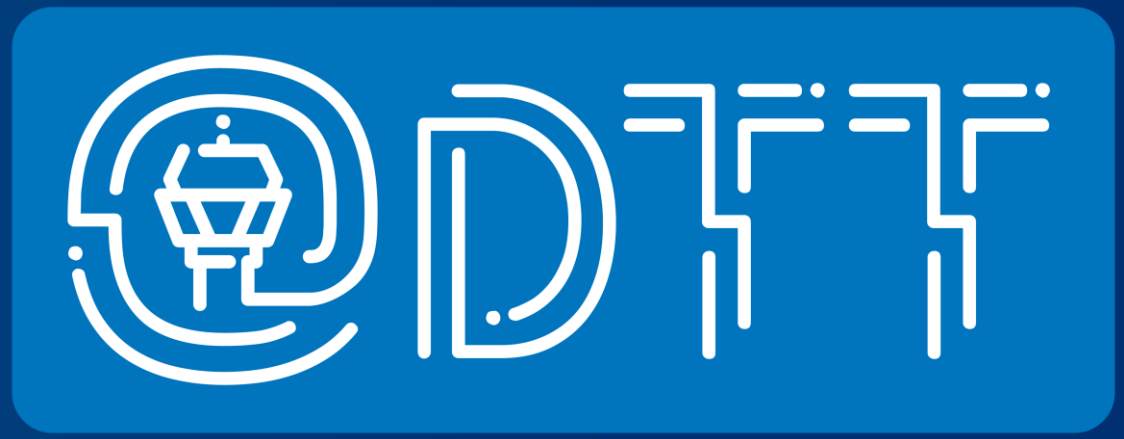
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PJ.05-W2 Digital Technologies for Tower

Close-out Meeting

Jörn Jakobi, DLR, Project Coordinator

Geneva, 7 March 2023

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Agenda

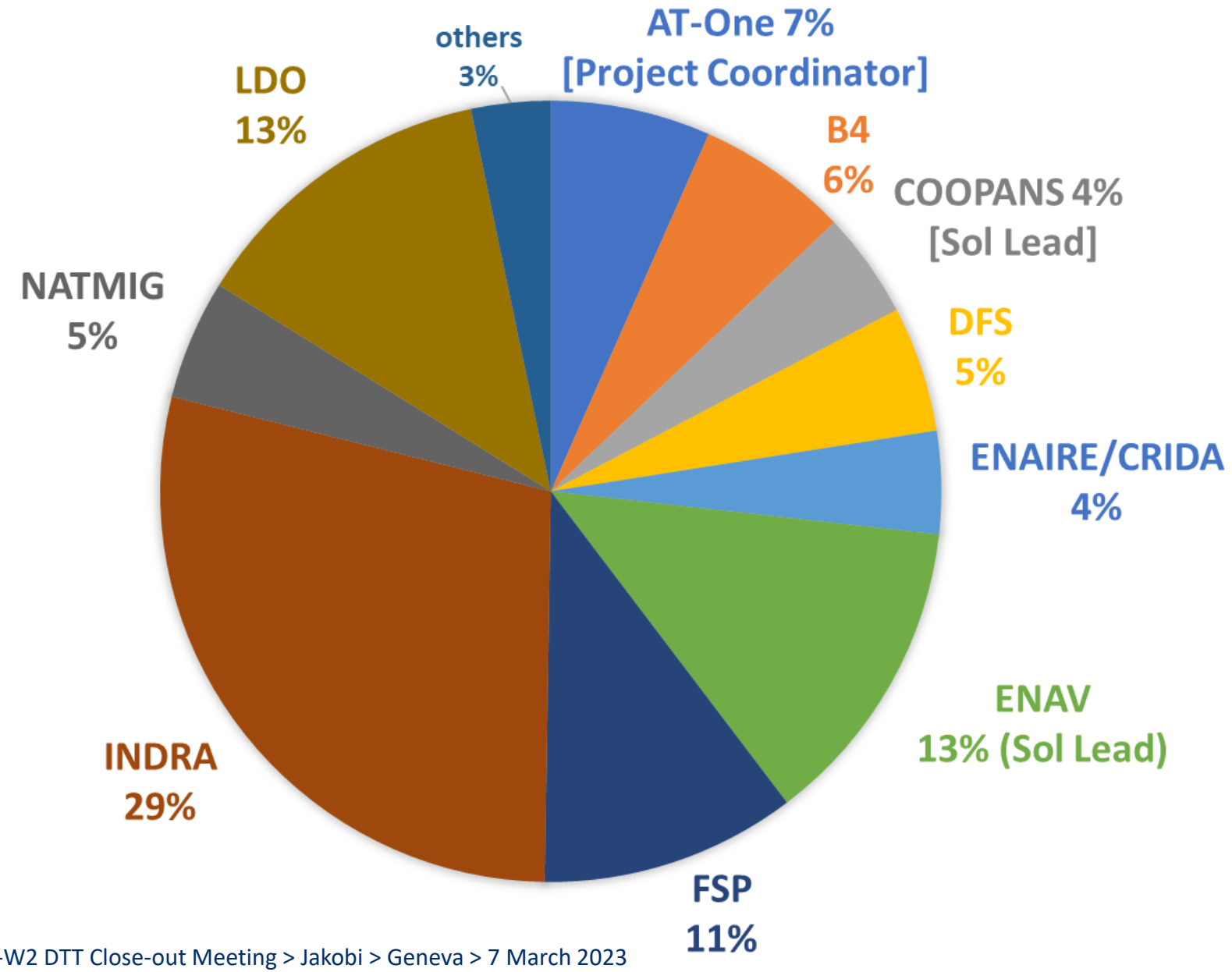
12.15 – 13.00	**Registration and Welcome Coffee**
13.00 – 13.15	**Welcome** • Jörn Jakobi, PJ05 Coordinator, DLR
13.15 – 13.30	**SESAR Introduction** • Olivier Mongenie, SESAR 3 JU
13.30 – 14.25	**PJ05-W2 Solution 35 conclusions and discussion** • Marcus Filipp, Solution 35 leader, LFV
14.25 - 14.55	**COFFEE BREAK**
14.55 – 15.50	**PJ05-W2 Solution 97.1 conclusions and discussion** • Ramona Santarelli, Solution 97.1 leader, ENAV • Jürgen Teutsch, EXE-001 leader, NLR • Walter Rinaldi, Leonardo
15.50 – 16.45	**PJ05-W2 Solution 97.2 conclusions and discussion** • Ramona Santarelli, Solution 97.**2** leader, ENAV • Gyorgyi Balogh, EXE-004 leader, INDRA • Hartmut Helmke, EXE-006 leader, DLR • Walter Rinaldi, EXE-007 leader, Leonardo
16.45 – 17.00	**Summary and Outlook**

Project Overview

Project Start 01/12/2019 — *Project End 31/03/2023*

- 18 contributing Beneficiaries
- 31 contributing Partners (incl. LTPs)
- € 9.2 Mio JU contribution
- 1242 person months in total

EFFORT SHARE %



Project Overview

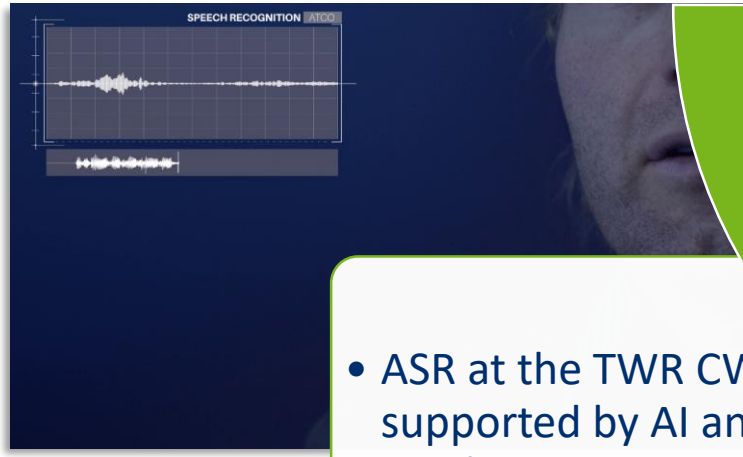
WP1
Project
Management
DLR

WP2
Solution 35
LFV/COOPANS

- Multiple Remote Tower & Remote Tower Center

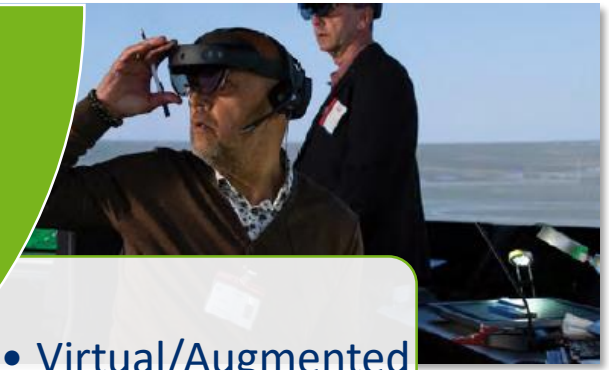


WP3
Solution 97.2
ENAV



- ASR at the TWR CWP supported by AI and Machine Learning

WP3
Solution 97.1
ENAV



- Virtual/Augmented Reality applications for tower

Publications

Title	Authors	Title of the Journal/Proc./Book	Solution
Supervising Multiple Remote Tower Operations: How to develop and test a new work position in the ATC Domain?	M. Friedrich, F. Timmermann, J. Jakobi	HCII 2021, Harris D., Li WC. (eds) Engineering Psychology and Cognitive Ergonomics. HCII 2021. Lecture Notes in Computer Science, vol 12767. .	35
Active Supervision in a Remote Tower Center: Rethinking of a New Position in the ATC Domain	M. Friedrich, F. Timmermann, J. Jakobi	HCII 2022, Harris, D., Li, WC. (eds) Engineering Psychology and Cognitive Ergonomics	35
Attention Guidance for Tower ATC Using Augmented Reality Devices	J. Teutsch, T. Bos, M. van Apeldoorn and L. Camara	Integrated Communication, Navigation and Surveillance Conference (ICNS), 2022	97.1
Towards a Digital Control Tower: the Use of Augmented Reality Tools to Innovate Interaction Modes	R. Santarelli, S. Bagassi, J. Teutsch, R.Lasheras, M. Carmona, A. Groskreutz	SESAR Innovation Days 2022, Budapest	97.1
Understanding Tower Controller Communication for Support in Air Traffic Control Displays	O. Ohneiser, H. Helmke, S. Shetty, M. Kleinert, H. Ehr, Š. Murauskas, T. Pagirys, G. Balogh, A. Tønnesen, G. Kis-Pál, R. Tichy, V. Horváth, F. Kling, W. Rinaldi, S. Mansi, G. Piazzolla, H. Usanovic	SESAR Innovation Days 2022, Budapest	97.2

https://www.remote-tower.eu/wp/

Remote Tower



Home

www.remote-tower.eu

The modernisation of air traffic management is one of the main challenges of current aeronautics research.The Single European Sky ATM Research (SESAR) project defines, develops and deploys what is needed to increase ATM performance and build Europe's intelligent air transport system.

Part of SESAR are the projects **PJ05 "Remote Tower for Multiple Airports"** and **PJ05-W2 "Digital Technologies for Tower"**, which focus on the safe and efficient airport of the future. By bringing the concept of remotely controlling multiple airports as well as HMI interaction modes for airport towers to higher maturity levels, the SESAR projects aim at providing small and medium sized airports with more cost-efficient and service tailored air traffic services.

The current programme is SESAR 2020 supports projects to deliver solutions in four key areas, namely airport

Recent News



SESAR PJ05-W2-35 Multi Remote Tower Online Open Day on 6 December

15. November 2021



EUROCAE WG-100

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PJ.05-W2 Solution 35

Close-out Meeting

Marcus Filipp, LFV COOPANS – Solution Manager

Geneva, 7 March 2023

EUROPEAN PARTNERSHIP

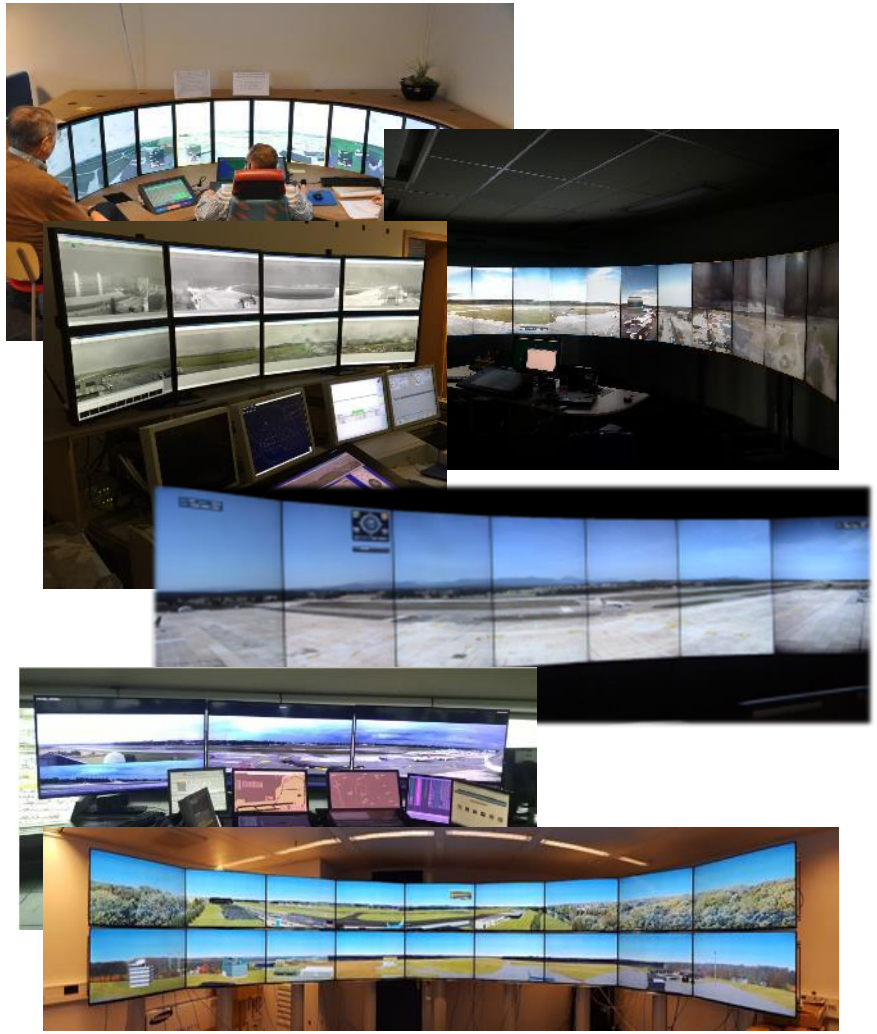
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Solution leader presentation

