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Authors of the document

Name/Beneficiary	Position/Title	Date
R. BEAULIEU THALES AIR SYS	PJ.16 Project Coordinator	28/09/2019
M. DEBUSMANN DFS	PCIL	28/09/2019
S. NAGAHWATTE NATS	PJ.16 Member	28/09/2019
T. BUCHANAN SKYGUIDE	Communication Leader	28/09/2019
P. HLOUSEK ANS CR (B4)	PJ.16 Member	28/09/2019
L. VOKOUN ANS CR (B4)	PJ.16 Member	28/09/2019
R. HORAK LPS SR (B4)	PJ.16 Member	28/09/2019
V. CANADYOVA LPS SR (B4)	PJ.16 Member	28/09/2019
M. LE FEVRE ACG/COOPANS CCL/COOPANS IAA/COOPANS LFV/COOPANS Naviair/COOPANS	COOPANS SESAR Programme Manager	28/09/2019
A. MAREST DSNA	PJ.16 Member	28/09/2019
R. GARCÍA LASHERAS CRIDA on behalf of ENAIRE	PJ.16 Member	28/09/2019
K.HAGEMANN DFS	PJ.16 Member	28/09/2019
O. OHNEISER DLR (AT-One)	PJ.16 Member	28/09/2019
H. HELMKE DLR (AT-One)	PJ.16 Member	28/09/2019
M.ROMANO ENAV	PJ.16 Member	28/09/2019
J. SEIXO EUROCONTROL	PJ.16 Member	28/09/2019
M. POIGER FRQ (FSP)	PJ.16 Member	28/09/2019
B. BACSI HC (FSP)	PJ.16 Member	28/09/2019
T. BAKKEN (NATMIG)	PJ.16 Member	28/09/2019
J.M. BERNAD RIPOLL INDRA	PJ.16 Member	28/09/2019
G. MARRAZZO LDO	PJ.16 Member	28/09/2019
F. PICARD THALES AIR SYS	PJ.16 Member	28/09/2019
C. SALLES DSNA	PJ.16 Member	28/09/2019
P. PRYSE DAVIES NATS	PJ.16 Member	28/09/2019
C. SEBASTIAN DEL RIO	PJ.16 Member	28/09/2019

C. GOMEZ CRESPO	PJ.16 Member	28/09/2019
N. VINK NATS	PJ.16 Member	28/09/2019
K. CHRISTIANSEN INTEGRA (ANS CR)	PJ.16 Member	28/09/2019
S. MOOS THALES AIR SYS	PJ.16 Member	28/09/2019

Reviewers internal to the project

Name/Beneficiary	Position/Title	Date
R. BEAULIEU THALES AIR SYS	PJ.16 Project Coordinator	04/10/2019
M. DEBUSMANN DFS	PCIL	04/10/2019
S. NAGAHWATTE NATS	PJ.16 Member	04/10/2019
T. BUCHANAN SKYGUIDE	Communication Leader	04/10/2019
P. HLOUSEK ANS CR (B4)	PJ.16 Member	04/10/2019
L. VOKOUN ANS CR (B4)	PJ.16 Member	04/10/2019
R. HORAK LPS SR (B4)	PJ.16 Member	04/10/2019
V. CANADYOVA LPS SR (B4)	PJ.16 Member	04/10/2019
M. LE FEVRE ACG/COOPANS CCL/COOPANS IAA/COOPANS LFV/COOPANS Naviair/COOPANS	COOPANS SESAR Programme Manager	04/10/2019
A. MAREST DSNA	PJ.16 Member	04/10/2019
R. GARCÍA LASHERAS CRIDA on behalf of ENAIRE	PJ.16 Member	04/10/2019
K.HAGEMANN DFS	PJ.16 Member	04/10/2019
O. OHNEISER DLR (AT-One)	PJ.16 Member	04/10/2019
H. HELMKE DLR (AT-One)	PJ.16 Member	04/10/2019
J. RATAJ DLR (AT-One)	PJ.16 Member	04/10/2019
M. ROEDER DLR (AT-One)	PJ.16 Member	04/10/2019
M.ROMANO ENAV	PJ.16 Member	04/10/2019
J. SEIXO EUROCONTROL	PJ.16 Member	04/10/2019
M. POIGER FRQ (FSP)	PJ.16 Member	04/10/2019
B. BACSI HC (FSP)	PJ.16 Member	04/10/2019
T. BAKKEN (NATMIG)	PJ.16 Member	04/10/2019
J.M. BERNAD RIPOLL INDRA	PJ.16 Member	04/10/2019
G. MARRAZZO LDO	PJ.16 Member	04/10/2019

F. PICARD THALES AIR SYS	PJ.16 Member	04/10/2019
C. SALLES DSNA	PJ.16 Member	04/10/2019
P. PRYSE DAVIES NATS	PJ.16 Member	04/10/2019
C. SEBASTIAN DEL RIO	PJ.16 Member	04/10/2019
C. GOMEZ CRESPO	PJ.16 Member	04/10/2019
N. VINK NATS	PJ.16 Member	04/10/2019
K. CHRISTIANSEN INTEGRA (ANS CR)	PJ.16 Member	04/10/2019

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

Name/Beneficiary	Position/Title	Date
R. BEAULIEU THALES AIR SYS	PJ.16 Project Coordinator	05/12/2019
M. DEBUSMANN DFS	PCIL	05/12/2019
S. NAGAHWATTE NATS	PJ.16 Member	05/12/2019
T. BUCHANAN SKYGUIDE	Communication Leader	05/12/2019
P. HLOUSEK ANS CR (B4)	PJ.16 Member	05/12/2019
R. HORAK LPS SR (B4)	PJ.16 Member	05/12/2019
V. CANADYOVA LPS SR (B4)	PJ.16 Member	05/12/2019
M. LE FEVRE ACG/COOPANS CCL/COOPANS IAA/COOPANS LFV/COOPANS Naviair/COOPANS	COOPANS SESAR Programme Manager	05/12/2019
A. MAREST DSNA	PJ.16 Member	13/12/2019
R. GARCÍA LASHERAS CRIDA on behalf of ENAIRE	PJ.16 Member	13/12/2019
K.HAGEMANN DFS	PJ.16 Member	13/12/2019
O. OHNEISER DLR (AT-One)	PJ.16 Member	13/12/2019
H. HELMKE DLR (AT-One)	PJ.16 Member	13/12/2019
M.ROMANO ENAV	PJ.16 Member	13/12/2019
J. SEIXO EUROCONTROL	PJ.16 Member	13/12/2019
M. POIGER FRQ (FSP)	PJ.16 Member	13/12/2019
B. BACSI HC (FSP)	PJ.16 Member	13/12/2019
T. BAKKEN (NATMIG)	PJ.16 Member	13/12/2019
J.M. BERNAD RIPOLL INDRA	PJ.16 Member	13/12/2019
G. MARRAZZO LDO	PJ.16 Member	13/12/2019

Rejected By - Representatives of beneficiaries involved in the project

Name/Beneficiary	Position/Title	Date

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PJ16 CWP HMI

CONTROLLER WORKING POSITION / HUMAN MACHINE INTERFACE - CWP/HMI

This final project report is part of a project that has received funding from the SESAR Joint Undertaking under grant agreement No 734141 under European Union's Horizon 2020 research and innovation programme.

Abstract

The SESAR Project 16 contains two solutions.

