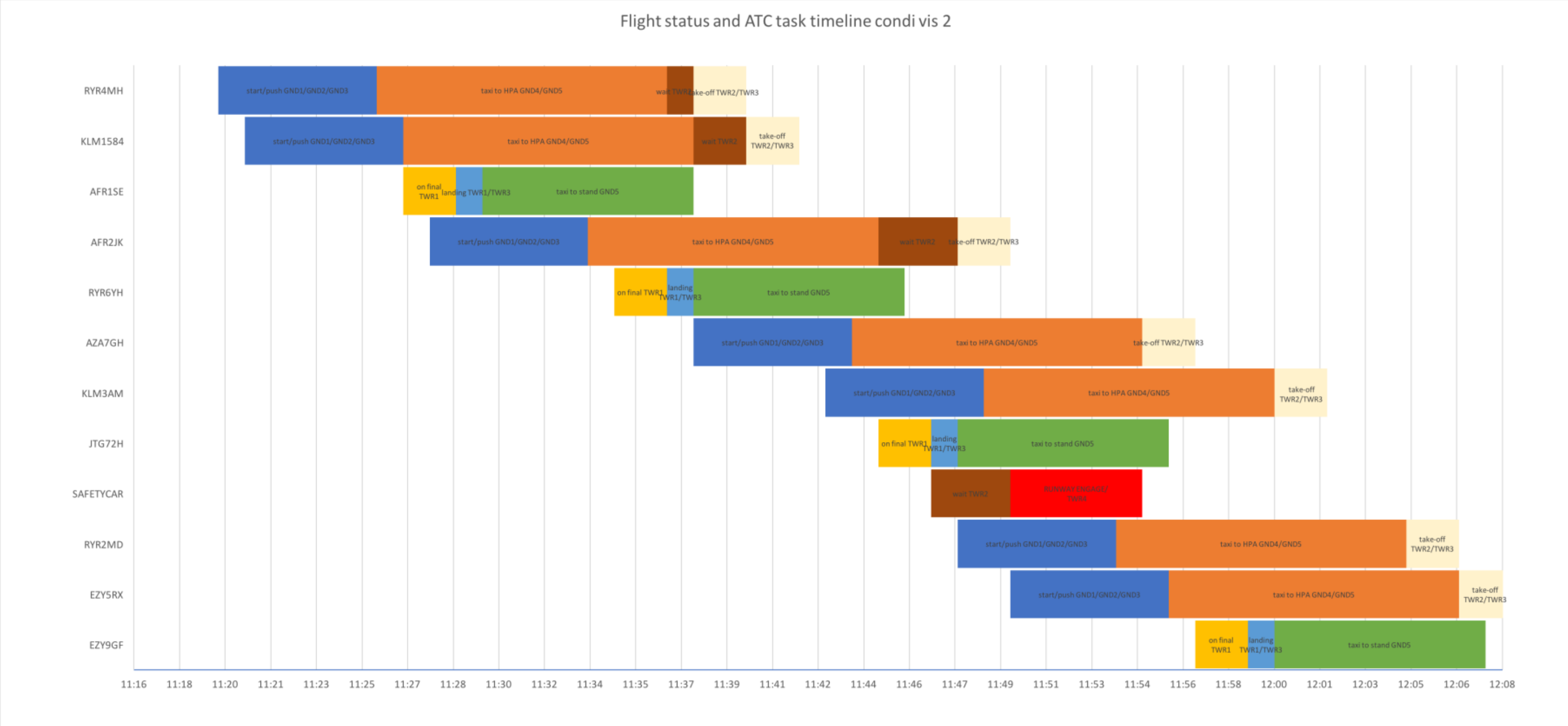


Figure 16 Duration of tasks for each flight of a sample exercise in CONDIVIS2

EUROPEAN UNION EUROCONTROL

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

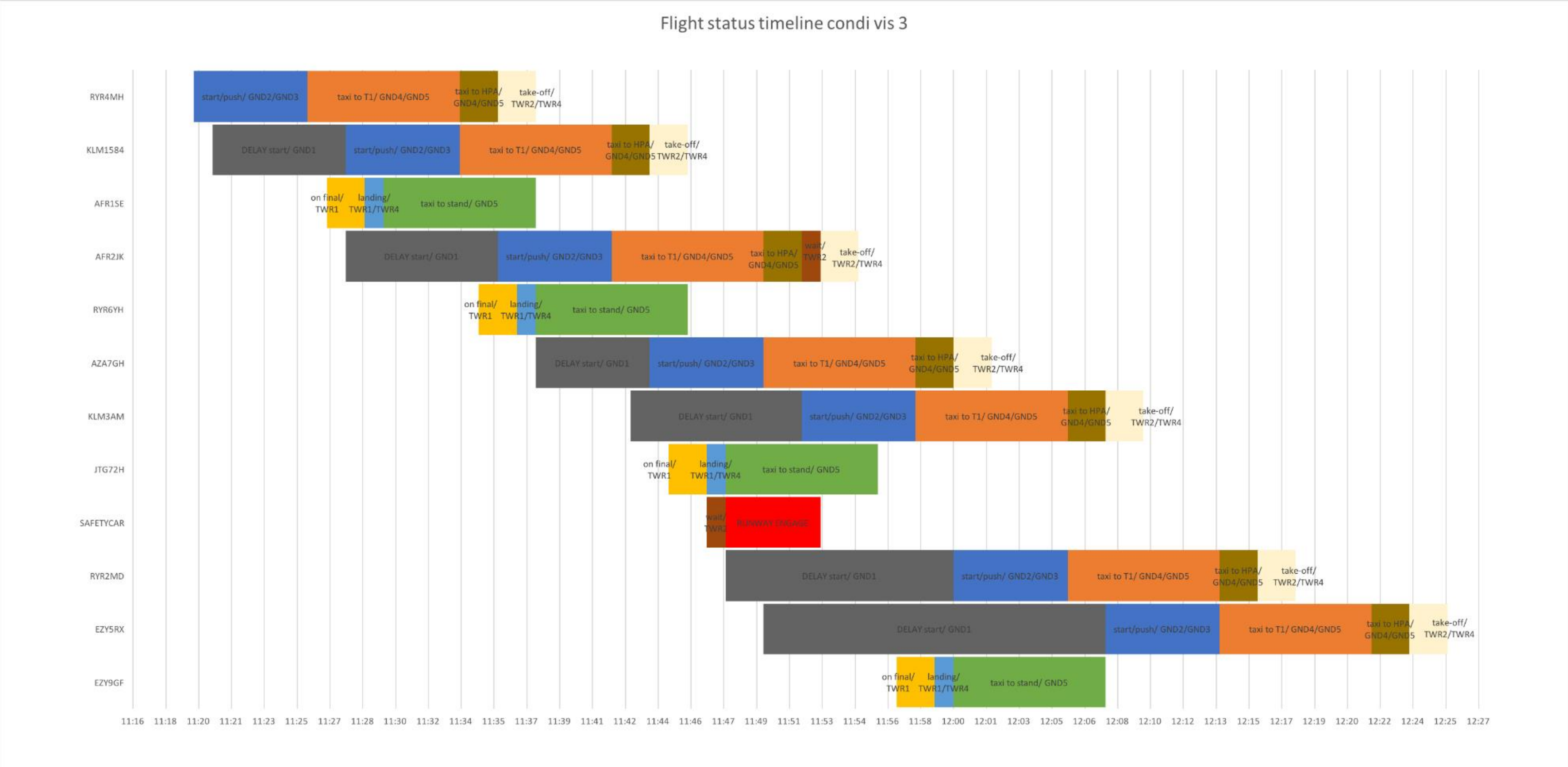