- Agenda:
  - History recap
  - Ongoing deployment – Single RTWR
  - Solution 35 – wave 1 (solution PJ.05.03)
  - Solution 35 – wave 2
  - Exercises
  - Summary
  - LFV deployment

History recap

- SESAR 1 – LFV, Saab and DFS, FRQ
  - Single RTWR
    - Deployment ongoing
  - Contingency RTWR
    - LFV, Saab trial
    - ENAIRE, trial
  - MRTR – low traffic 1:2
    - Deployment initiated
  - Large Scale Demonstrations
    - LFV, DFS, LVNL – Single and Multiple RTWR
    - IAA – Multiple RTWR
    - HC – Contingency RTWR
      - Deployed at Budapest
    - ENAV – Single RTWR

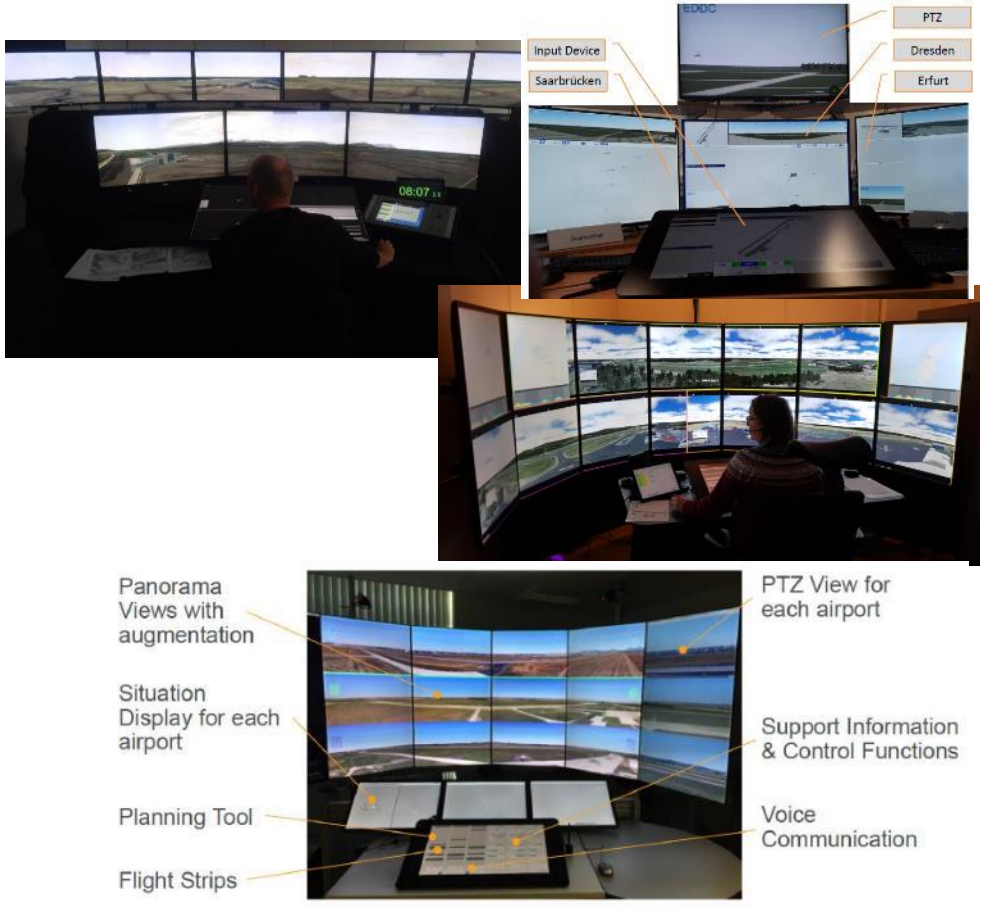


Deployment – Single RTWR



Solution 35 – PJ.05.03 wave 1

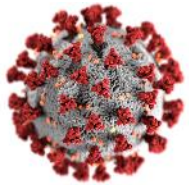
- 3 airports
- Dynamic allocation of aerodromes
- ATCO and Supervisor
- 4 exercises
  - ON – DLR platform
  - COOPANS – Saab IBP
  - Avinor – INDRA IBP
  - DFS – DFS/FRQ IBP



Solution 35 – PJ.05.03 wave 2

- Management perspective
  - Kick Off Meeting 200225 – Malmö
    - All OK – plan for OSED and VALP set
- 1 month later
  - New plan
- Initial OSED and TS
  - 6 months delayed
- VALP
  - 8 months delayed
- Exercises
  - 5-10 months delayed
- VALR
  - First review



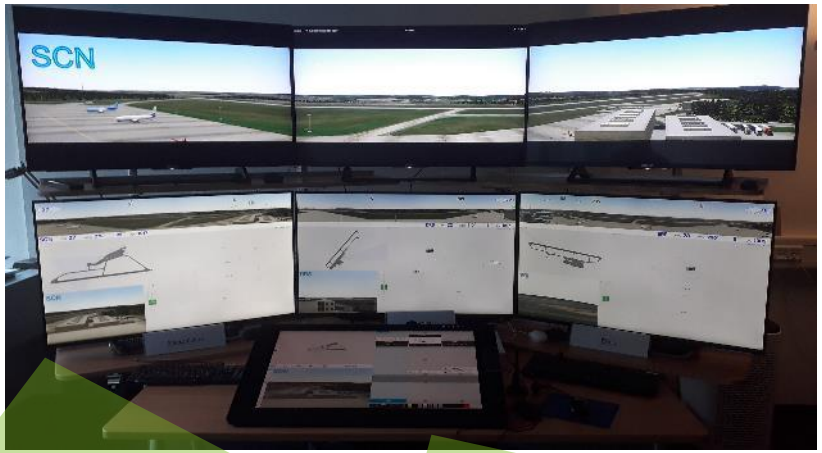




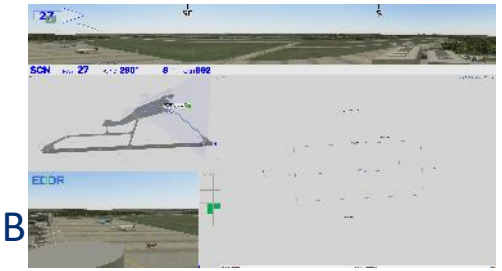
Multiple Remote Tower – DFS

- Objective
  - Safety and HP is maintained
  - Increase ATCO Productivity
  - MRTM with 3 Aerodromes
    4-6 simultaneous Movements

- Automation Support
  - Selection of relevant Information (Label Selection)
  - Provision of Events
    - Clearances to be provided
    - Airport Safety Net
  - Ground Surveillance
    - Low Cost Surveillance (MLAT / ADSB



Status Display for each Airport



Interaction Monitor



Multiple Remote Tower – DLR

- Objective
  - Safety and HP is maintained
  - Proof of concept
  - Supervisor position
- Exercise
  - 3 aerodromes on top of each other
  - Supervisor planning tool
    - 15 airports
  - 15 participants
  - Balancing ATCO workload

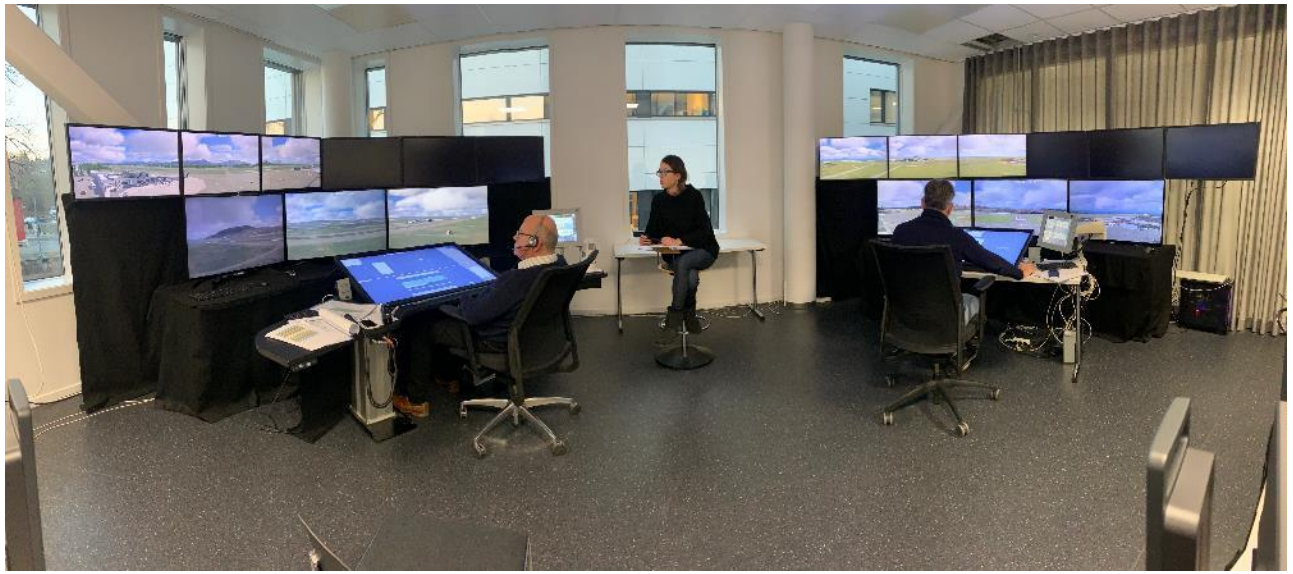


Multiple Remote Tower – INDRA

- Objective
  - Safety and HP is maintained
  - MRTM with 3 Aerodromes
  - Supervisor planning tool for work balance

Exercises

- 3 validations – 1 platform – 2 ANSPs (AVINOR/HC)
- Shadow mode trial



Multiple Remote Tower – COOPANS

- Objective
  - Safety and HP is maintained
  - Increase ATCO Productivity
  - Operational concept for flexible allocation

- RTC with flexible allocation
  - 4 aerodromes – 2 MRTMs
    - Next generation MRTM
  - Full flexibility
    - Aerodrome handover
    - Support tools
  - Planning tool
    - ATCO planning for split and merge



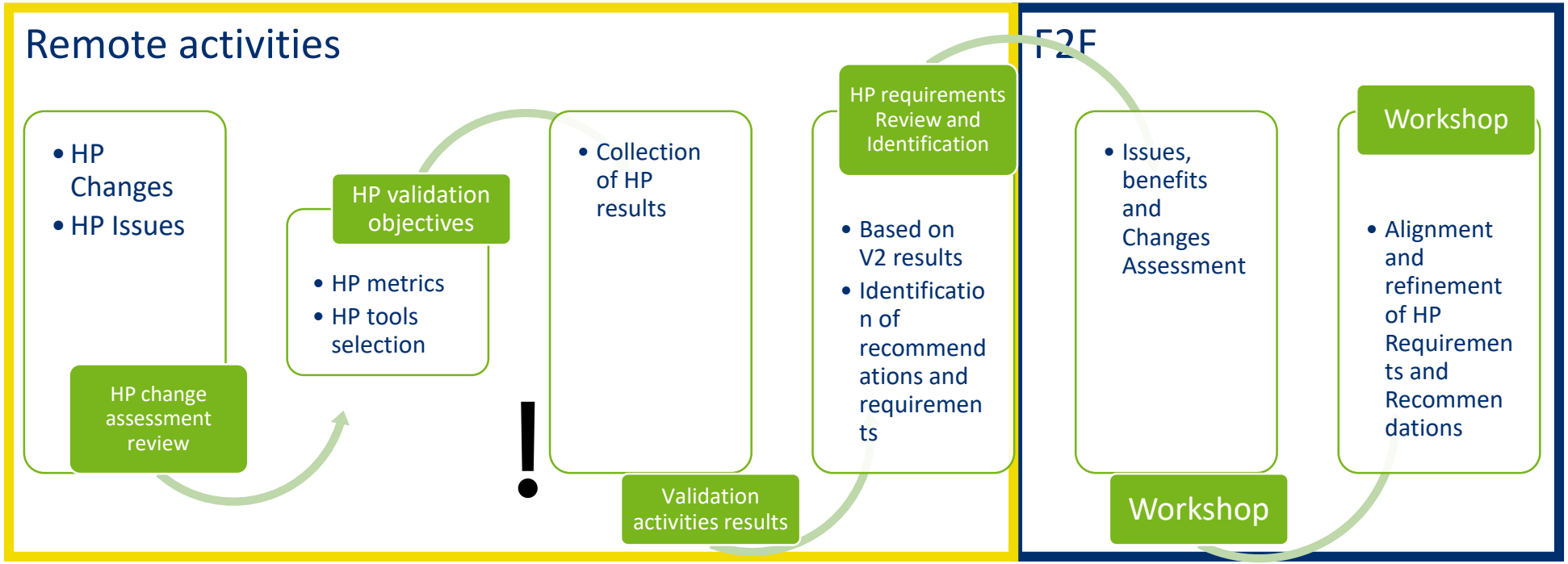
Multiple Remote Tower – ENAV

- Objective
  - Maintained SA and SAF
  - Increased ATCO productivity
- Exercise
  - 3 Aerodromes
  - RTC with 2 MRTMs with up to 3 aerodromes simultaneously
  - Dynamic allocation of the aerodromes with RTC Supervisor support
  - RTC Supervisor planning tool