The Solution PJ.16-03 "**Enabling rationalisation of infrastructure using virtual centre based technology"** develops a concept for separating the Controller Working Position (CWP) from the datacentre where the data is produced. It allows non-geographical Air traffic management to take place and therefore responds to the Airspace Architecture Study outcome.

The **PJ.16-04 solution Workstation, Controller Productivity**, deals with new methods of Controller interaction with the Human Machine Interface (HMI). It allows for increased controller productivity, reduce workload, stress level and enable the use of SESAR advanced tools to safely facilitate performance based operations.

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Executive Summary

The Solution **PJ.16-03 "Enabling rationalisation of infrastructure using virtual centre based technology"** (former "Work Station, Service Interface Definition & Virtual Centre Concept") has developed a concept for separating the Controller Working Position (CWP) from the data centre where the data is produced. This lean and efficient use of ANSP infrastructure tackles the issues presented by fragmented European ATM systems and country-specific architectures, enabling Europe to move to an interoperable, cost effective and flexible service provision infrastructure. Decoupling of the CWPs should enable a more efficient use of the most valuable and expensive resource, the human. By enabling increased flexibility, the ANSPs are able to better manage staffing for prevailing traffic conditions and assure service continuity. This solution has already delivered to the SJU concrete results as an agreed definition of the concept, a target architecture recognised by the ATM community, a definition of ADSP services. It has also provided a clear technical input for the recently finalised Airspace Architecture Study (AAS) mandated by the European Commission.

The **PJ.16-04 solution Workstation, Controller Productivity** has dealt with new methods of Controller interaction with the Human Machine Interface (HMI), applying mature technologies from other domains to ATM. This increase controller productivity, reduce workload, stress level and enable the use of SESAR advanced tools to safely facilitate performance based operations. This solution has concentrated in the development of five different interaction modes: Multi Touch Inputs (MTI), Automatic Speech Recognition (ASR), Attention Guidance (AG), User Profile Management Systems (UPMS), and Qualification of CWP Virtualisation (CWPV).

1 Project Overview

The project CWP/HMI (PJ.16) dealt with operational and technical objectives of the Controller Working Position (CWP). PJ.16 was comprised of two solutions that should provide significant improvements at the CWP taking into consideration technical, economic and user performance.

PJ.16-03 Enabling rationalisation of infrastructure using virtual centre based technology

PJ.16-03 concentrated on the concept of virtual centre. By definition, *a virtual centre is a single Air Traffic Service Unit (ATSU) or a grouping of collaborative ATSUs using data services provided by ATM Data Service Provider (ADSP). The concept provides, at least, geographical decoupling between ADSP (s) and some ATSU (s), through service interfaces defined in Service Level Agreements. One ATSU may use data services from multiple ADSPs, just as an ADSP may serve multiple ATSUs. The objective of a virtual centre is to allow decoupling that could deliver the flexibility and performance aspects of the services to ensure the ability of the virtual centre solution to at least support or to improve the operational performance. This solution encompasses En-route and TMA and environments.*

PJ.16-04 Work station, Controller Productivity

The solution integrated new methods of controller interaction with the Human Machine Interface (HMI). Furthermore mature technologies, already successfully applied in other domains such as Multi Touch Inputs, Automatic Speech Recognition, Attention Guidance, and User Profile Management Systems, were also integrated into the CWP. This increased controller productivity, reduced workload, and stress level. The reduction in workload will allow the Air Traffic Controller to focus on his core duty whilst maintaining the safety levels even with increased traffic volumes.

1.1 Operational/Technical Context

PJ.16-03 solution Context:

The possible use of a lean and efficient ANSP infrastructure tackles the issues presented by fragmented European ATM systems and country-specific architectures, enabling Europe to move to an interoperable, cost effective and flexible service provision infrastructure. Decoupling of the CWPs should enable a more efficient use of the most valuable and expensive resource, the human. By enabling increased flexibility, the ANSPs will be in a position to better manage staffing for prevailing traffic conditions and assure service continuity.

PJ.16-04 solution Context:

In a context where it is needed to increase controller productivity, reduce workload, reduce stress level and enable the use of SESAR advanced tools, safely facilitating performance-based operations, the idea is to deal with new methods of controller interaction with the HMI, applying mature technologies from other domains to ATM.

1.2 Project Scope and Objectives

PJ.16-03 scope and objective

- The definition of the Virtual Centre (VC)

Objective 1 - The exact definition of a Virtual Centre shall be agreed among PJ.16-03 members and with SJU

Objective 2 – The list of Virtual Centre Use Case shall be identified and a list of criteria shall be defined to establish the most valuable Use Cases for the ATM community

Objective 3 - The architectural model of the Virtual Centre shall be defined

- The definition of services

Objective 4 - Service interfaces shall be defined among CWPs and ADSPs. These service interfaces shall be, as a target, based on SWIM standards and be ready for standardisation.

- The development of prototypes

Objective 5 – The defined service interfaces shall be implementable as a prototype in order to verify the developed architectural model of the Virtual Centre.

- The verification and validation

Objective 6 – A technical verification of the geographical separation of CWPs and ADSPs shall be demonstrated.

Objective 7 – A verification shall combine prototypes irrespective of the industrial supplier and therefore cross-validate different providers.

Objective 8 – The technical maturity of the prototypes shall be
- V1 in 2017 for a set of services

- V2 in 2018 for a set of services

- V3 in 2019 for a set of services

Objective 9 – The operational validation of the prototypes shall be
- V1 in 2017 for a set Use Cases

- V2 in 2019 for a set Use Cases

These objectives are crucial to enable the Virtual Centre approach and achieve its main benefits: cost reduction and flexibility to support load-balancing between ATSUs.

PJ.16-04 scope and objective

PJ.16-04 focuses on the HMI of the CWP. The project solution is driven by operational requirements for innovative HMI needs captured from interactions with the ATM Solution Projects. The project developed guidance and assessment methods regarding HMI, and investigates new HMI needs and interaction modes associated with the SESAR solutions (including new user interface technologies such as speech recognition, multi-touch, and gaze detection). The project focuses on technologies and interaction modes that are regarded as sufficiently mature. These technologies include Multi Touch Input Device (MTI); Automatic Speech Recognition (ASR); Attention Guidance (AG) and User Profile Management Systems (UPMS).

Relevant preconditions of solution PJ.16-04 are:

- The project addresses a predefined set of technologies:
  Precondition 1: The PJ.16-04 Controller Productivity Solution activities address innovative interaction technologies such as multi-touch input devices, automatic speech recognition, attention monitoring and guidance, user profile management, and thin client technologies.

- **Precondition 2**: Innovative interaction technologies are selected that are already beyond maturity level V1 / TRL2.

- The project considers relevant results that are available as input from previous projects:
  Precondition 3: The PJ.16-04 Controller Productivity Solution activities identify related work performed in SESAR1 as well as other projects and uses relevant input from those projects.

- The project uses quality criteria as outlined in the PJ.16-04 DoW:
  Precondition 4: The project activities take human factors, safety, productivity improvements against current interaction means, and workload reduction as quality criteria into consideration.

The objectives of solution PJ.16-04 are:

- The project follows the required process objectives outlined in the PJ.16-04 DoW:

Objective 1 - The development of workstation productivity solution shall follow a user-centred design approach including human performance assessments collected from operational users in an operationally relevant environment.

- Controller Productivity definition

Objective 2: Controller Productivity and its operationalization (e.g. its quantification through the use of Human Performance measurements) shall be defined at the beginning of the project in coordination with the Solution projects.