Figure 17 Duration of tasks for each flight of a sample exercise in CONDIVIS3

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

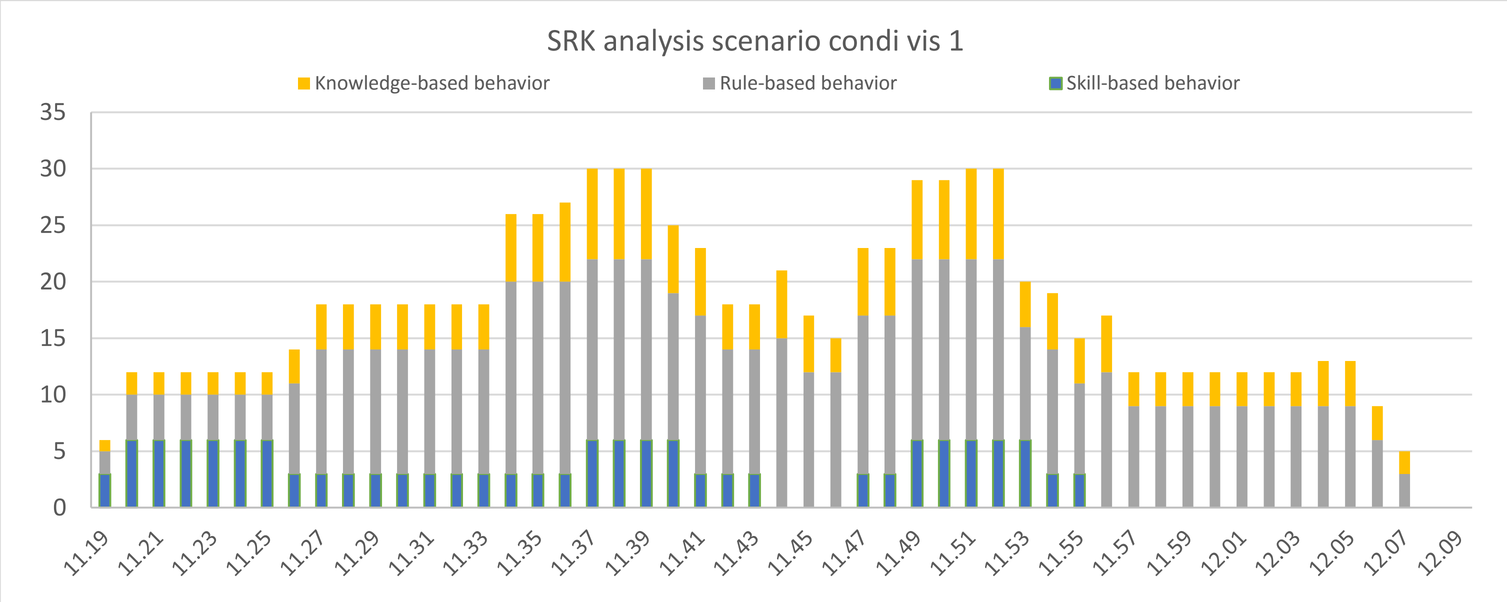


Figure 18 Cognitive behavior in use during a sample exercise in CONDIVIS1 at each minute of the simulation