HP and Safety as part of the program



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PJ.05-W2-Sol 97.1
Close-out Meeting

Ramona Santarelli, Jürgen Teutsch, Walter Rinaldi

PJ.05-W2 Close-out meeting, Geneva, 7 March 2023

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Solution 97.1 Team



KOM: 30-Jan-2020

Close-out: 7-Mar-2023

Motivation



HEAD UP
Out the Window View

HEAD DOWN
Displays
Keyboard
Strips



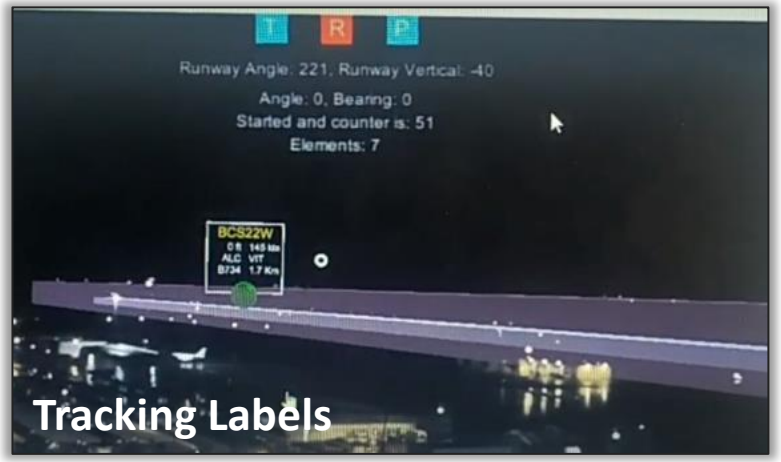


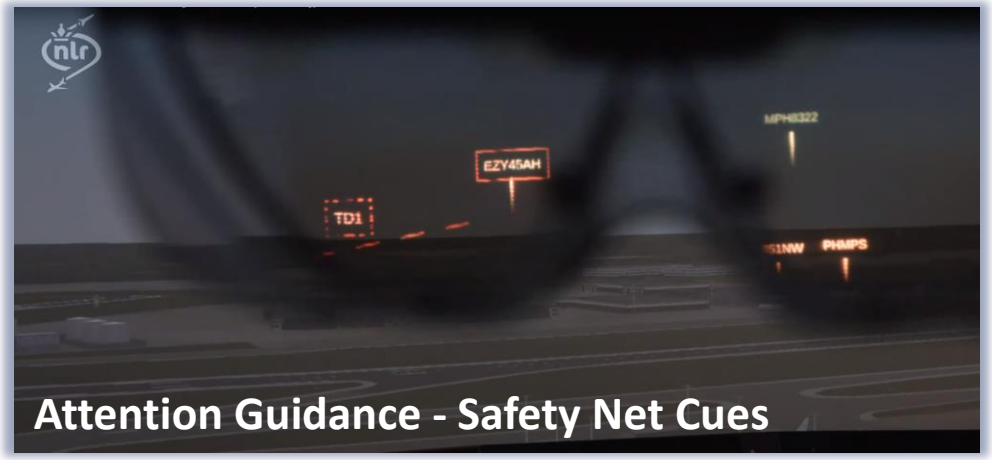


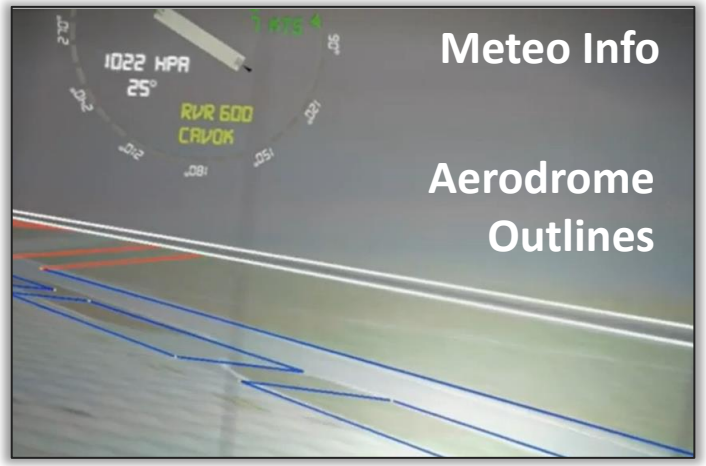
SESAR 2020
• Sol 97.1

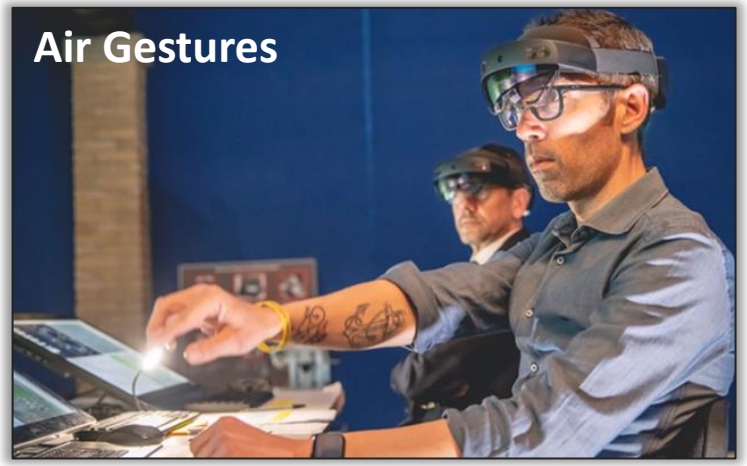
SESAR 1
• RETINA

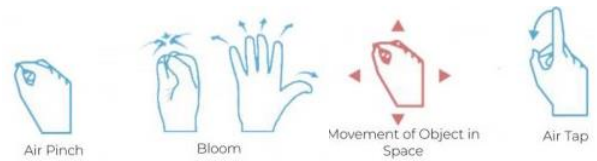
Keeping an Augmented Eye on the Traffic

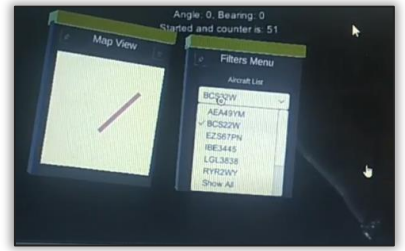




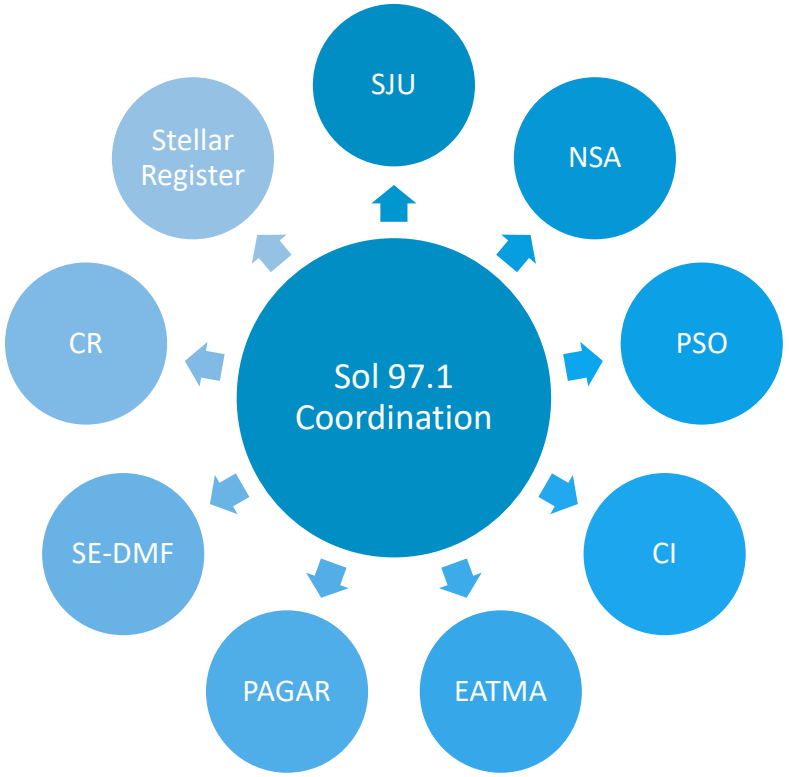








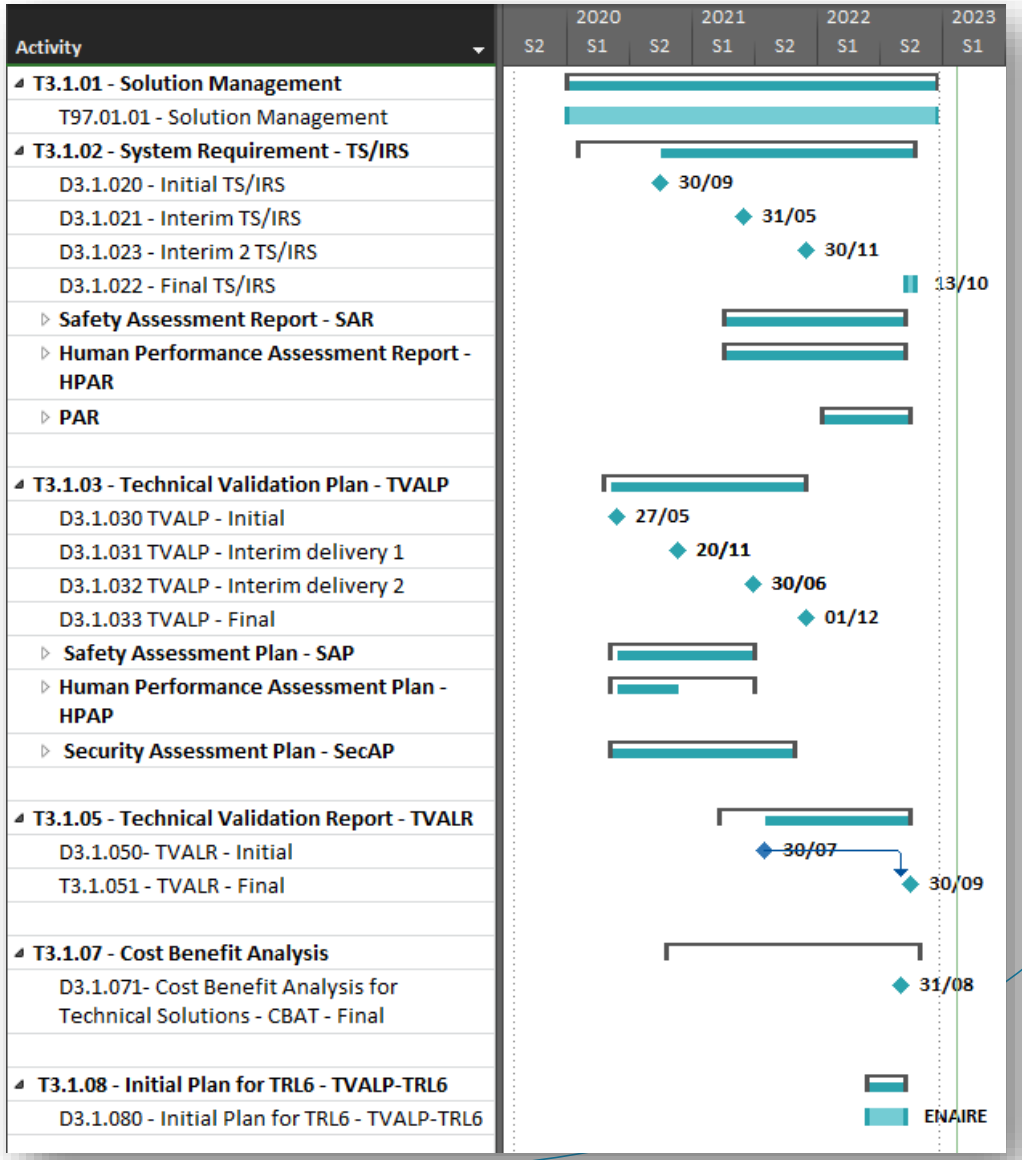
Tasks



Deliverables:

- TS/IRS, including
  - SAR
  - HPAR
  - PAR
- TVALP, including
  - SAP
  - HPAP
- CBAT
- TVALR
- iTVALP for TRL6
- Platform Availability Notes





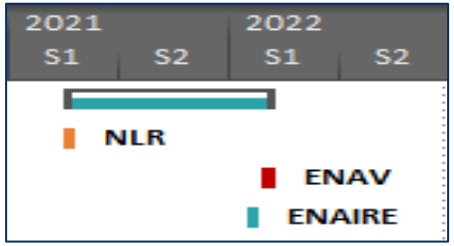
Technical Validations

High-performing Airport Operations



Maturity

TRL 2 → TRL 4 → TRL 6



Findings

- ✓ Feasibility
- ✓ Head-up time
- ✓ HMI Design
- ✓ Usability
- ✓ Workload
- ✓ Situation Awareness
- ✓ Safety
- ✓ Alternative/Additional Means