- Controller Productivity Solution HMI enablers

Objective 3: PJ.16-04 Controller Productivity Solution HMI user requirements, HMI technology concept of use and HMI technology specifications shall be available in time per activity (MTI; ASR; AG; UPMS and CWPV).

Objective 4: PJ.16-04 Controller Productivity Solution prototypes shall be developed per selected innovative interaction technology and shall be verified in time.

- Support to SESAR 2020 ATM Solution Projects in order to achieve their associated operational improvements

Objective 5: PJ.16-04 Controller Productivity Solution prototypes shall be integrated in time into validation platforms that are related to SESAR 2020 ATM solution projects V2 / V3 activities.

Objective 6: PJ.16-04 Controller Productivity Solution transversal enablers shall be addressed and documented including empirical evidence collected from operational users.

1.3 Work Performed

PJ.16-03 work performed

The solution was divided into 3 threads.

The ***Operational Thread*** handles all the operational aspects of the Virtual Centre concept.

The aim of this dimension was to clearly define what the Virtual Centre Concept is and to define the possible Use Cases improved by the Virtual Centre concept. Also, the Safety / Security / Performance requirements defined in this dimension feed the technical dimension. Finally, the possible risks to stop the concept are also identified (showstoppers).

The ***Technical Thread*** handled all the technical aspects of the Virtual Centre concept. This dimension conducted three main tasks:

- the design of the functional and service architectures fulfilling the operational needs,
- the definition of the infrastructure of communication,
- the definition of open services to be used between the ANSP and ATM Data Service Providers (ADSP).

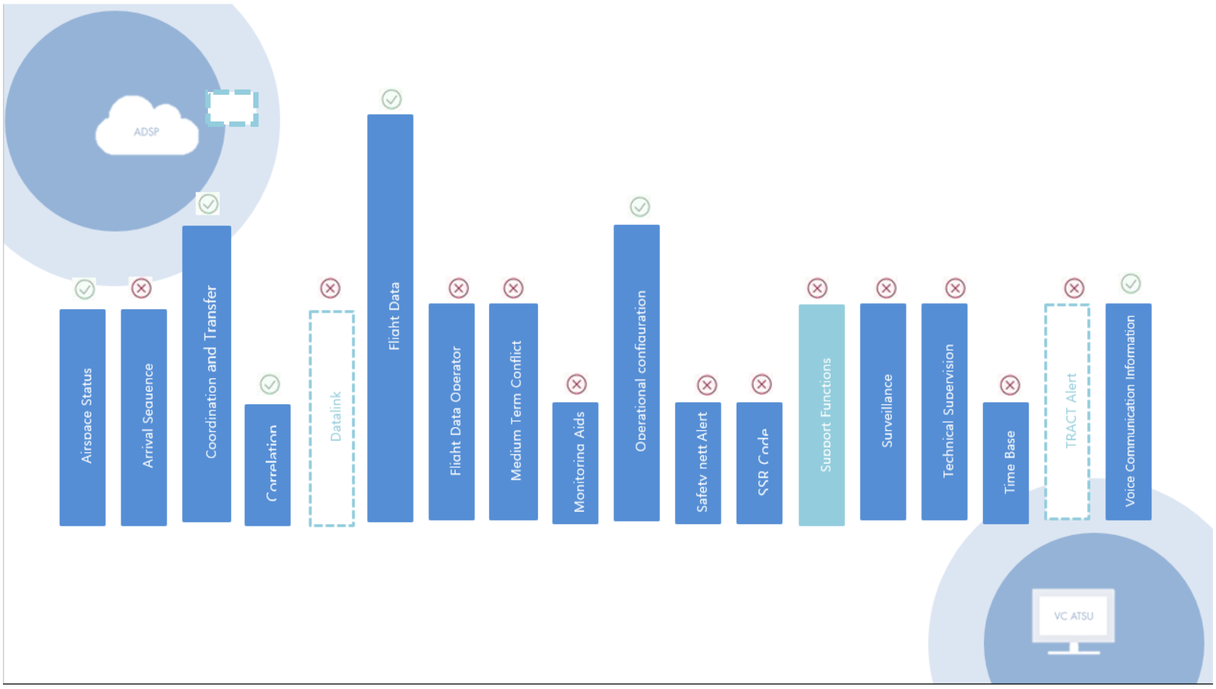
In addition, a ***Validation Thread*** handled all the validation aspects of the Virtual Centre concept. This dimension conducted four main tasks:

- the detailed definition of the maturity gate criteria at the beginning of the TRL2 phase,
- the validation plan for the next phase (TRL4 and TRL6) in place by the end of the TRL2 and TRL4 phases respectively,
- the assessment of the maturity gate criteria for TRL2, TRL4 and TRL6 at the end of each phase,

the development of adequate platforms and conducting of the validation activities for TRL4 and TRL6.the production of the TVALRs with the results obtained from the validation activities (Exercises)

Services specification status and validation status could be illustrative as follow:

- Specification is illustrative by the box:
    - size of the box indicating the relative complexity one service to another,
    - this colour indicates the service is completely defined,
    - this colour indicates the service is partially defined,
    - this colour indicates the service is identified.
- Validation status is illustrative as: Indicates the service is validated (based on validation of some operations), indicates the service is not validated



Safety :

A safety assessment has been conducted in accordance with the SESAR Safety Reference Material, as well as the Guidance on the safety process to be applied to Technological/Enablers solutions in SESAR 2020. This guidance material is used to derive technical safety requirements for the Virtual Centre concept and to document that the Virtual Centre concept is adequately safe, i.e. to demonstrate whether the assessed system architecture can reasonably be expected to achieve the Safety Objectives specified.

Thread analysis has been used for deriving safety requirements covering the success approach and Fault Tree Analysis (FTA) has been used to derive safety requirements covering the failure approach

PJ.16-04 work performed

Thirteen validation exercises (one demo among them) were successfully conducted to analyse the effects of modern interaction technologies at the controller working position human machine interface on controllers' workload, situation awareness, productivity, and other metrics. The exercises took place under the umbrella of the five activities as described in the following.

Multi-Touch Inputs (MTI)

Three validation exercises (EXE 110, EXE 120 and EXE 130) and a demo (DEMO 140) have been performed.

EXE-110: Madrid ACC and APP, multi-touch input device used by controllers with executive and planner roles. A Multi-Touch Inputs Device prototype was tested for several controller functions in the Spanish airspace environment for En-Route and Approach. The exercise was conducted jointly with ENAIRE embedding the MTI prototype into the validation platform of PJ.08-01.

The results showed up the following:

- It is feasible to integrate the MTI into the controller working position without negatively impacting its performance.
- The introduction of the MTI system and its sub-systems and functions didn't negatively affect the functioning of the existing CWP systems and tools, their performance, and availability.
- The impact on the controller performance was also measured, showing that it brings some benefits to the controller.
- The most significant benefit is in Human Performance (HP): MTI has shown to firstly not negatively impact HP which is an excellent starting point showing viability.

EXE-120: Prague ACC, addressing En-Route operation with the assistance of a Multi-Touch Input Device. General aim of this exercise was to compare operation with and without the MTI device in a series of runs using scenarios based on Prague ACC unit daily operations. In the validation exercise the focus was on the controllers, mainly Executive controller and validated with active licensed controllers as well as pseudo pilots from Air Navigation Services of the Czech Republic (ANS CR). The Shape platform of Thales Air Sys was used during the validation exercise that allowed the execution of runs with and without the MTI device available.