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

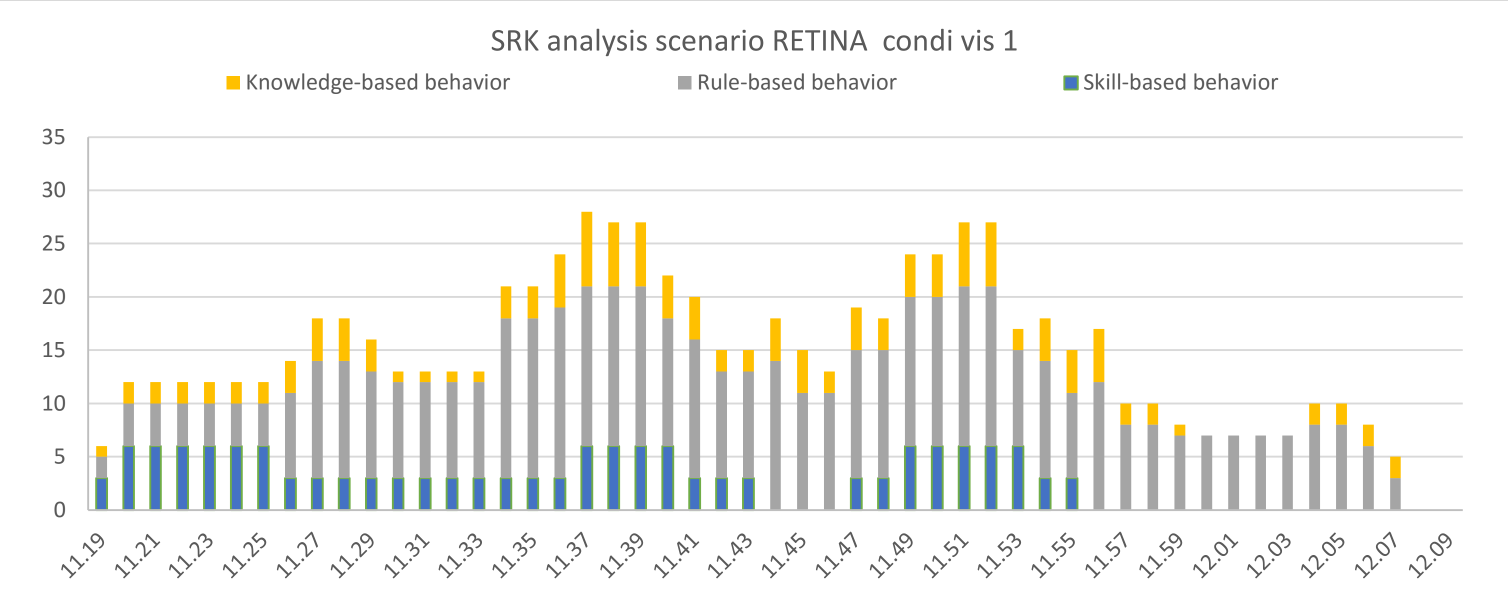


Figure 19 Cognitive behavior in use during a sample exercise in CONDIVIS1 with RETINA solutions at each minute of the simulation

Founding Members

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

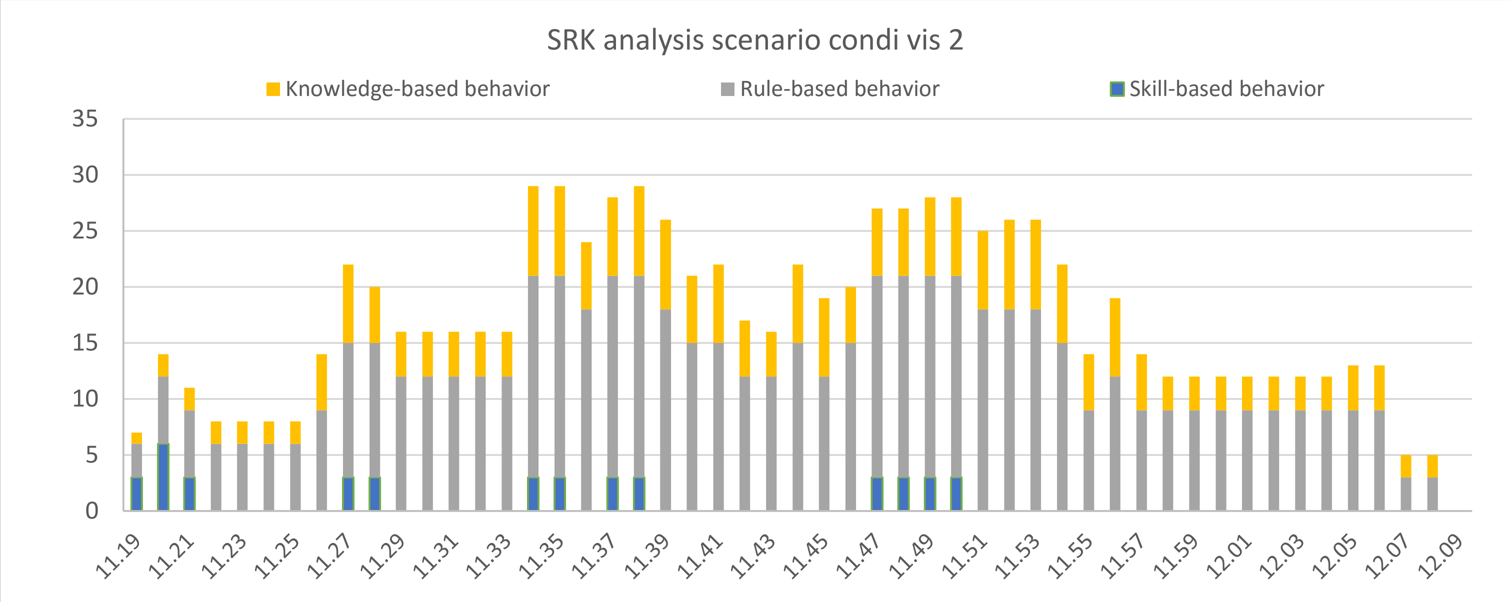


Figure 20 Cognitive behavior in use during a sample exercise in CONDIVIS2 at each minute of the simulation