Expected Benefits

	Key Performance Area	Key Performance Indicator
	CEF2 (ATCO Efficiency and Productivity)	Flights per ATCO hour on duty
	Safety	Indirect Safety Impacts
	Human Performance	User Acceptability of Solution (qualitative) Cognitive indicators
	Resilience	Loss of Airport Capacity avoided

Validation Description

- Real-time Simulation
- Tracking Labels
- Attention Capturing and Guidance for Safety Nets
- Amsterdam Airport Schiphol (EHAM)
- Good visibility conditions

EXE-05.97.1-VAR-001: Validation of AR Interaction Modes for Schiphol Tower with Focus on Attention Guidance



- Real-time Simulation
- Tracking Labels
- Air Gesture Interaction
- Safety Nets/Attention Guidance
- Bologna Airport (LIPE)
- Low visibility conditions

EXE-05.97.1-VAR-002: Augmented Reality Multimodal Control Tower Interaction



- Shadow-mode Trial
- Tracking Labels
- Air Gestures
- Vitoria-Gasteiz Airport (LEVT)
- Low visibility conditions

EXE-05.97.1-VAR-005: Augmented Reality in the Tower Environment

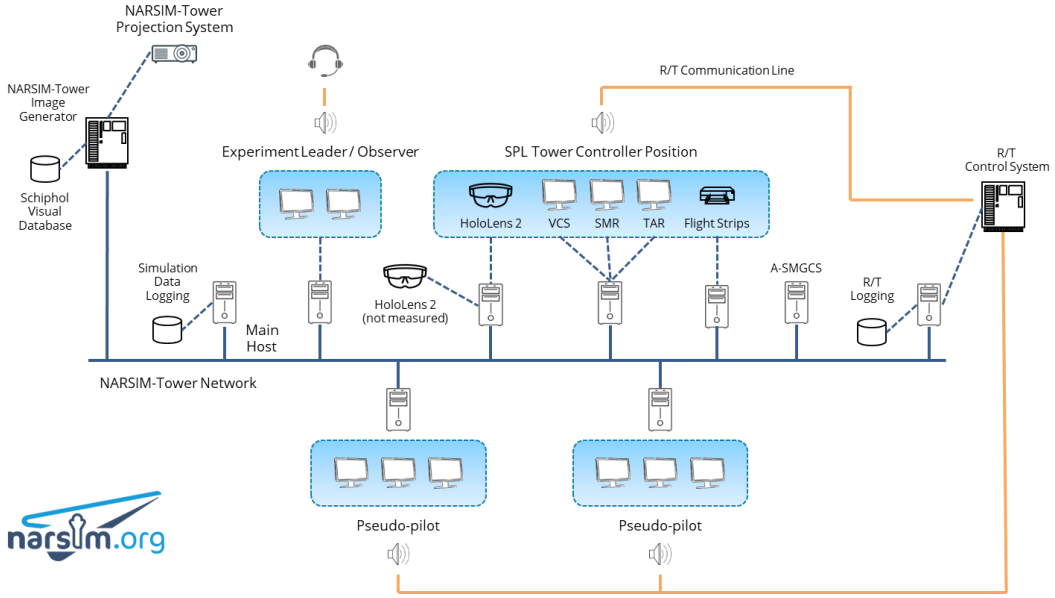


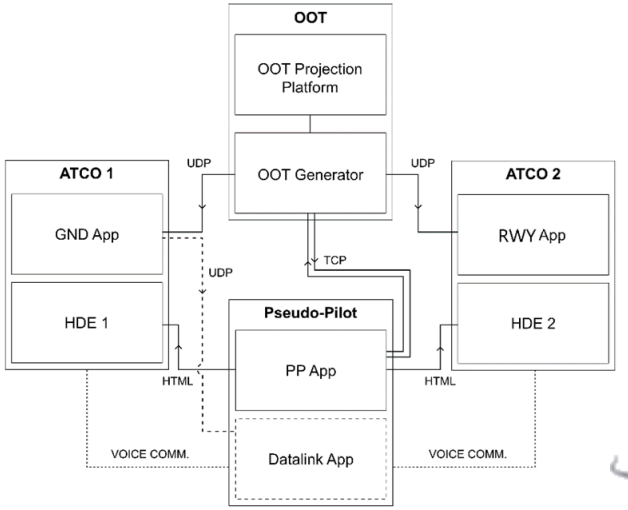
Validation Platforms







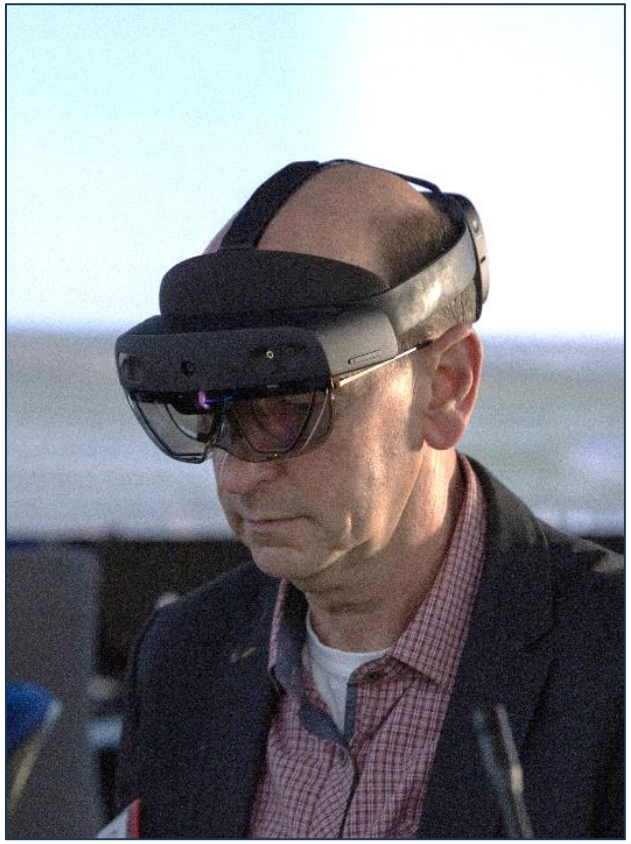






Augmented Reality with HoloLens 1 and 2™

- ***Head-mounted smart-glasses*** for perception of holograms that are integrated within real-world environment
- Features:
  - Tinted ***visor*** with transparent optical combiner lenses
  - Non-obstructing ***speakers*** with spatial sound
  - Hand and ***gesture tracking*** and ***eye-tracking***



Tracking Labels

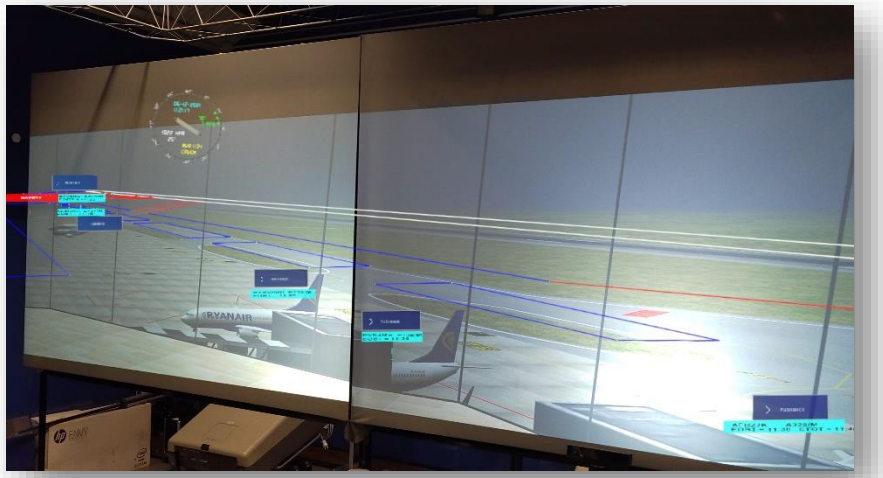




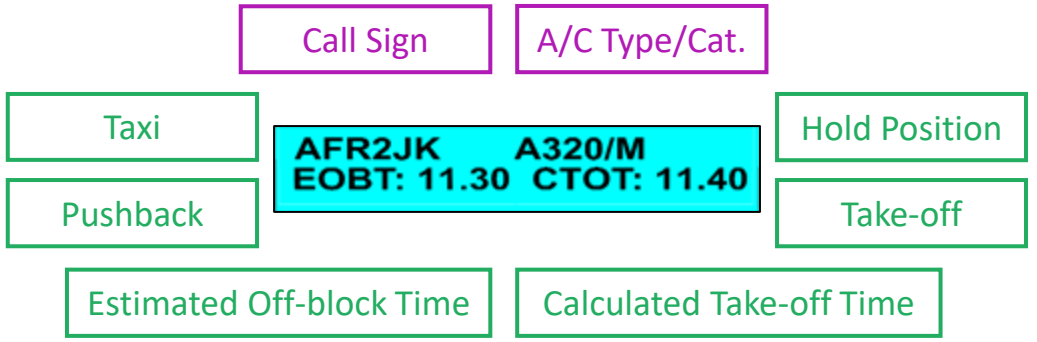


Adaptive HMI for Visibility Condition and Phase of Flight

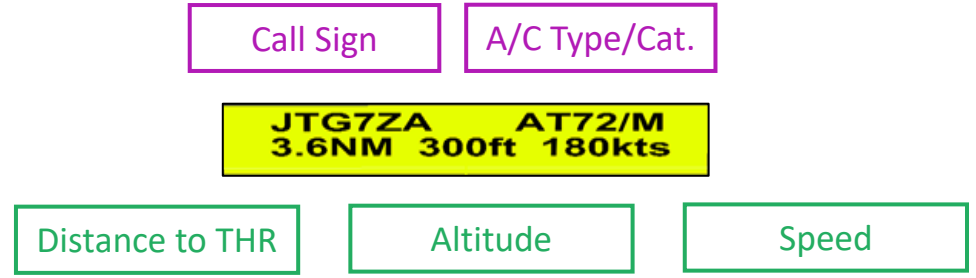




- Departure label (appears when handler is ready)

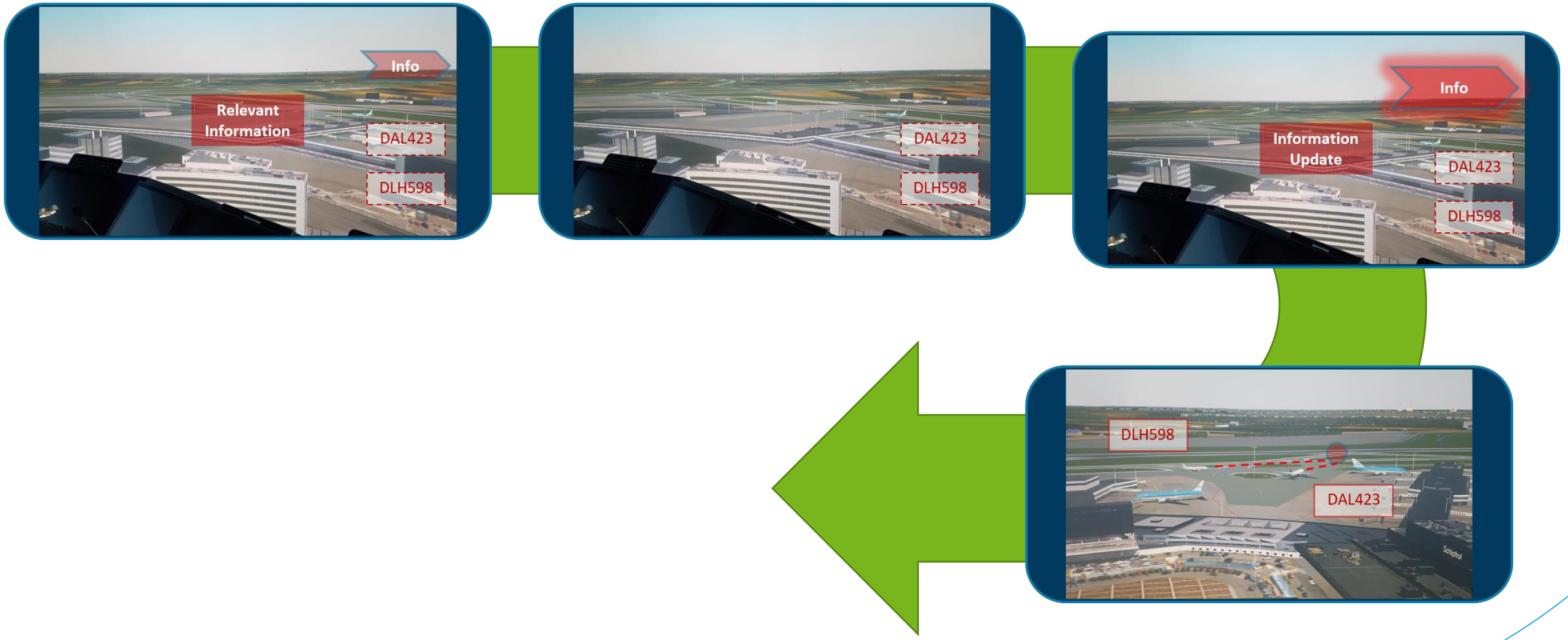


- Arrival label (appears at specific distance on final)



→ Adaptive information (in green)