The results showed up the following:

- Technical feasibility has been demonstrated. No negative impact of the introduction of the MTI system on the ATC platform.
- Operational feasibility has been demonstrated too:
    - Workload reduced
    - Safety and situational awareness not degraded
    - Usability improved
- The introduction of a MTI device is acceptable for an air traffic controller and will bring some benefits in term of Human Performance

EXE-130: Milan ACC, multi-touch was used to control a 3D visualization of the airspace to enhance the controllers' situational awareness when the airspace configuration changed while applying dynamic airspace configuration (DAC).

The exercise was a joint exercise with PJ.08-01, conducted in cooperation with ENAV, using airspace, sectorization, traffic loading and controllers from the Milan ACC.

The results showed the following:

- DAC approach is acceptable for controllers
- No significant differences in workload, situation awareness, performance and safety between MTI and traditional interaction
- Understanding vertical changes was not trivial
- Need for better understanding of other controllers' sectors
- Need for better support for obtaining an overview of changes in current and incoming traffic

DEMO-140 demonstrated the technical and operational feasibility of using multi-touch inputs for frequent tactical controls at the air traffic controller workstation. Over three days a Multi-Touch Concept Demonstrator and an Industrial Multi-Touch Prototype from INDRA were presented to 30 DFS participants with various professional backgrounds (controllers, engineers, software developers). User feedback collected via observations, questionnaires and debriefings indicated an overall acceptance of the concept. However, Multi-Touch Input was not considered faster than currently used mouse or pen, which might also have been a consequence of insufficient possibilities for training. In summary, more research involving extensive real-time simulations should be done to improve the set of gestures as well as to ameliorate error tolerance and investigate physical strain over longer periods (>1h).

The MTI activity introduces **Multi Touch Inputs** as a new functional block in EATMA with the new function “Touch Input”. The exercises have clearly shown the potential of using Multi Touch Input devices within ATC. All objectives were achieved in at least one exercise.

<u>**Automatic Speech Recognition (ASR)**</u>

Five validation exercises (210, 220a/b, 230, 240, 250) have been performed. Furthermore, an ontology for annotation of controller commands has been developed.

Exercise **EXE-210** validated two prototypes developed to assist air traffic controllers at their workstation. A target location assistance highlighted the callsigns of addressed flights on the radar display, while a controller command verification detected potential mismatches between spoken commands and system inputs and respectively showed a warning to the controller. To validate the concept a two-week human-in-the-loop simulation of Munich approach was conducted at the DFS research centre in Langen. Overall, eight controllers participated in the validation exercise and provided their feedback via questionnaires and debriefings. Results indicated a promising mean command recognition rate of 90%, but together with a high amount of false alerts. In summary, controllers were positive about using speech recognition systems in the future providing the recognition and false alert rate are improved. One way to achieve a higher controller acceptance may lie in a higher flexibility of the speech recognition system to allow processing of speech that covers a wider range of phraseology (extension of the language model).

Exercise **EXE-220** validated a radar display developed by Thales Air Sys and a Commercial-Off-The-Shelf (COTS) speech recognition engine from Nuance. Commands that controllers gave via voice to the pilot were recognized by the speech recognizer. If recognized commands are plausible with respect to a command prediction developed by DLR, they were shown to the controller in the aircraft labels of the radar display. The HMI was integrated into the SkyCentre in Rungis and validated with two controllers from Austro Control (test environment - Vienna airport) and four controllers from Air Navigation Services of the Czech Republic (test environment - Prague airport). The HMI was based on the Shape platform of Thales Air Sys and enables an easy integration into the operational TopSky system of Thales Air Sys. The HMI concept enables an easy correction of given ATC commands in the case that speech recognition fails to correctly recognize spoken ATC commands. When the recognition is correct, the controllers save cognitive resources (time) for more important tasks than "just" entering given commands into the ATM system via track Label. Exercises were mainly focused on the recognition and display of the call signs and the speed, direction, altitude and hand over commands. Command recognition rates varied for different controllers. For ANS CR controllers, the average recognition rates of the displayed commands were 74%, 78%, 79%, and 82%. The ABSR concept to use a Plausibility Checker based on predicted possible controller commands could dramatically reduce the command recognition error rate ranging between [14.7% .. 22.6%] to a range of [4.8% .. 6.6%], i.e. most of the false recognitions were not shown to the controller. The acoustic models for "Czech" and "Austrian" English weren't used during the exercises, which would further increase the recognition rate.

Exercise **EXE-230** was focused on analysing the performance of the ASR technology for En-Route and Terminal Manoeuvring Area sectors using VOICE speech recognition prototype developed by CRIDA. The exercise was applied in different environments: controllers' utterances used in simulation validation or controllers' utterances from different sectors in current day-to-day operations. The recognition rate varied from 71% in simulation environment to 82% in operational environment. The recognition rate is impacted in the simulation environment because they were less prone to using standard ATC phraseology. The command "Direct to" a waypoint had the higher recognition rate, 92.6%, and the command to change squawk the lowest with a 56.3%. Transcriptions included commands in English and Spanish as is current practice in Spanish airspace. Detected callsigns and commands from the transcriptions were used to calculate controllers' workload.

Exercise **EXE-240** validated a tower command hypotheses generator in a multiple remote tower environment with the data of four human-in-the-loop studies of PJ.05-02 at DLR, Braunschweig, Germany. The command hypotheses prototype developed by DLR predicted the most probable controller commands in the current situation based on the current surveillance data (weather, flight plan and radar data etc.). This was tested with three Hungarian and three Lithuanian airports at the same time. The recorded radar and speech data with actually given commands have been transcribed and annotated to compare them with the command hypotheses. These hypotheses generator is a pre-requisite to be integrated into a tower ABSR system. Roughly 45 hours of speech and corresponding radar data including approx. 4,600 voice utterances were recorded in the final simulation campaign. The tower command hypotheses generator showed operational feasibility with a sufficiently low command prediction error rate (down to 7.3%), low context portion predicted, and sufficiently fast command prediction frequency of once per 120ms.

Exercise **EXE-250** focused on the ongoing communications between pilots and controllers by processing the pilots' command by the ASR module and afterwards displaying the recognized commands and/or call signs in a way to enhance the situational awareness of the controllers working in a multi-remote tower environment. The exercise focused on the recognition of pilot commands with the goal to support air traffic controllers in the recognition of aircraft they are talking to. Especially in the multi-remote tower setup this could support the controller in directing the attention of the controller to the correct airport by highlighting the calling aircraft.

Although as the ASR module could not be integrated into the multi-remote tower environment it was only possible to test the recognition of pilots' commands by using recordings from the exercise. Recordings from altogether 9 exercise runs have been used to analyse the recognition rate of pilot voice. Additionally, voice files with a higher quality have been generated. With a recognition rate of 25 to 30% of the pilots voice, it has to be stated that the recognition rate of the received pilot audio was not sufficient for the intended use cases. A higher recognition rate of 90% could only be achieved with the additionally generated good quality audio files.

The exercise also showed another challenge in recognizing pilots voice; a lot of different accents of English are used which makes the recognition very challenging as the ASR module would have to be adapted to a large variety of different pronunciations.

The participants of the **five ASR exercises** agreed in advance on a so called ontology for command transcription and annotation, i.e. common rules were agreed with respect to the semantics of controller utterances. A safety assessment for all exercises taking into account the other activities was performed by Integra (LTP of ANS CR).