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

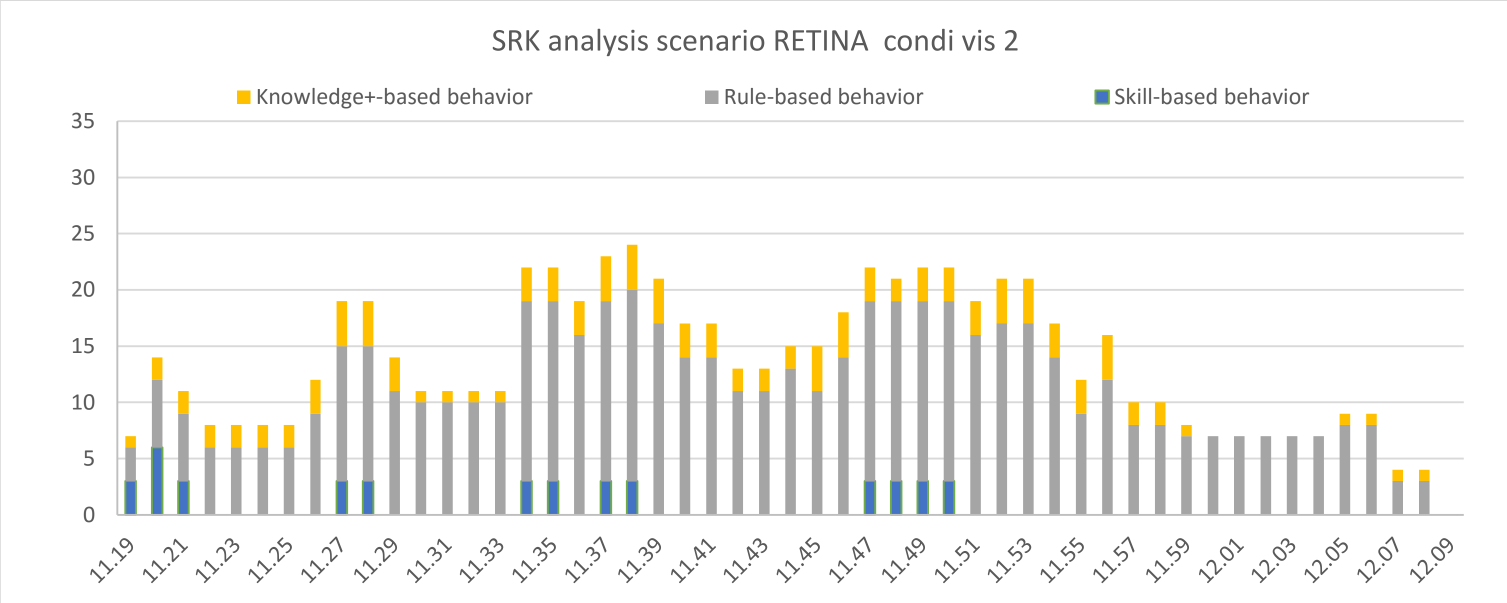


Figure 21 Cognitive behavior in use during a sample exercise in CONDIVIS2 with RETINA solutions at each minute of the simulation

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

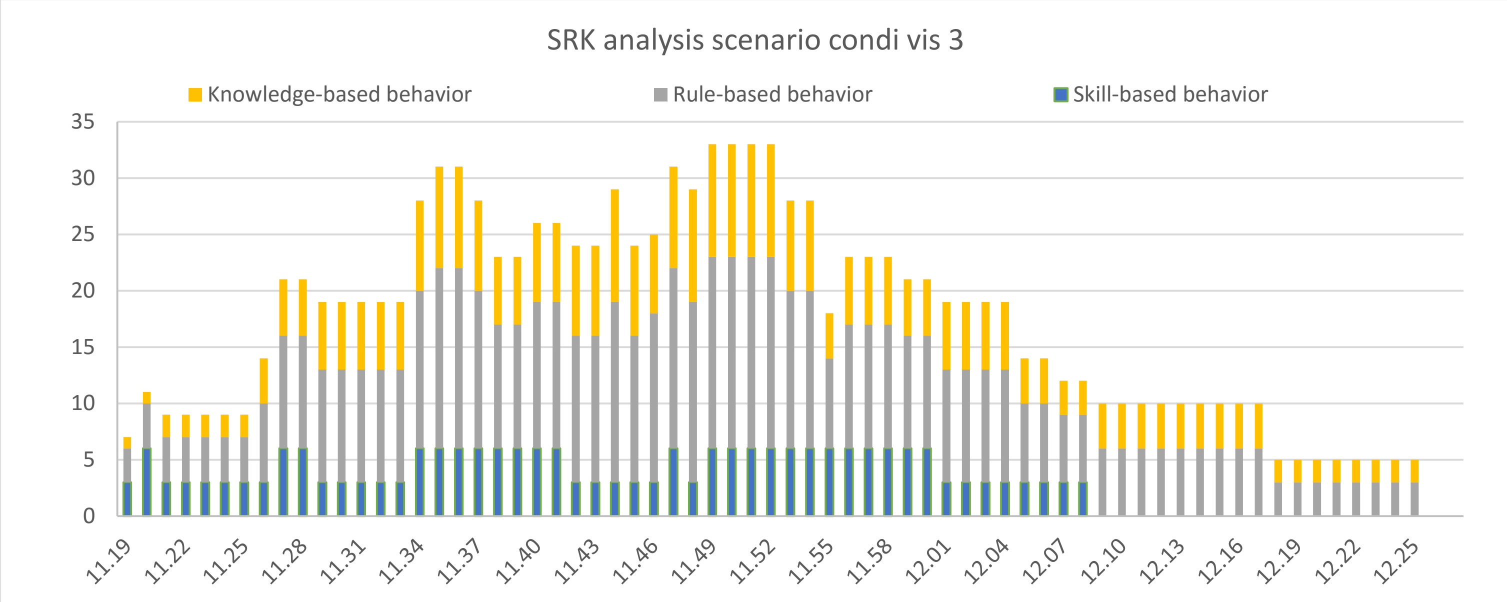


Figure 22 Cognitive behavior in use during a sample exercise in CONDIVIS3 at each minute of the simulation