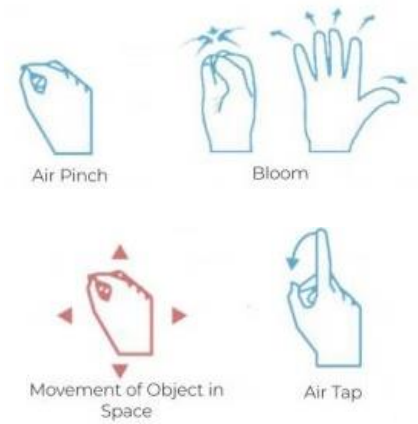
Attention Capturing and Guidance



Air Gestures

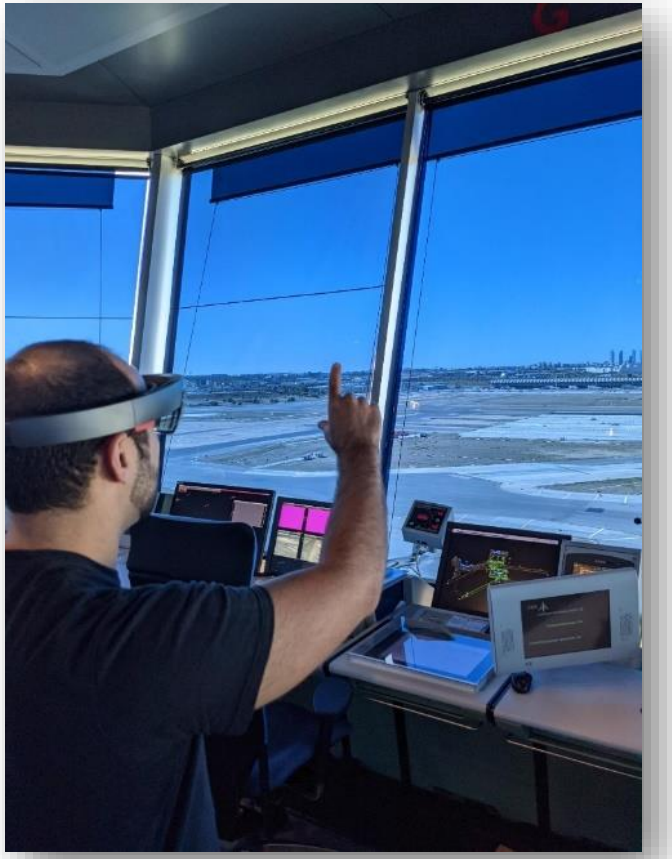
Non time-critical tasks:

- Pushback
- Start-Up





Interaction with ***Tracking Labels and Menus***:



Experimental Set-up

- Real-time Simulation
- 2 ATCOs
- 3 days
- 32 runs
- Questionnaires
- Debriefing/Interviews

EXE-05.97.1-VAR-001:
Validation of AR Interaction Modes for Schiphol Tower with Focus on Attention Guidance



- Real-time Simulation
- 10 ATCOs
- 2 weeks
- 50 runs
- Objective measures
- Questionnaires
- Debriefing

EXE-05.97.1-VAR-002:
Augmented Reality Multimodal Control Tower Interaction



- Shadow-Mode Trial
- 4 ATCOs
- 1 week
- Observations
- Questionnaires
- Debriefing

EXE-05.97.1-VAR-005:
Augmented Reality in the Tower Environment



Human Performance Results - Argument 1

- Role of human is consistent with human capabilities and limitations
  - ***Reducing the need for head-down operations*** improving Situation Awareness and Workload through:
    - Partially replacing CWP HMI ***monitoring task*** with OTW view monitoring
    - V/A-R layers displayed in ***low visibility*** conditions with the provision of wind/***weather information*** and airport ***layout*** overlay in the head-up device
    - ATCO interactions with virtual reality device to change the visualization and to ***provide non-critical clearances through predefined air gestures***
    - ATCO's attention recalled and guided by the new technology instead of requiring a periodic head-down scan, also ***improving critical situations' reaction time***



Human Performance Results - Argument 2

- Technical ***systems support*** human actors in performing their tasks
  - ***Attention guidance*** to ATC critical situation leading to the ***reduction of potential for human error*** (missed alerts) but might also introduce potential for overreliance
  - ATCO productivity benefits thanks to the performances of the technical system ***increasing head-up time*** and reducing switch between out of the window view and head down CWP HMI if the system works as intended
  - Output devices (***CWP-HMI***) are expected to be complemented: A/V-R and ***Attention Guidance*** head-up interface
  - Input devices (***mouse, keyboard/digital pen***) are expected to be complemented: ***air gesture*** to interact with A/V-R head-up interface



Human Performance Results - Argument 3

- Team structure and team communication support human actors in performing their tasks
  - No changes, but Team (TWR controllers) ***SA positively impacted by the sharing of information*** displayed in the Head up display, also reducing the need of team communication
  - Adaptive/configurable devices



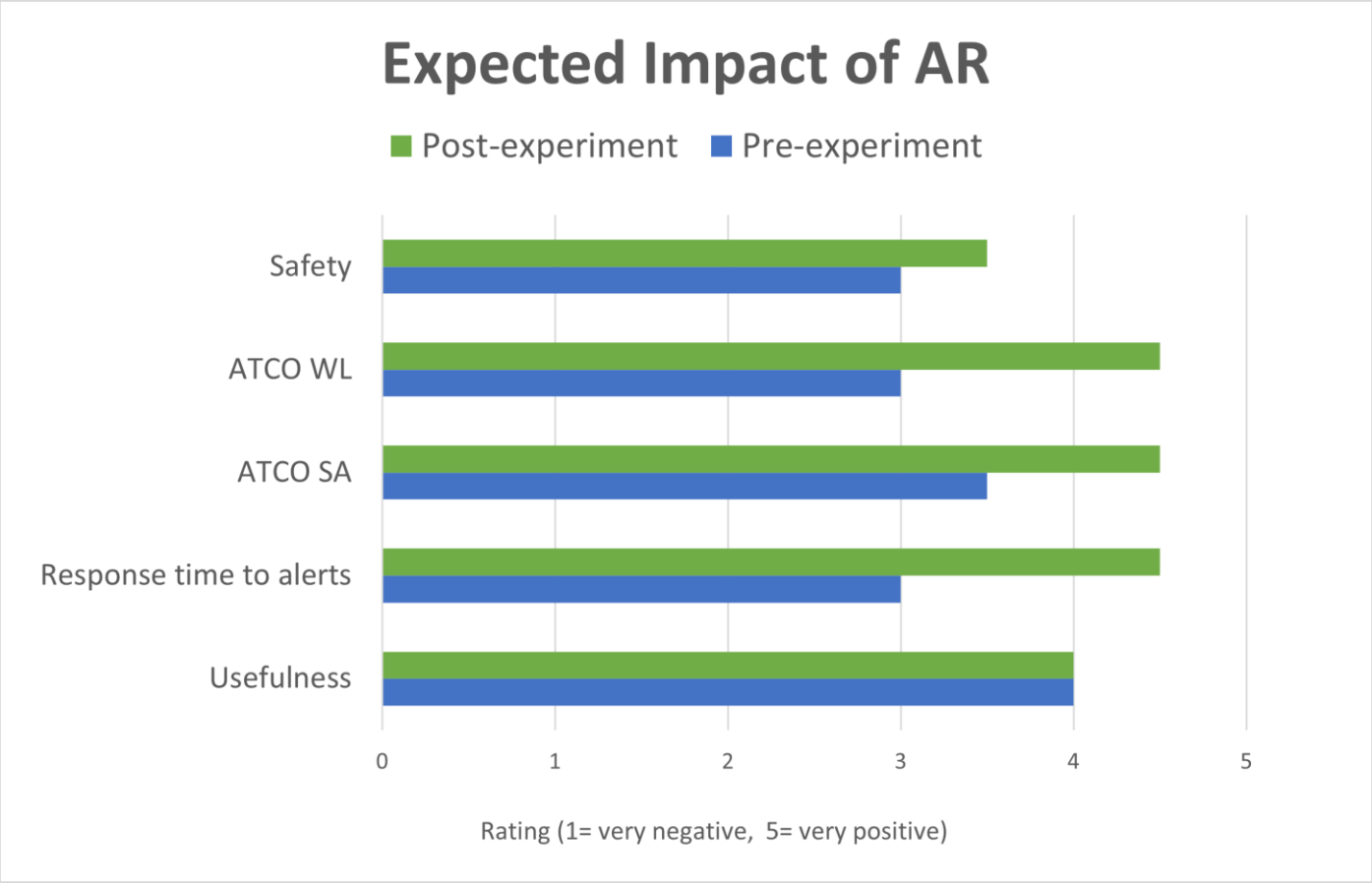
Human Performance Results - Argument 4

- Human Performance related transition factors are considered
  - A/V-R support ***improving job acceptance and satisfaction in case of very good system performance*** and in general smooth new technology attracts new ATCOs, but might also negatively affect both job acceptance and satisfaction in case of abnormal and degraded mode/malfunctions
  - The controllers will ***need to be trained*** on the A/V-R functionalities and system knowledge with consequent changes in the content of training



Selected Results

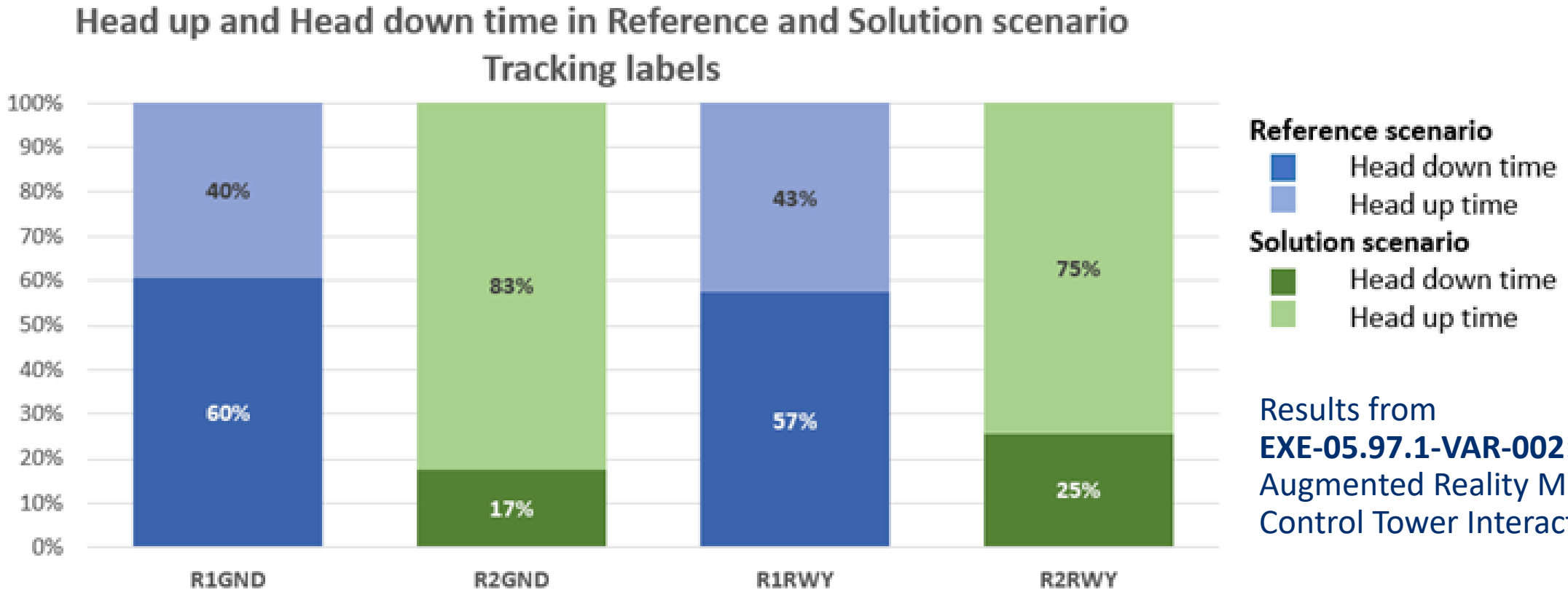
Expected Impact of Augmented Reality (Attention Capturing and Guidance)



Results from **EXE-05.97.1-VAR-001**: Validation of AR Interaction Modes for Schiphol Tower with Focus on Attention Guidance

Selected Results

Head-up vs. Head-down Time (Tracking Labels)



Results from **EXE-05.97.1-VAR-002**: Augmented Reality Multimodal Control Tower Interaction

Selected Results

Safety (Tracking Labels and Safety Nets)