The ASR activity introduces **Automatic Speech Recognition** as a new functional block in EATMA with the new functions "Command Prediction", "Concept Extraction", and "Usage of Speech Information". The exercises have clearly shown the potential of using Speech Recognition technology within ATC. The validation objectives ASR technical feasibility and interoperability (TFI) and ASR performance stability (PST) were achieved in all exercises which considered them. ASR operational feasibility (OPF) and Human performance (HUP) validation objectives were achieved in most of the exercises.

Due to the remaining challenges with respect to the used COTS ASR engines only limited results were achieved with respect to safety, human performance, and TMA capacity improvements. The evidence has shown in general that the longer an ASR engine has been in use at a partners premises (even for different purposes than the validation purposes of 16-04-02), the better the results with respect to recognition and error rates were.

Attention Guidance (AG)

Two validation exercises (310, 320) have been performed to primarily analyse workload effects on controllers and their confidence with the AG system. The two prototypes did influence the controllers' situation awareness regarding the presented information on the display.

Exercise **EXE-310** comprised an eye-tracking supported Attention Guidance prototype for the Flight-Centric ATC environment tested with a human-in-the-loop study in the PJ.10-01b environment in Budapest, Hungary at HungaroControl Zrt. The DLR-developed prototype used upcoming ATC events as a trigger to present escalation level dependent visual cues on the display if the controller does not pay attention to the event. Controllers perceived less workload and improved situation awareness during the Solution CWP run compared with the Baseline CWP run. Furthermore, their system acceptance and confidence was increased, because they felt strongly supported by the attention guidance functionality.

Exercise **EXE-320** tested the display of an uncertainty indicator at the CWP developed by SkySoft in Geneva, Switzerland. This indicator was calculated for medium-term conflicts, based on the variations on flight trajectory predictions due to unstable winds. The exercise demonstrated the benefits of making visible this new type of information for the controller's situation awareness.

The challenge for the controller is to filter and decide which information are relevant for accurate situation awareness. **Attention Guidance** delivers support with hints to improve situation awareness and further decision taking for required ATC actions. Controllers appreciated the support of AG tools that were designed for workload reduction and improved situation awareness. A new functional block "Attention Guidance" and two new functions "Attention Guidance Logic" and "Attention Guidance Measures" have been defined in order to document the basic concept of the activity to proceed to TRL6.

<u>User Profile Management Systems (UPMS)</u>

Currently, controllers set HMI on their CWPs according to their individual operational needs, requirements and preferences (depending on their role or task) manually, whilst maintaining situational awareness. **User Profile Management Systems** delivers a solution as follows: The system will automatically couple the identified controller with predefined user profile(s). Once the controller is identified in a safe and secure manner, their customized profile related to a particular role or a task on the CWP will be applied. Validation results show a controller´s workload decrease and situational awareness increase whilst using UPMS in comparison to manual setting of HMI – leading to a safety and performance increase.

One validation exercise (**EXE-410**) has been performed and validated the feasibility of integrating the User Profile Management Systems into the CWP. UPMS instantly personalized (automated customization) CWP and HMI settings according to the controller´s individual operational needs, requirements and preferences. Validation was conducted by ANS CR controllers at ACC/EN-ROUTE position of the DTC validation platform in LPS SR, Bratislava. It assessed the impact on the controller´s performance. UPMS did influence the controllers' situation awareness (increased by 20%) and decreased controller´s workload (by 28%), in comparison to manual setting of HMI.

Two systems have been implemented to reach the aim:

- Authentication system: controller´s Identification after logon into CWP, and
- User Profile Configuration system (UPCS) where controller's predefined profile (s) customizing test HMI settings / functions of HMI (range / zoom, altitude filter, speed vectors, history of track, label (#lines), font size change) are managed and automatically coupled with controller's ID and controller's task/role, immediately after logon into CWP.

Six scenarios were produced to prove the benefits of UPMS, including shift take over scenario and multi-profile principle (change of role or task).

<u>Qualification of CWP Virtualisation (CWPV)</u>

One validation exercise (**EXE-610**) has been performed to evaluate and analyse the different virtualisation technologies within a virtual environment introducing a new virtualization technical concept for Controller Working Positions in the Virtual Centre Air Traffic Service Unit (VC ATSU). The technical validation has been conducted on different remote sites within Europe (Vienna, Brétigny, Budapest) with Frequentis, Hungarocontrol, and Eurocontrol.

Following aspects have been analysed:

- Response time for the HMI
- Time to recover failure
- Environmental criteria
- Location independence within a virtual environment
- Cost of the CWP technologies

The **Controller Working Position Virtualization** (CWPV) demonstrated with the performed validation exercise, the technical feasibility of different CWP technologies used within the VC architecture. Each CWP technology has the maturity to be further evaluated in the context of virtual environments. Based on the measured results, each technology has its benefits and therefore VC shouldn´t be limited to one CWP technology. These results have been taken into account in the related requirements specification and within the modelling of the Virtual Centre architecture, to allow the flexibility of use of the different CWP concepts.

1.4 Key Project Results

PJ.16 has demonstrated the following maturity levels:

Code	Name	Maturity at project start	Maturity at project end
PJ.16-03	Enabling rationalisation of infrastructure using virtual centre based technology	TRL0	TRL6
PJ.16-04-01 MTI	Work station, Controller Productivity, Multi-Touch Inputs	TRL0	TRL4
PJ.16-04-02 ASR	Work station, Controller Productivity, Automatic Speech Recognition	TRL0	TRL4
PJ.16-04-03 AG	Work station, Controller Productivity, Attention Guidance	TRL0	TRL4
PJ.16-04-04 UPMS	Work station, Controller Productivity, User Profile Management Systems	TRL0	TRL4
PJ.16-04-06 CWPV	Work station, Controller Productivity, Qualification of CWP Virtualisation	TRL0	TRL4

Table 1: Final maturity

Note that for MTI activity has reached a maturity level ready to go to industrialisation.

Note that for CWPV activity, the process of maturity has stopped as the concept is now considered as part of the Virtual Centre concept.

1.5 Technical Deliverables

Reference	Title	Delivery Date[1]	Dissemination Level[2]
Description			
D2.1	Solution PJ.16-03: V1 Data Pack	25/07/2017	CO
D2.2	Solution PJ.16-03: V2 Data Pack	29/04/2018	CO
D2.3	Solution PJ.16-03: V3	09/12/2019	CO

[1] Delivery data of latest edition

[2] Public or Confidential

	Data Pack		
D3.1	Solution PJ.16-04: V1 Data Pack	14/11/2018	CO
D3.2	Solution PJ.16-04: V2 Data Pack	01/10/2019	CO

Table 2: Project Deliverables

2 Links to SESAR Programme

2.1 Contribution to the ATM Master Plan

Code	Name	Project contribution	Maturity at project start	Maturity at project end
PJ.16-03	Enabling rationalisation of infrastructure using virtual centre based technology	25 Services have been developed by the solution for DS19. A part of these services have been technically validated. The Solution created the OIs POI-0002-SDM in DS18a and the Enablers SVC-008 – SVC-010 in DS18. The Enablers SVC-013 – SVC-025, SVC-028, SVC-031 – SVC-034, and ER APP ATC 184 – ER APP ATC 186 were created in DS19.	TRL0	TRL6
PJ.16-04	Work station, Controller Productivity	Five new functional blocks with seven functions and a service interface have been defined in EATMA (DS19). The Solution created the OIs POI-0003-SDM and POI-0004-SDM and the Enabler ER APP ATC 175 in DS18. The Enablers AERODROME-ATC-100 and AERODROME-ATC-101 and ER APP ATC 180 – ER APP ATC 183 were created in DS19.	TRL0	TRL4