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

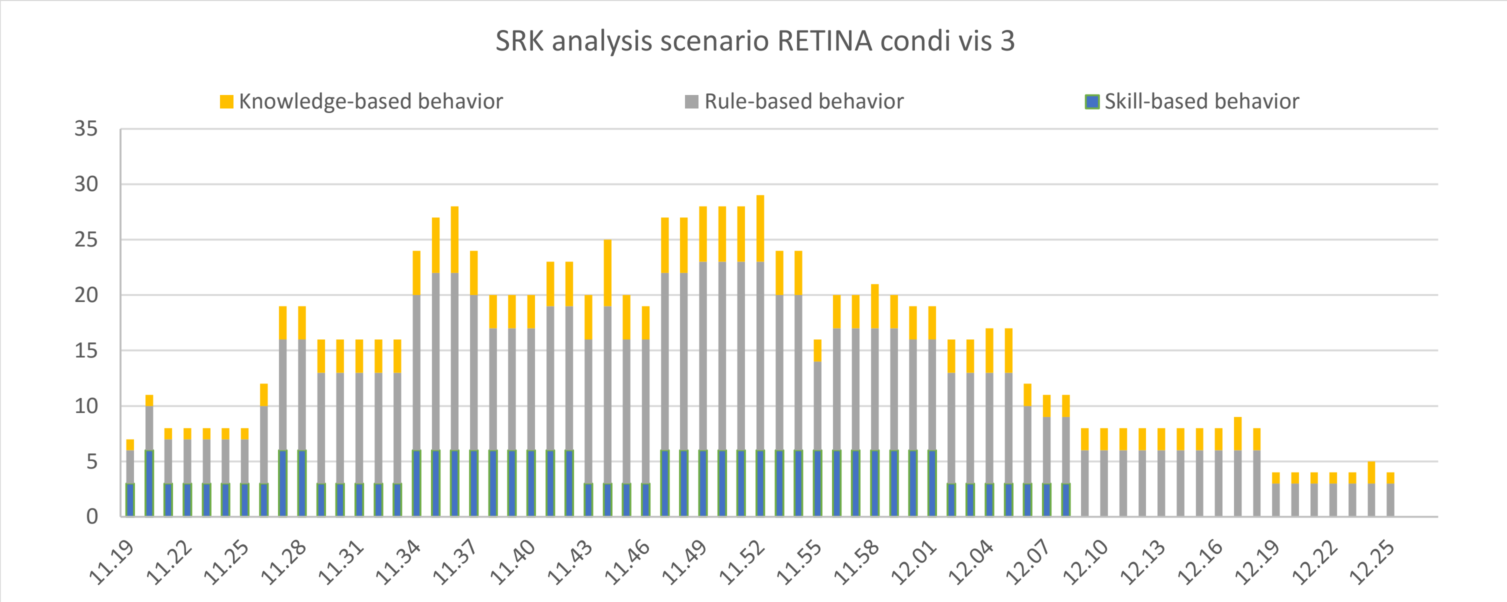


Figure 23 Cognitive behavior in use during a sample exercise in CONDIVIS3 with RETINA solutions at each minute of the simulation

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

4.4 Conclusion

Air traffic controllers of middle/high complexity airports, such as Bologna airport, use CWP instruments to know the state and the position of each flight. This is currently essential to maintain the situational awareness that allows identification and decision making to plan tasks and optimize arrival and departure air traffic flow. As mentioned in 4.2.1.4, nowadays air traffic controllers look for information on different screens that are placed in front of them while they are keeping visual contact with the air traffic. This implies a huge temporal and cognitive effort that is necessary to interpret all the inputs.

As described in [1] the information presented through RETINA solutions well support important tasks, especially those that require conflict detection and conflict solving. Moreover, the representation of information by means of RETINA tools supports skill- and rule-based behaviors in familiar tasks, implying that more cognitive resources may be devoted to knowledge-based behaviors, which are important for managing unanticipated events.

This leads to the reduction of the perceived workload as it was recorded during the validation [4].

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

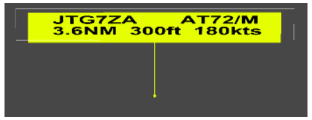
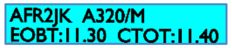
5 4D Model and Concept Integration

5.1 RETINA solutions update

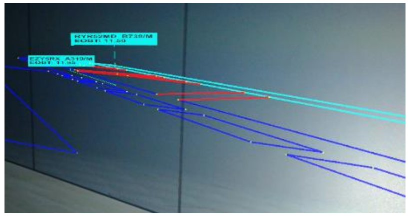
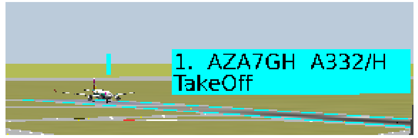
The two conceptual solutions were updated based on validation results and they are described in the following paragraphs.

The AR overlays implemented for the two solutions proposed are depicted in table 1.