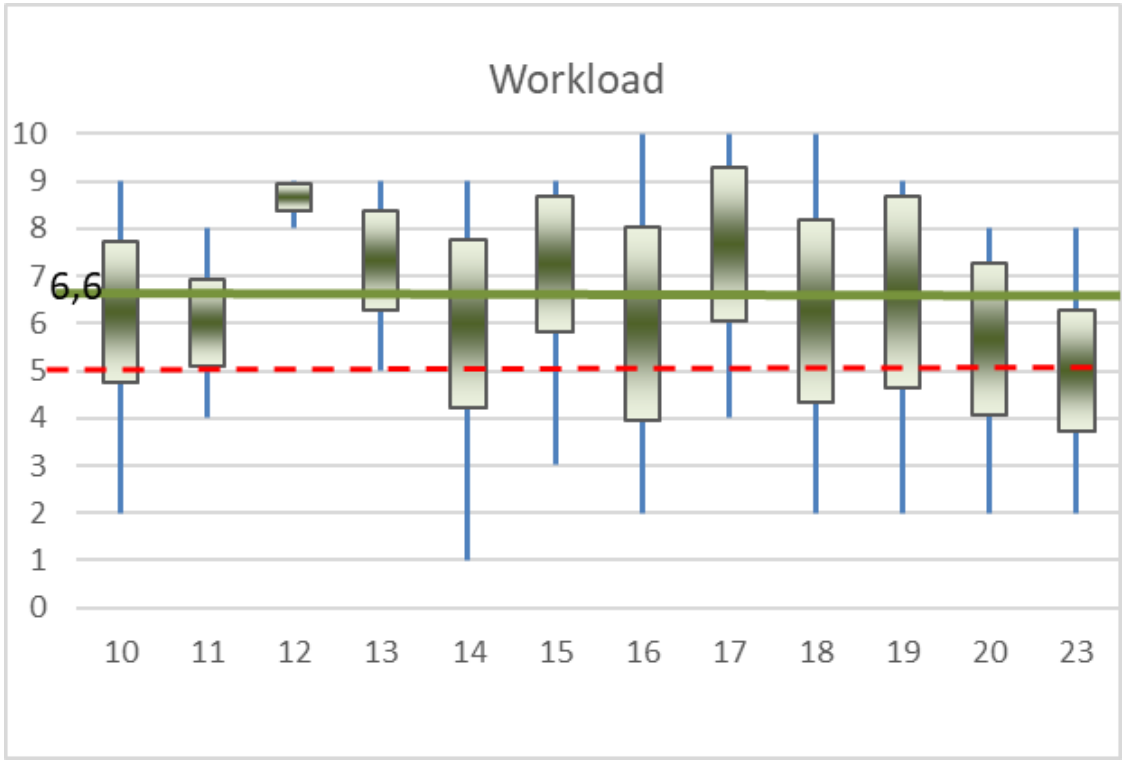


Results from
EXE-05.97.1-VAR-002:
Augmented Reality Multimodal Control Tower Interaction

Selected Results

Human Performance

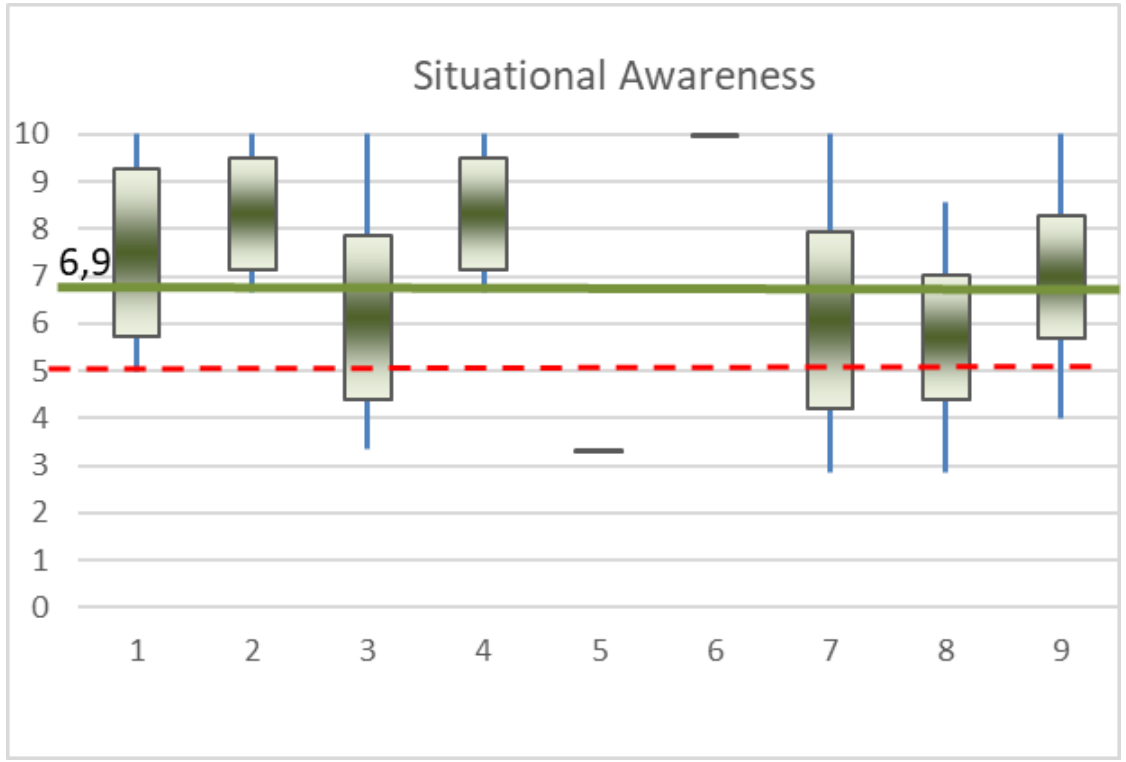
Results from
EXE-05.97.1-VAR-005:
Augmented Reality in the
Tower Environment



In the previous working period,....	
10	Mental Demand
11	Physical Demand
12	Temporal Demand
13	Performance
14	Effort
15	Frustration
16	Identify the a/c in my operational area
17	Access relevant a/c or flight information
18	Integrate information from various sources to form a mental picture.
19	Recall necessary information
20	Recognise a mismatch of available data with the traffic picture
23	Compared to your current situation, how do you think the new tools available affected your perceived workload?

Selected Results

Human Performance



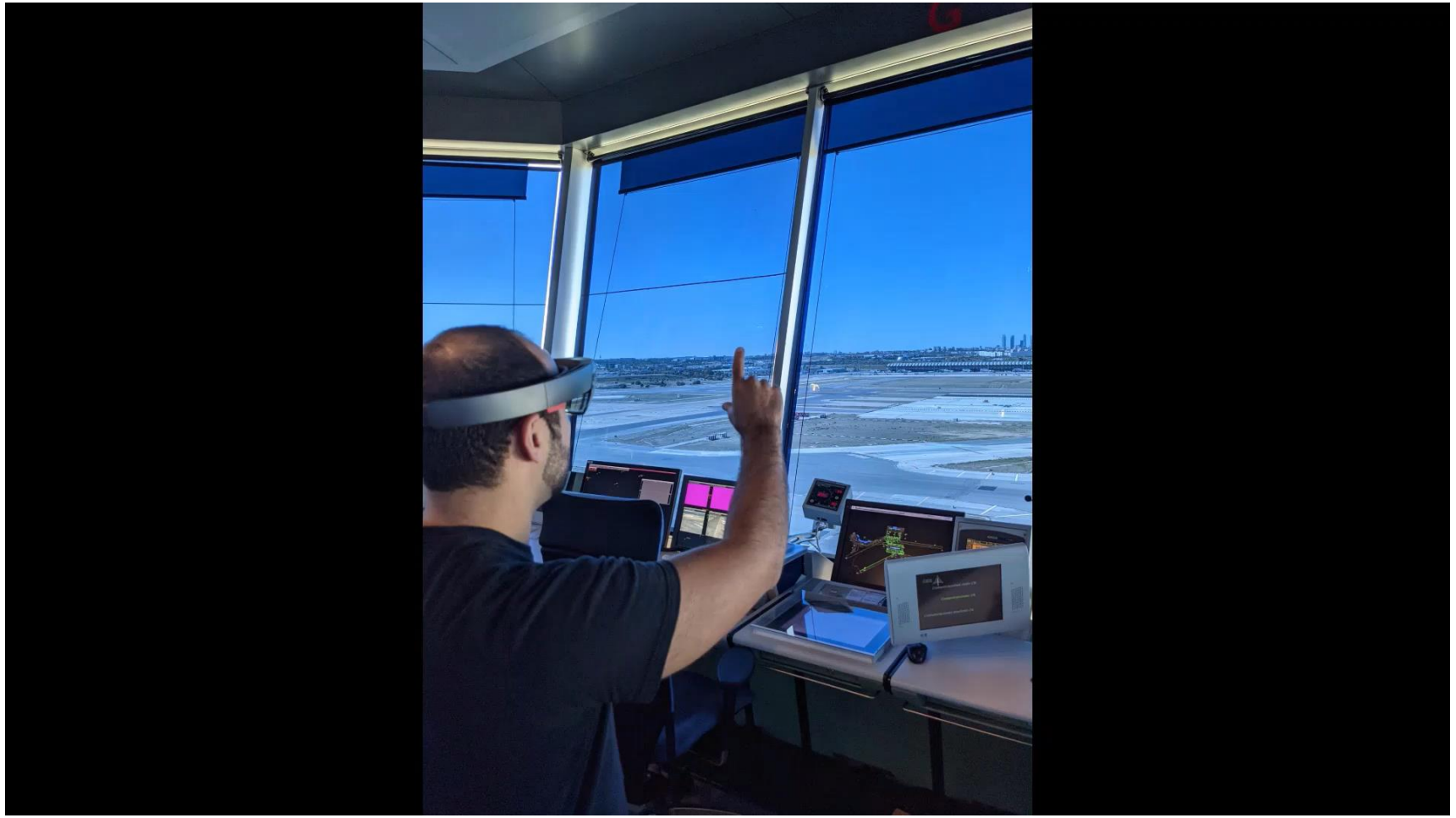
Results from
EXE-05.97.1-VAR-005:
Augmented Reality in the Tower Environment

In the previous working period,....	
1	I was ahead of the traffic
2	I started to focus on a single problem or a specific area of the airport surface.
3	there was a risk of forgetting something important (like providing a clearance on time or communicating a change to an a/c).
4	I was able to plan and organise my work as I wanted.
5	I was surprised by an event I did not expect (like an a/c call).
6	I had to search for an item of information.
7	Do you think that with the objects offered by the new functionality you have a **complete and reliable** representation of the traffic picture?
8	The new HMI (AR Goggles) **improves the capacity to focus attention** when and where appropriate.
9	Compared to your current situation, how do you think the new tools affected your situational awareness?

UNIBO - ENAV



ENAIRE-CRIDA



Conclusions

- ***Technical feasibility***, at target maturity TRL4
- ***Human aspects***
  - The solution has a clear effect in stimulating the ATCOs to ***work in head-up position***, reducing the number of switches between head-up and head-down mode
  - ***Workload*** and ***Situational Awareness*** are acceptable and sometimes improved with respect to the reference
  - Large variations in ***Acceptability and Usability*** ratings between ATCOs were observed
  - ***Usability of complex Air Gestures*** needs for training/further investigations
- ***Implementations***
  - ***HMI design*** works fine but could be further improved
    - Time/duration of alerts, position of labels, brightness…
  - ***Ergonomics aspects***
    - Depending on Hololens version
- ***Operational impacts***
  - ***Attention Capturing and Guidance*** concepts could be implemented satisfactorily and (related) ***Safety Net visualisation*** has a potential to improve safety
  - Benefits are enhanced in ***Low Visibility Conditions***

Questions



sesar
JOINT UNDERTAKING

THANK YOU FOR YOUR ATTENTION

Co-funded by the European Union

Close out meeting
Solution 97.2

Ramona Santarelli, Hartmut Helmke, Gyorgyi Balogh, Walter Rinaldi

PJ.05-W2 Close out meeting, Geneva, 7 March 2023

EUROPEAN PARTNERSHIP

Co-funded by the European Union

Solution 97.1 Team



KOM: 30-Jan-2020

Close-out: 7-Mar-2023

SESAR activities line

Automatic speech recognition at the TWR CWP supported by AI and machine learning

High-performing airport operations



Previous SESAR Validations

- **MALORCA**, Machine Learning of Speech Recognition Models for Controller Assistance
- **PJ16.04,** CWP HMI
- **HAWAAII** project

Recommendations for W2

- Use of **Machine Learning**
- **Validate** ASR with command prediction in **Tower environment**
- **Update requirements** in consideration of results
- CBA

SESAR W2 validations

- **PJ.05-W2-Sol.97-2, ASR at the TWR CWP supported by AI/Machine Learning**
- PJ.10-W2-Sol.96 Validations in ENR/TMA environment

Technical Validations



EXE-004-TRL4-ASR (RTS)

- INDRA and HUNGAROCONTROL

EXE-006-TRL4 (RTS)

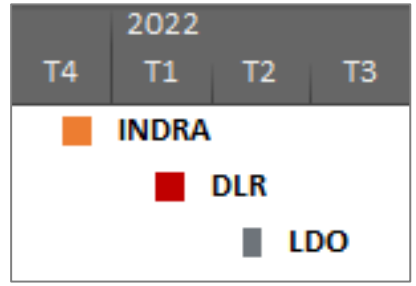
- DLR (AT-One) with B4 and COOPANS

EXE-007-TRL4 (RTS)

- LEONARDO

Maturity

TRL 2 → TRL 4 → TRL 6



Expected Benefits

	Key Performance Area	Key Performance Indicator
	CEF2 (ATCO Efficiency and Productivity)	Flights per ATCO hour on duty
	Safety	Indirect Safety Impacts
	Human Performance	User Acceptability of Solution (qualitative) Cognitive indicators Human Error

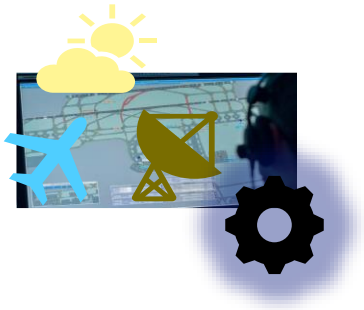
Use Cases

TWR Clearance Delivery ATCO

TWR Ground ATCO

TWR Runway ATCO

(delivered by one ATCO)