Table 3: Project Maturity

2.2 Contribution to Standardisation and regulatory activities

The following paragraphs describe in detail the contribution per solution:

PJ.16-03 standardization activities

One of the main goals of PJ.16-03 as described by the grant is to define services that 'are ready for standardisation'. Within the solution 25 services have been defined and introduced into EATMA by corresponding Change Requests. Due to the large number of services being developed by the solution, their maturity is different: some services are quite mature while others are at an early stage of development. PJ.16-03 has put extra effort into the development of the FlightDataDistribution, FlightDataManagement and CoordinationAndTransferManagement services which together define the very core of the ATS systems. The work on these services had already started in SESAR1 B.04.04 and as a result of the work in PJ.16-03, the services were harmonised to a great extent, so that they are the first candidates for a standardisation at EUROCAE

PJ.16-04 MTI standardization activities

The topic of standardization was addressed for example for the gestures which could have been a topic for a potential standardization. The TS/IRS provides a table with the list of potential gestures. However, if ensuring consistence with commonly used gestures on public devices (pinch and spread for zooming or drag for panning for example) is key for avoiding human errors, the more ATM dedicated gestures are solution specific. There is thus no need standardizing those gestures as there is no risk of error for having multiple solutions. An analogy can be achieved with shortcut keys on a keyboard for example for which there is no need to standardize.

PJ.16-04 ASR standardization activities

The solution has defined and published an ontology for command annotation. The ontology defines how a sequence of spoken words (transcription) should be transformed into ATC concepts (annotation). The sequence “oscar november kilo good morning descend three thousand feet speed two five zero or greater” should be transformed into a callsign, command types, values, units, optional qualifiers and conditions (Figure 1).

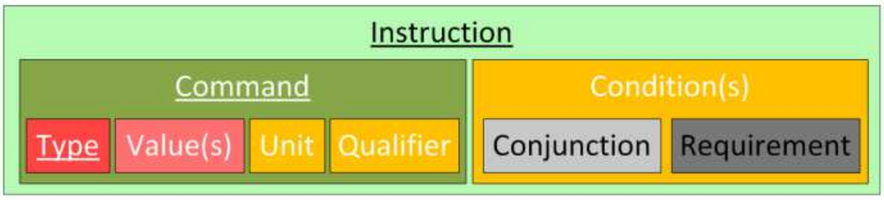


Figure 1: Controller command in Ontology

The above defined word sequence is annotated into the following ATC concepts “OEINK DESCEND 3000 ft OEINK SPEED 250 none OR_GREATER”. This eases exchange of training data and also the exchange of building blocks. The above agreement on unique rules on how a sequence of words should be transformed into ATC concepts is not a trivial process. The example shows that

- “good morning” is not a relevant ATC concept.
- Context knowledge should be used, so that “oscar november kilo” is not transformed into “ONK”, but into a valid callsign OEINK.
- The units “knots”, “feet” or “flight level” are a relevant ATC concept, to be annotated. This information is mostly irrelevant for the controller, but nevertheless is important e.g. for machine learning task.

The sequence of ATC concepts “OEINK DESCEND 3000 ft OEINK SPEED 250 none OR_GREATER” is easily readable by human experts, which eases the agreement on a common ontology within PJ.16-04 solution. It is, however, much more difficult for a computer to extract specific parts from this sequence, i.e. what is callsign, command type, qualifier etc? Therefore, the next logical step is to extend the ontology to ease automatic interpretation e.g. by XML-tagging. Last, but not least, it should be mentioned that the task of the building blocks defined in Horizon 2020 funded project MALORCA are also a candidate for standardization. The output of the building blocks, however, is not always unique. Therefore XML-tagging must be extended to enable multiple sequences of ATC concepts. More details are provided in TRL4 TVALR of the ASR activity.

PJ.16-04 AG standardization activities

Basic considerations have been described following the standardization process. On the input side ASTERIX already is a standardized format for radar data. However, there is no standard for eye tracking data. A format for eye tracking data was developed and used in the AG exercise. However, this interface is up to external hardware manufacturers as hardware-off-the-shelf could be bought. On the output side, the interface between the HMI and the support system e.g. in case of highlighting aircraft labels would ease communication between different hardware/software manufacturers. The visual cues itself might be unique selling points of the ATM system providers. Hence, there can be recommendations for the design, but probably no standard. So, standardization activities can be investigated further up to TRL6.

PJ.16-04 UPMS standardization activities

No specific recommendations have been identified for regulation and standardisation needs.

PJ.16-04 CWPV standardization activities

For the usage of CWPV technologies no need for further standardisation due to the use of COTS technology is seen. Still, the used hardware has to conform with country specific regulations for the use of CWPV technologies. This might make updates in regulations necessary.

3 Conclusion and Next Steps

3.1 Conclusions

PJ.16-03 Conclusion

The following items have been addressed successfully by the solution PJ.16-03:

- Virtual Centre definition: this definition has been proposed by the solution and is now endorsed by the community.
- VC Architecture for Rationalization of infrastructure: this architecture has been developed by partners as the reference architecture. As a result, this architecture has been analysed in detail, including its modelling in EATMA.
- Design of VC Services: Service orientation is one of the pillars of the ATM Master plan. The solution has defined most of the services in detail that are needed for implementing the developed VC architecture.
- Convergence in the choice of technologies: this solution is a technical solution and it is also a success to have a convergence in the choice of technologies among the industrial partners. AMQP, being part of the SWIM Yellow Profile, has been chosen as the core technology for implementing the validation exercises.
- Validation of the concept: Five TRL4 exercises and two TRL6 exercises have been conducted. The validation objectives, defined by partners and agreed with SJU at each maturity level, were achieved.
- Reach TRL6 level: TRL2, TRL4 and TRL6 Gates have been passed successfully during the Wave 1 period i.e. in 3 years.

PJ.16-04 Conclusion

The solution 16-04 Workstation, Controller Productivity reached TRL4 also revealing aspects requiring further investigations. The different advanced HMI technologies have shown that a reduction of workload and increase of situation awareness for controllers is possible. The results should be used to proceed to TRL6 for the approach CWP and to reach a comparable TRL4 level with respect to the tower CWP that has not been a central part of PJ.16-04. More details about the five different activities of PJ.16-04 are explained in the following.

3.2 Plan for next R&D phase (Next steps)

PJ.16-03 plan for future

The future of this solution will be embedded in SESAR 2020 Wave 2 PJ10 solution 93.

Therefore, a specific analysis on the Technical and Operational Threads at the beginning of the Wave 2 Solution 93 is necessary. It will be based on the results of the Wave 1 PJ.15-09 and Wave 1 PJ.16-03 Maturity Gate.

Based on the existing Services in the PJ.16-03 Technical Thread, the definition of open services to be used between the ATM Services Unit (ATSU) and ATM Data Services Provider (ADSP) are considered the base for the Solution 93 Delegation of ATS Services.

Some services already technically validated in PJ.16-03, need further development and testing in more defined PJ.15-09 use cases; for example, Operational Supervision and Airspace Status Distribution. It is considered mandatory to meet the expectations of the Operational Requirements. The adopted environment will be validated as well during the W2 Solution 93 Exercises.

The interaction of the Technical Services in the context of Delegation- and the new Operational possibilities have allowed identifying a series of use-cases (already analysed in the PJ.15-09) that use a totally new architecture and totally new ways of operating. This new working methodology has already been defined in the scope of PJ.16-03; it will be validated with a different maturity level in the Wave 2 Solution 93. A change in regulations and/or applicable laws, adaptations to operational rules and procedures will be needed to clearly identify the roles and responsibilities between the intervening units.