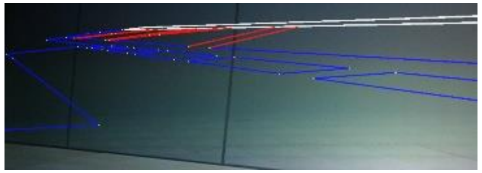
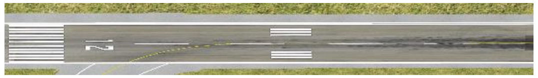
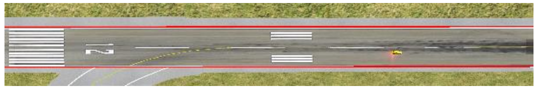
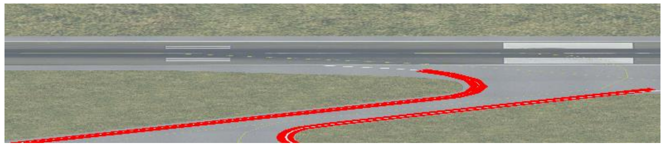
© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

INFORMATION	REGISTERED TO MOVING OBJECTS	REGISTERED TO FIXED OBJECTS	UNREGISTERED	CONDI VIS	HMD	SD
Aircraft/Ground Vehicle position and attitude (close vehicles)	X			IMC 2, 3	Position (label bar ending point):  ARR DEP Safety Vehicle	 DEP: cyan bars  ARR: yellow bars  Safety Vehicle: red marker
Aircraft Bounding Box (far aircraft)	X			VMC; IMC 1, 2, 3	See "Aircraft/Ground Vehicle position and attitude" above	See "Aircraft/Ground Vehicle position and attitude" above.
Aircraft Label: Identification, Altitude, Speed, Type/WCAT, CTOT, Distance from Touch Down (only arrival), Ready Message (only departure at stand)	X			VMC; IMC 1, 2, 3	 ARR before landing  ARR on the ground  DEP	 ARR before landing  ARR on the ground  DEP at the stand  DEP during pushback  DEP during taxi

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

						 DEP during take-off with sequence number
Assigned Taxi Route		X		VMC; IMC 1, 2, 3		
Landing/take-off clearance	X			VMC; IMC 1, 2, 3	Take-off clearance: rwy borders change color to cyan; 	Take-off clearance: 1) rwy borders change color to cyan and start blinking; 2) the DEP label displays take-off indicator and starts blinking 
Ground Vehicle: Identification and speed.	X			VMC; IMC 1, 2, 3		

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

Aerodrome layout (apron and manoeuvring area)		X		IMC, 2, 3		
RWY status (free, occupied, closed)		X		VMC; IMC 1, 2, 3	   	Free Occupied by ARR (from 5NM before touch down to rwy exit sensor) Occupied by DEP (from take-off clearance/rwy entry sensor to take-off sensor) Occupied by safety vehicle (from rwy entry sensor to rwy exit sensor) Overlay blinking at each RWY status change in the SD solution
Restricted areas		X		VMC; IMC 1, 2, 3		

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

Stop-bars (including intermediate)		X		IMC 2, 3		
Wind			X	VMC; IMC 1, 2, 3		
Visibility (RVR)			X	IMC 2, 3		
Ceiling			X	IMC 1		
QNH			X	VMC; IMC 1, 2, 3		
RWY surface conditions,			X	VMC; IMC 1, 2, 3		
NAVAIDS status			X	VMC; IMC 1, 2, 3		
Warning for some RWY incursion		X		VMC; IMC 1, 2, 3	See "RWY status" above	

Table 1 Classification of information according to the RETINA concept and example of AR overlays implementation

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

5.1.1 Solution 1: See-Through Head Mounted Display

In this solution, both Ground/Delivery and Tower controllers will be provided with a HMD to be used as a personal device. The device shows ad-hoc generated images based on the controllers' position, gaze orientation, and outside visibility condition.

The solution implemented for the validation campaign is based on Microsoft™ Hololens™, an optical see-through head mounted display developed and manufactured by Microsoft™ and described in Chapter 3.

Wearing that device, the user's capability to see the external world is preserved and, in a limited portion of his/her field of view, the AR overlays are displayed. The user accessibility to the whole information provided by the overlays is ensured by the natural ability to look in the direction the information is expected to be. Thus, the user's field of view is not reduced and a limited portion of it is enriched with AR overlays (Fig.24).

The HMD includes headsets and a microphone which can be used for voice communications instead of the traditional equipment.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

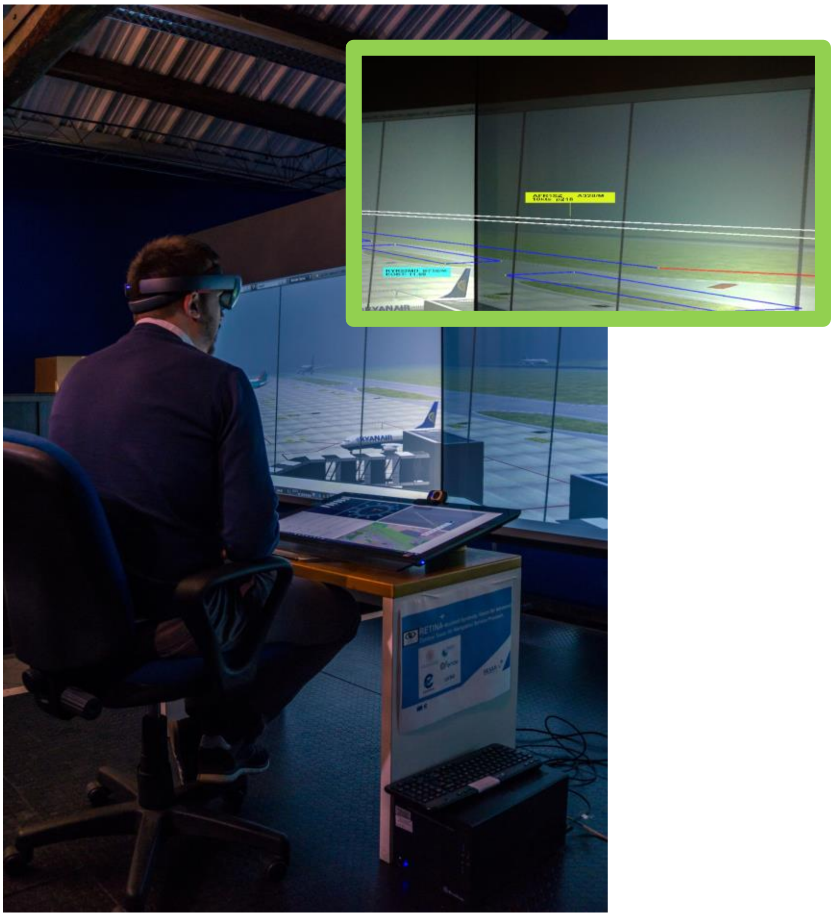


Figure 24 RETINA Validation Platform for Head Mounted Display Conceptual Solution. The green squared box depicts the view the user has through Microsoft Hololens.