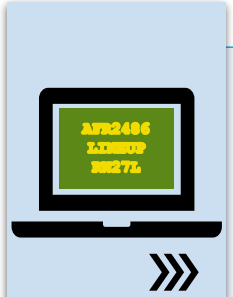
HIGHLIGHTING OF RECOGNIZED **CALLSIGN**



SHOWING FULL RECOGNISED **COMMAND** IN HMI



MANUAL **MANIPULATION** OF ASRU OUTPUT

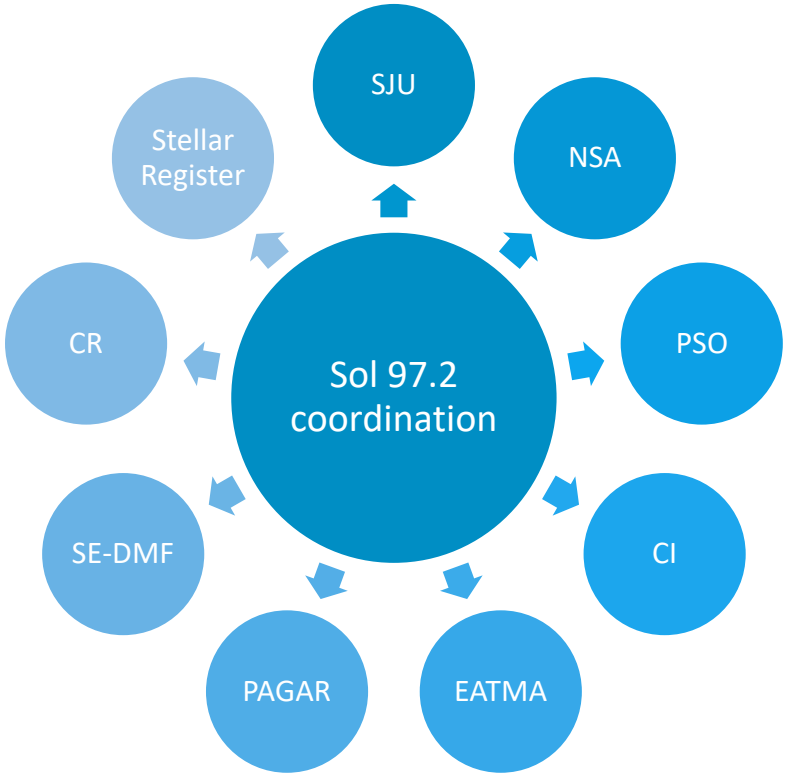


(AUTOMATIC) **ACCEPTANCE** OF ASRU OUTPUT

PHRASEOLOGY

Callsign	Command-Name	2nd part of cmd	Value	Unit
	CLEARED	TAKEOFF	runway	
	CLEARED	TOUCH_GO	runway	
	PUSHBACK			
	STARTUP			
	TAXI	Preposition	TX-Point(s)	
	HOLD_AT		TX-Point	

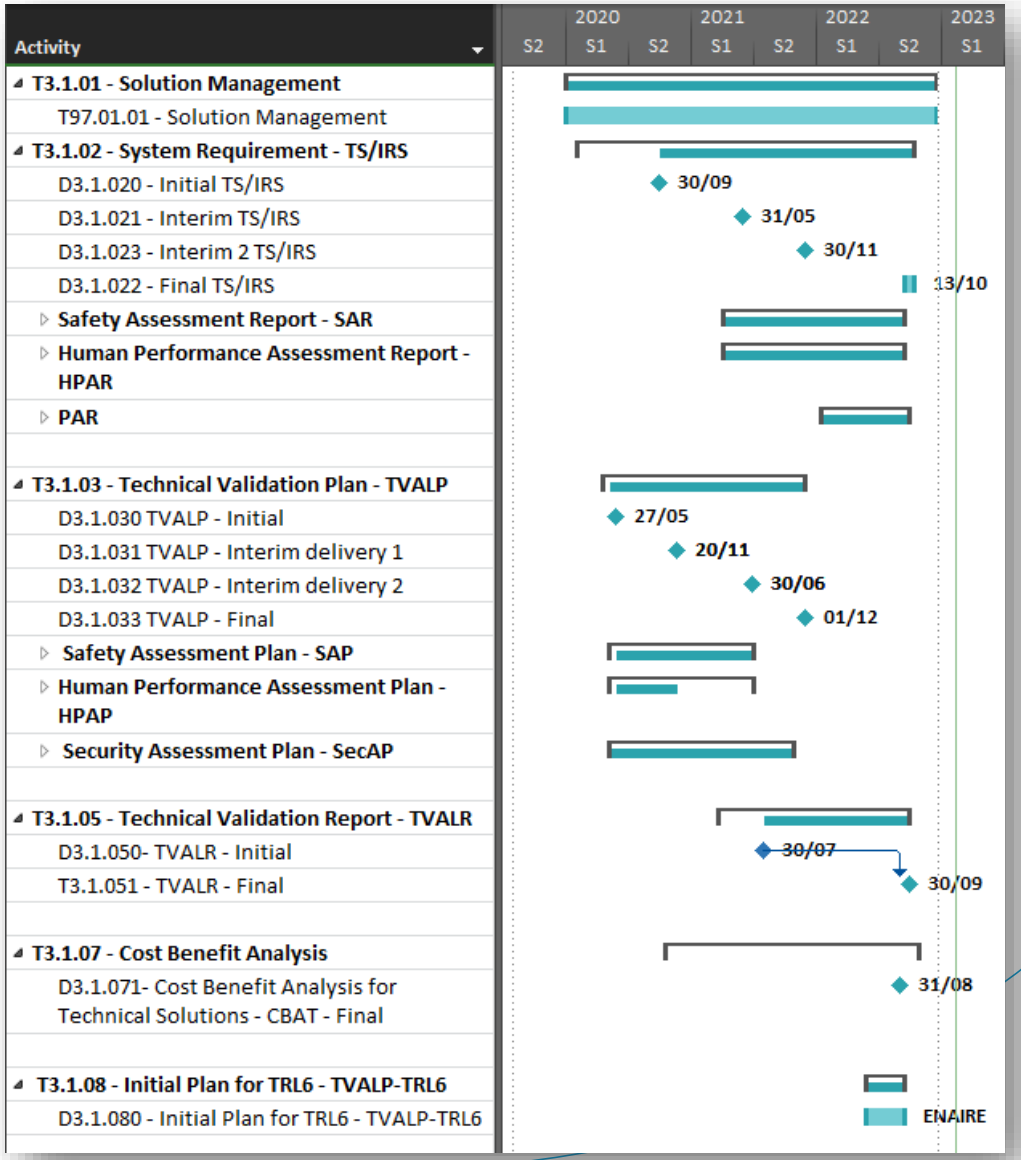
Tasks



Deliverables:

- TS/IRS, incl.
  - SAR
  - HPAR
  - PAR
- TVALP, including
  - SAP
  - HPAP
- CBAT
- TVALR
- iTVALP for TRL6
- Platforms Availability Notes





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1. **Introduction to Sol97 Speech Understanding**

2. Description of the 3 Validations
   a. Norwegian airspace (EXE-004)
   b. Lithuanian airspace (EXE-006)
   c. Bulgarian airspace (EXE-007)

3. Results of the experiments

4. Summary and Outlook

Understanding Tower Controller Communication for Support in Air Traffic Control Displays

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HungaroControl
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Haris Usanovic
Austro Control (ACG),
Schnirchgasse 17,
1030 Vienna, Austria

This presentation is based on an article submitted to SID 2022 in Budapest:
O. Ohneiser, H. Helmke, S. Shetty, M. Kleinert, H. Ehr, Š. Murauskas, T. Pagirys, G. Balogh, A. Tønnesen, G. Kis-Pál, R. Tichy, V. Horváth, F. Kling, W. Rinaldi, S. Mansi, G. Piazzolla, H. Usanovic, “Understanding Tower Controller Communication for Support in Air Traffic Control Displays”, SESAR Innovation Days 2022, Budapest, 2022.

5:00

What the Air Traffic Controller says

- *oscar bravo alfa [hes] bravo alfa six*
- Audio → Word Sequence (**Transcription**, Speech-To-Text)

and what (s)he means (semantics):

- *OKVBA* TAXI VIA *B A*
- *OKVBA* TAXI TO *STAND_6*
- Word Sequence → Semantic (**Annotation**, Text-To-Concept, Ontology)

- Actually – what we learned from MALORCA, HAAWAII, Turing etc.

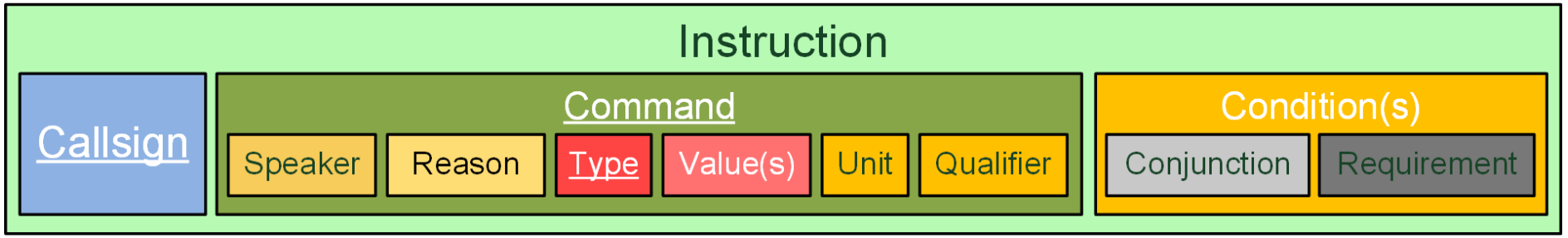
Speed Recognition is NOT Speech Understanding
Alan Turing 1952

Rules for Transcriptions and Annotations

Transcription rules

- “speed bird” not “speedbird”, “bye bye” not “byebye” …
- Non-understandable words: “[unk]” / “[UNKNOWN]”
- Human noise / thinking loud: “[hes]” / “[HNOISE]”
- Non-English words: “[NE Icelandic] [/NE]” / “<FL></FL>”
- Spelled letters – not pronounced using the International Civil Aviation Organization (ICAO) alphabet such as “*alfa”, “bravo”*, etc.: ”KLM” “K L M” ”~k~l~m”
- Truncated / broken word parts:
  “luf*”, “luf-”, “luf=” if *“lufthansa”* was not uttered fully till the end

Ontology Scheme for **Annotation**
(agreed between major European ATM stakeholders in PJ.16-04 and updated by HAAWAII)



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8:10

NOR: Validation Platform

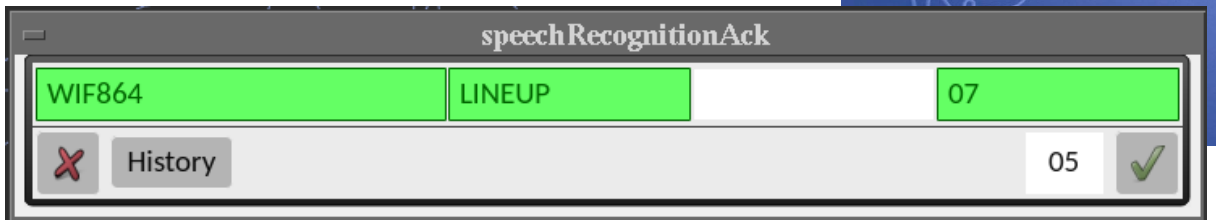
- HungaroControl ASR Prototype Module
- Indra Command Predictor
- Indra InNOVA TWR
- Indra GAREX VCS
- Micro Nav BEST simulator



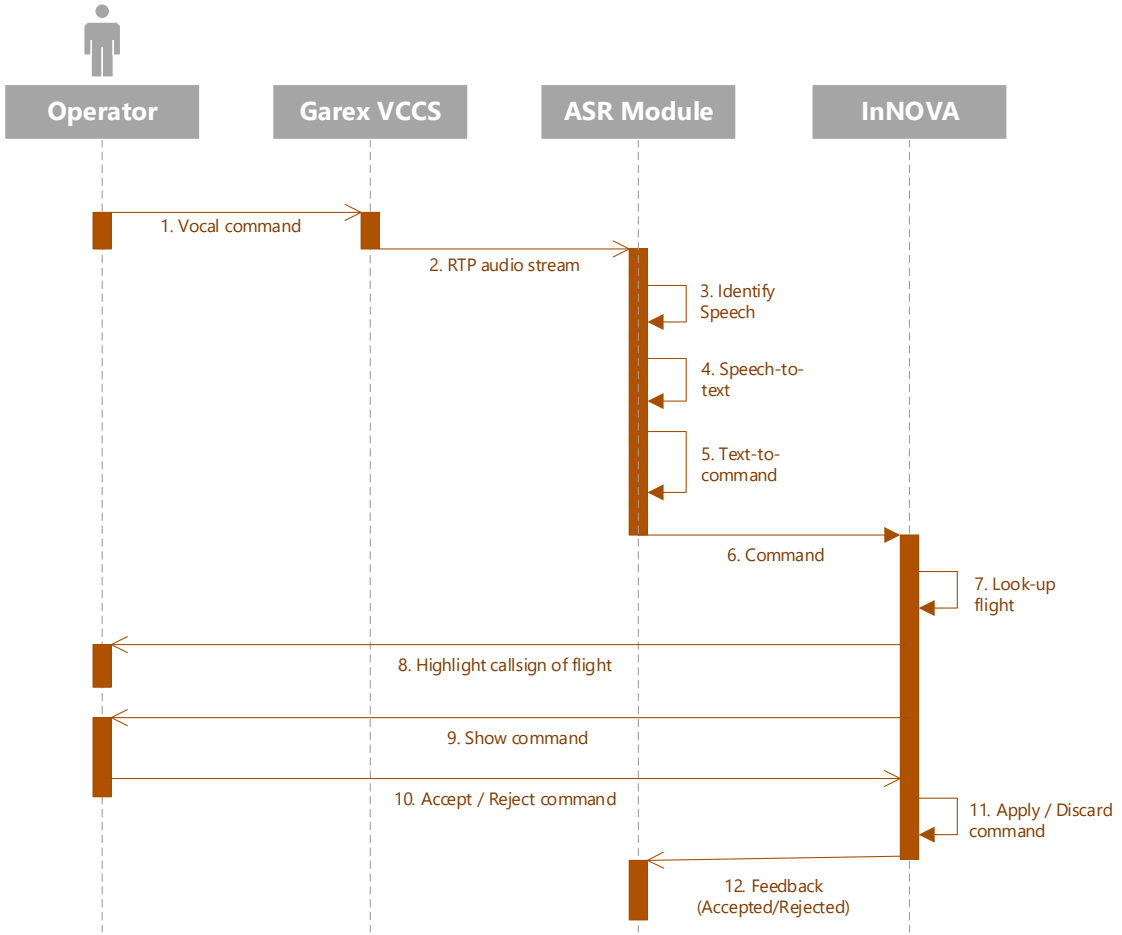
NOR: Functionality for ATCo

- Highlight callsign in flight strip
- Highlight target in map
- Show recognized commands
- Automatically apply command
  ...or manually reject command





NOR: How?