PJ.16-04 plan for future

The four topics user profile management systems, attention guidance, multi-touch inputs, and automatic speech recognition are considered for future industrial research concentrating on advanced not yet investigated aspects. One of such aspects is the use of interaction technologies at the tower CWP. This will be handled in Wave-2 Solution PJ.05-97 starting at TRL2 and aiming to reach TRL4. Some of the above listed interaction technologies will be studied further to TRL6 in the course of Solution PJ.10-96. One important overall step would be the integration of different interaction technologies into a CWP prototype, i.e. all relevant activities of PJ.16-04 (ASR, MTI, AG, UPMS), for a combined validation exercise respectively validation stream.

The UPMS activity identified the following recommendations for the next UPMS concept development:

- Develop appropriate controller training and manage change to ensure a safe and efficient transition with the implementation of the UPMS;
- Develop operational and technical procedures to mitigate and manage system failures;
- Develop procedures detailing how information gained from technical enablers and systems can be used in operations;

- Implement Biometrics: According to questionnaire from TRL2, based on controllers' responses, the most appropriate combination for controllers' identification is combination of voice and face recognition;
- Implement additional Use Cases;
- Manual change of profile – as a part of Authentication system to enable online configuration of the profile;
- On-the job training - as a part of User Profile Configuration system;
- Extension of set of functions: establish the subject of customisation based on the results from questionnaire in TRL2, but ensure mitigation of negative effect and possible safety issues;
- Introduce a function to save the settings for the profile during the run-time;
- Application and validation of UPMS concept for Tower and Approach environment;

The AG activity identified the following recommendations for the next phase:

- Continue to work to tune the existing implementation with additional cues and review of timing parameters.
- Investigate further safety and operational feasibility aspects.
- Investigate the effect of large screen sizes on the robustness of eye-tracking.
- Test on more extensive and complete validation platforms with different CWPs and operational environments.
- Continue to define HMI improvements to support the controller to get the adequate level of awareness on more complex traffic situations.
- Collaborate closely with controllers in design and validation phases to maintain the usability of the developed solutions.

In the framework of PJ.16-04 activities, with respect to tower and tower controller HMI, TRL4 maturity is not completely fulfilled and was not aimed at either. So more research and development work is needed towards the industrialization phase in wave-2.

In consideration of the main results stemming from PJ.16-04 solution, it is recommended to pursue the investigation on new interaction techniques and technologies aimed to minimise the load and mental strain on controllers. In particular, further innovative development in human machine interface field is hoped and envisaged, to get a direct benefit for controllers, hence improving their productivity.

The Automatic Speech Recognition technology potential, that the exercises have clearly shown, leaves room to further enhance ontology for tower commands and applications. Besides, integration with COTS can reveal aspects of interest for the Programme. Aspects such as Attention Guidance/Attention Control, Multi Touch Input features and Machine Learning algorithms can be further analysed in order to overcome mental bottlenecks in the human-system interaction. Those aspects are envisaged in six exercises of Solution PJ.05-97 between late 2020 and early 2022.

The ASR activity in PJ.16-04 identified the following recommendations:

- Common building blocks, which are exchangeable between different partners and exercises, might be an option to strengthen European competitiveness, because all ASR engines used are COTS developments based on implementations from US companies.

- A more detailed analysis on safety aspects is necessary. This requires improved ASR command recognition performance. Currently it is not even clear, if a command recognition rate of 90% with a command recognition error of 0.1% is safer than a recognition rate of 95% with a corresponding error rate of 4%. In the first case the controller may rely too much on the correctness of the ASR output.
- The adaptation of the Speech Recognition Models by machine learning should be integrated into the COTS tools, i.e. its usage should be possible by ATC experts and ATC maintenance staff and not limited to machine learning and ASR experts.
- Especially machine learning for cost efficient adaptation of acoustic models (e.g. local accents) and for language model adaptation to really use phraseology and prediction of possible commands to reduce command recognition error rate without disturbing command recognition rate itself are necessary.

Although this might result in re-doing some of the performed Wave-1 validation exercises within Wave-2 IR, the additional effort is limited. Validation Plan, HMI design and evaluation environment are already available. The consequences are already considered in the description of some of the Wave-2 IR exercises of solution 96 (for approach control) and solution 97 for (tower control).

3.3 Deployable solutions

For the MTI activity, as the validation results are positive and consistent across the exercises, it is considered that no further research is needed. In addition, no technical blocking point has been identified which could jeopardize the industrialisation of the MTI. So there is a possibility to proceed with an industrialisation of the MTI. This activity is consequently identified as an independent solution (CR 03781 Create Solution for Multi-Touch Inputs under assessment at the date of this document).

However, some aspects need to be scrutinized when achieving the industrialization:

- The solution needs to be assessed with a wider number of ATCos.
- The training should be carefully considered, and time should be given for the end-users to adapt their way of working to the MTI.
- Close the gap on safety elements. Safety has not been evaluated in abnormal conditions. SARs are based on expert judgement only.
- The reported effect of technology costs reduction in PAGAR (Table 23) needs to be updated.
- Introduction of ASR systems as an additional sensor will increase the technology costs of a CWP, but it is expected that ATCo’s costs are reduced, because ATCo’s productivity is expected to increase.

4 References

4.1 Project Deliverables

PJ.16 Deliverables

- D1.1 - Project Management Plan (04 August 2017)
- D1.3 - Q4 2016 (30 January 2017)
- D1.4 - Q1 2017 (28 April 2017)
- D1.5 - Q2 2017 (20 September 2017)
- D1.6 - Q3 2017 (14 November 2017)
- D1.7 - Q4 2017 (01/02/2108)
- D1.8 - Q1 2018 (03 May 2018)
- D1.9 - Q2 2018 (31 July 2018)
- D1.10 - Q3 2018 (08 November 2018)
- D1.11 - Q4 2018 (31 January 2019)
- D1.12 - Q1 2019 (19 April 2019)
- D1.13 - Q2 2019 (25 July 2019)
- D1.14 - Q3 2019 (04 November 2019)

- D4.1 - H - Requirement No. 1 (31 May 2018)
- D4.2 - POPD - Requirement No. 2 (13 July 2018)
- D4.3 - NEC - Requirement No. 3 (31 May 2018)
- D4.4 - M - Requirement No. 4 (31 May 2018)

PJ.16-03 Deliverables

- D2.1 - Solution PJ.16-03: V1 Data Pack (01 June 2018) including
  - D2.1.010 TRL2 FRD
  - D2.1.020 TRL2 TVALR
  - D2.1.030 TRL4 TVALP

- D2.2 - Solution PJ.16-03: V2 Data Pack (19 March 2019) including
  - D2.2.010 TRL4 TS/IRS
  - D2.2.020 TRL4 TVALR
  - D2.2.030 TRL6 TVALP
  - D2.2.040 AVAILABILITY NOTE

- D2.3 - Solution PJ.16-03: V3 Data Pack (09 December 2019) including
  - D2.3.010 TRL4 TS/IRS
  - D2.3.020 TRL4 TVALR
  - D2.3.040 AVAILABILITY NOTE
  - D2.3.050 TRL2 Transition Plan