5.1.1.1 Data sources update

Data sources are the same as explained in the previous paragraphs. According to the feedback provided by ATCOs during validation debriefing sessions, the information to be displayed at a certain time should be filtered according to the specific phase of flight or condition.

5.1.1.2 AR overlays

5.1.1.2.1 HMD: meteo and NAVAIDS status

The HMD shows a semi-transparent display that provides ATCOs with the most relevant environmental information based on the current visibility condition, RWY surface condition and NAVAIDS.

During the validation exercises the display was positioned on the outside view, within the line of sight of strategic points, such as the runway end-point, the apron mid-point and the manoeuvring area left and right edges.

According to the feedback of ATCOs during debriefing, the position of the "weather display" should be set according to the user's preference or, even better, in a fix position within the AR field of view. This

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

would reduce the effort spent to look for data moving the head, and help the ATCO to maintain a continuous visual contact with the position of moving aircraft while reading weather data.

5.1.1.2.2 Aircraft's billboards

Alphanumeric text labels (billboards) are displayed near those aircraft/vehicles which fall inside the HMD AR FOV. Hereafter, this concept will be referred to as the "billboard" concept.

Based on the feedback of ATCOs during debriefing the billboards should provide controllers with only the data they need at that time. To identify which data should be displayed it is important to link data to the status of flight.

For each departing aircraft, the following four phases can be distinguished: park, start up/push back, taxi, take off.

For arriving aircrafts, the following four phases can be distinguished: on final, landing, taxi, park

For departing aircrafts, the billboards should provide the controller with:

- Aircraft position, identification and type/WCAT always
- EOBT, ready message until is at parking stand
- CTOT until take off
- Sequence number during taxi
- Altitude and speed during take off

For arriving aircrafts, the billboards should provide the controller with:

- Aircraft position, identification and type/WCAT always
- Distance from touch down when on final
- Stand when landed and during taxi

The selected colour coding is depicted in Figg. 25 and 26.

- Yellow for arriving flights
- Cyan for departing flights

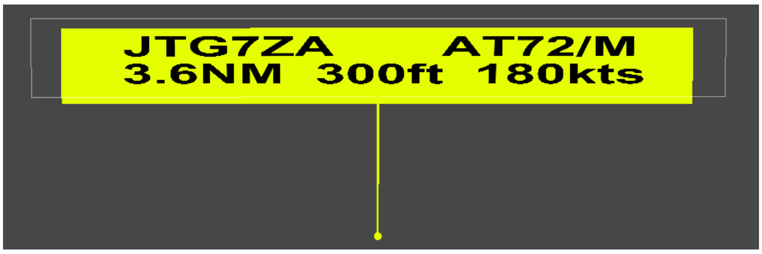


Figure 25 Label for arriving flight is colour-coded in yellow

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

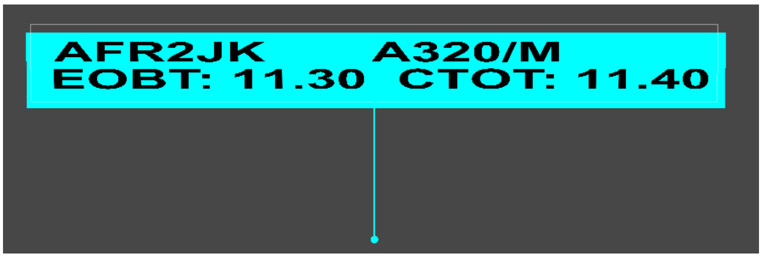


Figure 26 Label for departing flight is colour-coded in cyan

5.1.1.3 Impact

The “weather display” allows controllers to retrieve basic environmental information such as wind direction and speed, QNH, RWY surface condition, NAVAIDS status and the RVR, by simply looking towards the control tower windows. The improvement to make available this data always in the ATCO’s field of view is expected to reduce physical stress reducing the movement of controller’s head needed to look for data.

Billboards provide controllers with dynamic data, thus the operator's view is not overloaded with too much information, and at the same time he/she can retrieve the information more quickly.

5.1.1.4 Recovery procedures

In case of noticeable error or failure of the AR equipment, the controller will remove the HMD and seamless retrieve all the necessary information from the “head-down” equipment, similarly to how he or she would do nowadays.

5.1.1.5 Recommendations for implementation

In some critical points of the airport layout, for example where aircraft are in line at a holding point, it may happen that the billboards overlap for a specific line of sight. It will be helpful to find a strategy to avoid overlapping among labels, and between the single label and the airport view, so that the ATCO should not move the head to better read data on billboards or to see a part of runway covered by billboards.

Two solutions are proposed for HMD:

1. the first one is to implement an algorithm that identifies when the overlap occurs and automatically spread billboards making them readable. It is important to notice that this algorithm should work considering the line of sight of the specific user.
2. the second is to allow ATCO to move the label in the 3D space according to his/her preference. Although easy to implement, this solution might add extra workload to the user.

5.1.2 Solution 2: See-Through Spatial Display

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

As mentioned above, due to the fact that Augmented Reality technology for Spatial Display is not yet available, the conceptual solution based on see-through SD was implemented in a simulated environment that replicates the AR technology for SD as it is expected to be in the next decades.