PJ.16-04 Deliverables

- D3.1 - Solution PJ.16-04: V1 Data Pack (14 Nov 2018) including
  - D3.1.010 TRL4 TVALP
  - D3.1.020 TRL2 TVALR
  - D3.1.030 TRL2 FRD
- D3.2 - Solution PJ.16-04: V2 Data Pack (01 Oct 2019) including
  - D3.2.010 TRL4 TS
  - D3.2.030 TRL4 AN
  - D3.2.040 TRL4 TVALR

PJ.16-04-01 MTI Deliverables (8 documents)

- D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-MTI _01_00_00 with D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-MTI Part II SAP_v01_00_00
- D3_1_020-SESAR 2020 PJ_16-04 TRL2 TVALR-MTI_01_00_00
- D3_1_030-SESAR 2020 PJ_16-04 TRL2 FRD-MTI_01_00_00
- D3_2_010-SESAR 2020 PJ_16-04 TRL4 TS-MTI_02_00_00
- D3_2_030-SESAR 2020 PJ_16-04 TRL4 AN-MTI_v02_00_00
- D3_2_040-SESAR 2020 PJ_16-04 TRL4 TVALR-MTI_v02_00_00 with D3_2_040-SESAR 2020 PJ_16-04-01 TRL4 TVALR - MTI - Appendix E - v02_00_00

PJ.16-04-02 ASR Deliverables (8 documents)

- D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-ASR_v01_00_00 with D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-ASR Part II SAP_v01_00_00
- D3_1_020-SESAR 2020 PJ_16-04 TRL2 TVALR-ASR_01_00_00
- D3_1_030-SESAR 2020 PJ_16-04 TRL2 FRD-ASR_01_00_00
- D3_2_010-SESAR 2020 PJ_16-04 TRL4 TS-ASR_02_00_00
- D3_2_030-SESAR 2020 PJ_16-04 TRL4 AN-ASR_v02_00_00
- D3_2_040-SESAR 2020 PJ_16-04 TRL4 TVALR-ASR_v02_00_00 with D3_2_040-SESAR 2020 PJ_16-04-02 TRL4 TVALR - ASR - Appendix G - v02_00_00

PJ.16-04-03 AG Deliverables (8 documents)

- D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-AG_v01_00_00 with D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-AG Part II SAP_v01_00_00
- D3_1_020-SESAR 2020 PJ_16-04 TRL2 TVALR-AG_01_00_00
- D3_1_030-SESAR 2020 PJ_16-04 TRL2 FRD-AG_01_00_00
- D3_2_010-SESAR 2020 PJ_16-04 TRL4 TS-AG_02_00_00
- D3_2_030-SESAR 2020 PJ_16-04 TRL4 AN-AG_v02_00_00
- D3_2_040-SESAR 2020 PJ_16-04 TRL4 TVALR-AG_v02_00_00 with D3_2_040-SESAR 2020 PJ_16-04-03 TRL4 TVALR - AG - Appendix C - v02_00_00

PJ.16-04-04 UPMS Deliverables (8 documents)

- D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-UPMS_v01_00_00 with D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-UPMS Part II SAP_v01_00_00
- D3_1_020-SESAR 2020 PJ_16-04 TRL2 TVALR-UPMS_01_00_00

- D3_1_030-SESAR 2020 PJ_16-04 TRL2 FRD-UPMS_01_00_00
- D3_2_010-SESAR 2020 PJ_16-04 TRL4 TS-UPMS_02_00_00
- D3_2_030-SESAR 2020 PJ_16-04 TRL4 AN-UPMS_v02_00_00
- D3_2_040-SESAR 2020 PJ_16-04 TRL4 TVALR-UPMS_v02_00_00 with D3_2_040-SESAR 2020 PJ_16-04-04 TRL4 TVALR - UPMS - Appendix B - v02_00_00

PJ.16-04-06 CWPV Deliverables (6 documents)

- D3_1_010-SESAR 2020 PJ_16-04 TRL4 TVALP-CWPV_v01_00_00
- D3_1_020-SESAR 2020 PJ_16-04 TRL2 TVALR-CWPV_01_00_00
- D3_1_030-SESAR 2020 PJ_16-04 TRL2 FRD-CWPV_01_00_00
- D3_2_010-SESAR 2020 PJ_16-04 TRL4 TS-CWPV_02_00_00
- D3_2_030-SESAR 2020 PJ_16-04 TRL4 AN-CWPV_v02_00_00
- D3_2_040-SESAR 2020 PJ_16-04 TRL4 TVALR-CWPV_v02_00_00

4.2 Project Communication and Dissemination papers

The following communication and dissemination activities took place during the project timeframe:

PJ.16-03 Communications

Demonstration events:

Large Attendance meeting called Episode 1 (Brussels, March 2017)

Large Attendance meeting called Episode 3 (Brussels, September 2017)

Large Attendance meeting called Episode 4 (Brussels, June 2018)

Large Attendance meeting called Episode 5 (Brussels, May 2019)

Demo Event (Malmö, October 2019)

Demo Event: Virtual Centre @next level (Vienna, October 2019)

Participation to SJU Walking Tour during WAC 2018, Madrid

Participation to SJU Walking Tour during WAC 2019, Madrid

PJ.16-04 Communications

Demonstration events:

- Demo Event at 1st European Research and Innovation Days in Brussels (24-26 September), PJ.16-04 (posters) to present project results & MALORCA (demo) have been presented next to other ER projects at SESAR booth: https://www.sesarju.eu/news/sesar-ju-showcased-projects-results-european-ri-days

- DFS roadshow at Centre Munich, June 2019
- World ATM Congress, Madrid, 2019. PJ.16-04 presentations at SESAR Walking Tour of DLR, NATS (with LPS-SR), and SINTEF.
- Various Open Days with connected other projects such as PJ.05 and PJ.10

Journal article:

- Hagemann, K. & Udovic, A. (2019). Tactical inputs for a stripless ATC system via Multi-Touch Gestures. Innovation im Fokus, 01/19, Langen: Deutsche Flugsicherung.

  https://d-nb.info/1190060892/34

Scientific papers at conferences:

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Already submitted and accepted abstract for full paper:

- J. Rataj, O. Ohneiser, G. Marin, R. Postaru, ”Attention: Target and Actual – The Controller Focus“, ICAS 2020, Shanghai, China, 2020.

Project homepage:

- https://www.sesarju.eu/projects/cwphmi

Appendix A Glossary of Terms, Acronyms and Terminology

A.1 Glossary of terms

Term	Definition	Source of the definition

Table 4: Glossary

A.2 Acronyms and Terminology

Term	Definition
AG	Attention Guidance
ADSP	ATM Data Service Provider
AN	Availability Note
ASR	Automatic Speech Recognition
ASTERIX	All Purpose Structured Eurocontrol Surveillance Information Exchange
ATCo	Air Traffic Controller
ATM	Air Traffic Management
ATSU	Air Traffic Services Unit
CBA	Cost Benefit Analysis
COTS	Commercial-off-the-shelf
CWP	Controller Working Position
CWPV	Qualification of CWP Virtualisation
BM	Business Model
EATMA	European Air Traffic Management Architecture
HLA	High Level Architecture
HMI	Human Machine Interface
MTI	Multi-touch inputs
SDD	Service Definition Document
SESAR	Single European Sky ATM Research Programme

SJU	SESAR Joint Undertaking (Agency of the European Commission)
TVALP	Technical Validation Plan
TVALR	Technical Validation Report
UPMS	User Profile Management Systems
VC	Virtual Centre

Table 5: Acronyms and technology

Appendix B Additional Material

B.1 Final Project maturity self-assessment

Not applicable as for the 2 solutions the Maturity Gates were the last activity performed in the solution.