Based on this assumption, the SD was made to coincide with 9 out of 32 tower windows overlapping most of the airport's apron, taxiways, and runway. The user's awareness about the spatial range of augmentation is enhanced by a green frame that highlights the portion of tower windows equipped with see through spatial displays (Fig. 27). As a result, the AR overlay is visible if the object it is related to falls within the spatial range of augmentation. In case the object is placed out of that range, no AR overlay is displayed.

The device shows ad-hoc generated imagery based on controllers' eyes position and outside visibility condition.

Figure 27 A green frame highlights the portion of tower windows equipped with see through spatial displays

5.1.2.1 Data sources update

Data sources are the same as explained in the previous paragraphs. According to the feedback provided by ATCOs during validation debriefing sessions, the information to be displayed at a certain time should be filtered according to the specific phase of flight or condition.

5.1.2.2 AR overlays

5.1.2.2.1 SD: meteo and NAVAIDS status

The Spatial Display shows a semi-transparent display that provides ATCOs with the most relevant environmental information based on the current visibility condition, RWY surface condition and NAVAIDS.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

During the validation exercises the display was positioned on the top of the third window from the left of the augmentation range. This position was selected as it was considered the most visible not intrusive location on the tower windows.

According to the feedback of ATCOs during debriefing, the position of the "weather display" should be set according to the user's preference, adding a customization feature to the interface.

5.1.2.2.2 SD: Aircraft's billboards

Alphanumeric text labels (billboards) are displayed near those aircraft/vehicles which fall inside the spatial display range of augmentation (Fig. 28). As described above, this concept is referred to as the "billboard" concept.

Based on the feedback of ATCOs during debriefing the billboards should provide controllers with only the data they need at that time. To identify which data should be displayed it is important to link data to the status of flight.

For each departing aircraft, the following four phases can be distinguished: park, start up/push back, taxi, take off.

For arriving aircrafts, the following four phases can be distinguished: on final, landing, taxi, park

For departing aircrafts, the billboards should provide the controller with:

- Aircraft position, identification and type/WCAT always
- EOBT, ready message until is at parking stand
- CTOT until take off
- Sequence number during taxi (Fig. 29)
- Altitude and speed during take off

For arriving aircrafts, the billboards should provide the controller with:

- Aircraft position, identification and type/WCAT always
- Distance from touch down when on final
- Stand when landed and during taxi

The selected colour coding is the same as the HMD.

- Yellow for arriving flights
- Cyan for departing flights

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

Figure 283 Aircraft labels are displayed near those aircraft/vehicles which fall inside the spatial display range of augmentation

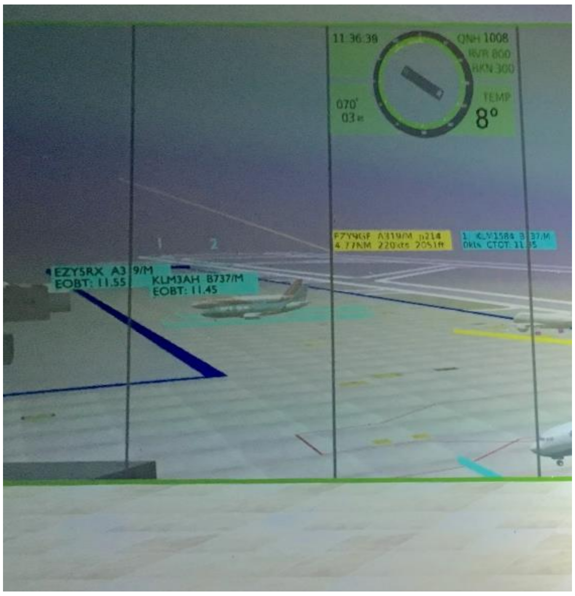


Figure 29 The sequence number is added to each aircraft during taxi phase

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

5.1.2.3 Impact

The spatial display concept impacts controllers' working practice by providing them with easy to understand updated information on the runway and taxiways status. Thus, controllers' will rely less on working memory and look outside the tower windows to easily retrieve such information.

Alphanumeric labels identify aircraft by call sign, type/WCAT and provide controllers with CTOT/EOBT/DTD and ready message. This feature reduces the visual scanning needed to locate specific aircraft on the apron and manoeuvring area. Also, the time spent looking down at the RADAR and flight strips to retrieve aircraft related information decreases, as demonstrated by the validation results [ref to VALR].

5.1.2.4 Recovery procedures

In case of noticeable error or failure of the AR equipment, the controller will switch off the SD and seamless retrieve all the necessary information from the "head-down" equipment, similarly to how he or she would do nowadays.

5.1.2.5 Recommendations for implementation

As for the solution based on HMD, in some critical points of the airport layout (e.g. where aircraft are in line at a holding point), it may happen that the billboards overlap for a specific line of sight. It will be helpful to find a strategy to avoid overlapping among labels, and between the single label and the airport view, so that the ATCO should not move the head to better read data on billboards or to see a part of runway covered by billboards.

Two solutions are proposed for SD:

1. the first one is to implement an algorithm that identifies when the overlap occurs and automatically spread billboards making them readable. It is important to notice that this algorithm should work considering the line of sight of the specific user.
2. the second is to allow ATCO to move the label in the 3D space according to his/her preference. Although easy to implement, this solution might add extra workload to the user.

The space available to spread the billboards in the Spatial Display solution is larger than the one offered by Head Mounted Display solution. On the other hand the interactive features, such as moving labels, can be more easily implemented in the HMD rather than in SD.

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.

6 References

[1] D2.1 RETINA Concept of Operations

[2] D5.1 RETINA Dissemination and Exploitation Plan

[3] D1.1 RETINA State of the Art

[4] D4.3 RETINA Validation Report

Founding Members

EUROPEAN UNION EUROCONTROL

© – 2017 – RETINA Consortium. All rights reserved. Licensed to the SESAR Joint Undertaking under conditions.