Assisted by Machine Learning

The machine learning command predictor builds experience by continuously monitoring and logging contextual information, like:

- Flight position and destination
- Type of flight
- Clearances given

Results integrated into InNOVA HMI's flight strips and traffic situation display

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10:00

LIT: Electronic Flight Strips and Outside View of Multiple Remote Tower Setup

- Validation Trials in DLR TowerLab
- Controlling three remote airports

- Outside View
- Radar Displays
- Electronic Flight Strip System



LIT: Transcription (Speech-To-Text) and Annotation (Text-to-ATC-concepts) View

- Baseline without Assistant Based Speech Recognition (ABSR)
- Solution with ABSR
  - Callsign Highlighting
  - Highlighting of status icons for flight strip maintenance
  - Output of transcription and annotation
- Assessment of
  - Technological feasibility (e.g., system usability)
  - Operational feasibility (e.g., automatic flight strip maintenance)
  - Human performance (e.g., workload, situation awareness, errors, acceptance)



LIT: Electronic Flight Strip System



Air Traffic Controller (ATCo) Utterance

Transcription [Utterance Speech-to-Text word-by-word]

airest cargo five five zero vilnius tower you are cleared to destination via erlos one delta departure squawk is two one seven four startup approved QNH one zero two one [hes] runway one three



AEG550 STATION VILNIUS_TOWER
AEG550 CLEARED TO DESTINATION
AEG550 CLEARED VIA ERLOS_1D
AEG550 SQUAWK 2174
AEG550 STARTUP
AEG550 INFORMATION QNH 1021
AEG550 INFORMATION ACTIVE_RWY 13

LIT: Supported Command Types

Command Type	Portion of all Commands
STATION	20.2%
INFORMATION WINDSPEED	7.5%
INFORMATION WINDDIRECTION	7.5%
TAXI TO	6.4%
GREETING	5.6%
TAXI VIA	4.8%
AFFIRM	4.0%
INFORMATION QNH	3.3%
CLEARED VIA	2.9%
STARTUP	2.9%
CLEARED TO	2.9%
CLEARED TAKEOFF	2.8%
FAREWELL	2.8%
CLEARED LANDING	2.8%
SQUAWK	2.8%
LINEUP	2.4%
REPORT	1.5%
PUSHBACK	1.4%
INFORMATION ACTIVE_RWY	1.4%
NO_CONCEPT	1.4%
REPORT_MISCELLANEOUS	1.4%
VACATE VIA	1.2%
CLEARED TOUCH_GO	1.1%
others	8.9%

- 7,560 commands in total
  (20 simulation runs of one hour each)
- Only command types are shown, which at least occur 50 times.

LIT: Available Data (Status May 2022)

Solution 97, Exercise 006, Lithuanian Airport (ON)

- 2,000 manually transcribed and annotated utterances (3.6 hours)
- 3.3 hours of untranscribed data

Solution 97, Exercise 006, Austrian Airport (ACG)

- 500 manually transcribed and annotated utterances (0.9 hours)

HAAWAII NATS

20,600 utterances (20.5 hours)
16,600 manually transcribed (16 hours)
4,100 (4 hours) annotated
400 hours of untranscribed data

HAAWAII Isavia

17,700 utterances (21.5 hours)
17,500 manually transcribed (21 hours)
3,010 (3.5 hours) annotated
80 hours of untranscribed data

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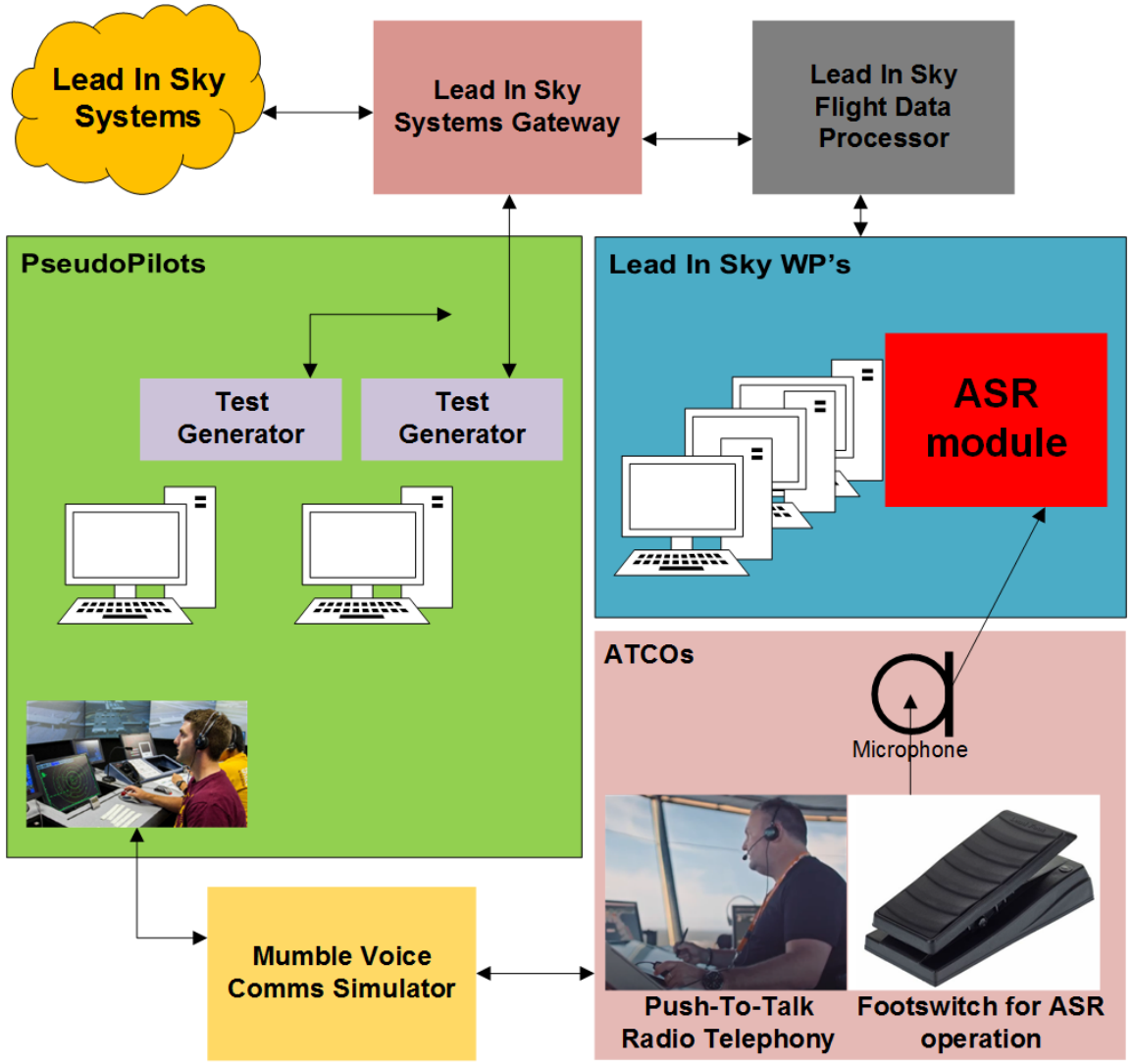
3. Results of the experiments

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14:10

BUL : Setup

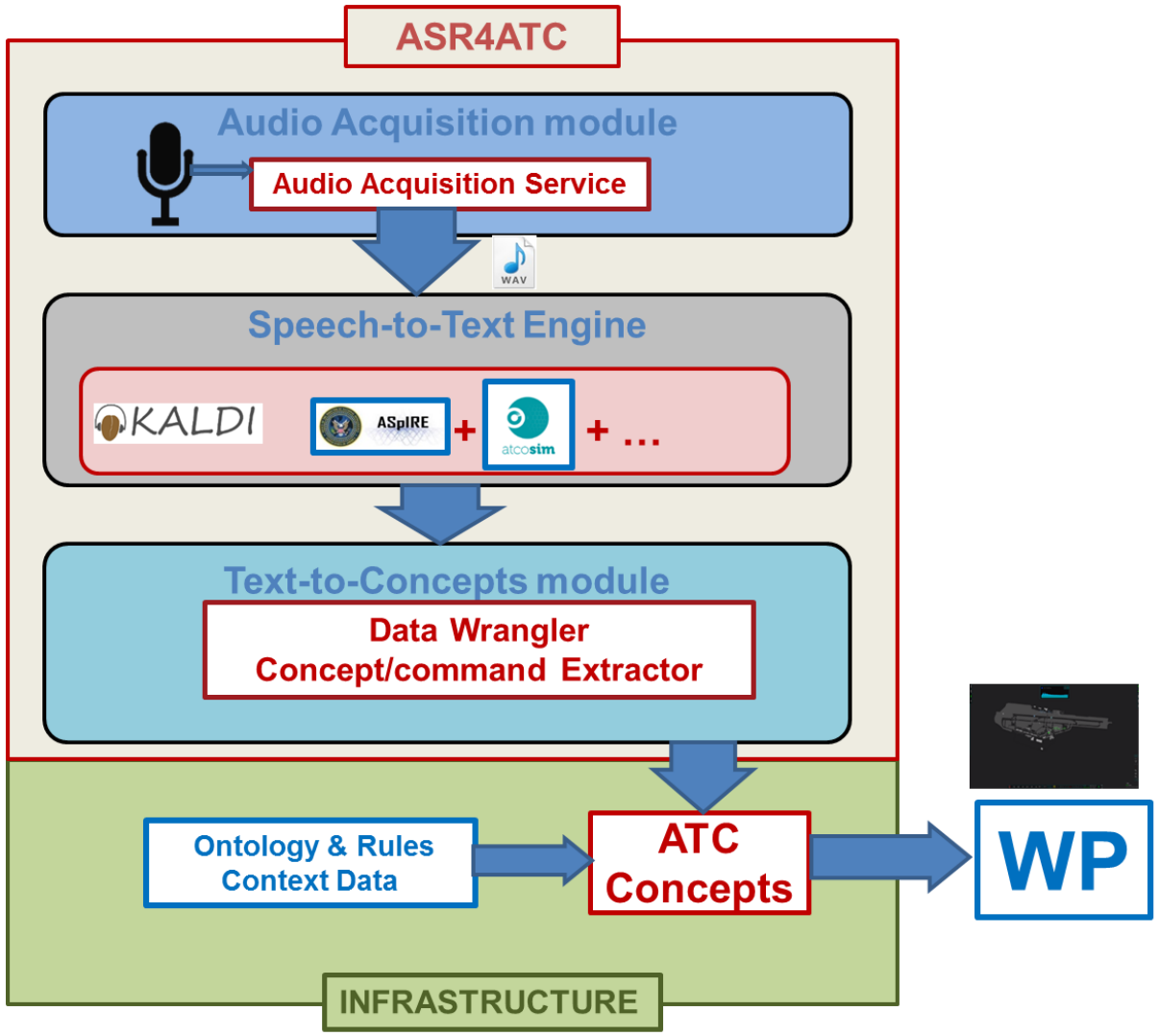


- Developed from scratch in one year
- Better Integration with "Lead in Sky" and A-SMGCS can improve recognition performance

- Footswitch activates ASR;
- PTT activates R/T

PTT = Push-to-Talk, R/T = Radio Telephony,
A-SMGCS= Advanced Surface Movement Guidance and Control System

BUL: ASRU Components



- Strict usage of ICAO phraseology
- ATM Ground/Tower environment
  - Basic command range
  - Reduced part of ontology
  - -> reduced error rate

- Callsign list of active/live flights used as context-based data (command prediction)

- ASR applications:
  - Callsign highlighting
  - recognized commands

ICAO = International Civil Aviation Organization

ABSR Prototypes and Simulation Platforms with Validation Info

	LIT	NOR	BUL
Organizations	DLR, ON, ACG (Idiap)	Indra Navia, HungaroControl	Leonardo, ENAV
STT	based on KALDI: Idiap, Switzerland	HungaroControl (voice system from Indra)	based on KALDI: Leonardo
Audio Recording	16 kHz mono	8 kHz mono	8 kHz mono
Text to Concept	DLR	HungaroControl	Leonardo
Human Machine Interface	DLR Electronic Flight Strip System Prototype	Indra Navia InNOVA System	Leonardo Lead In Sky Ground Working Position, A-SMGCS
Environment	Multiple Remote Tower and Ground (three airports for Lithuania)	Remote Tower (Norwegian airports)	Tower and Ground (Sofia airport from Bulgaria)
Validation Place and Date	Braunschweig, Germany, Q1, 2022	Asker, Norway, Q4, 2021	Rome, Italy, Q2, 2022
ATCos (Validation Participants)	10 ATCos: 5 from ON (Lithuania), 5 from ACG (Austria)	6 ATCos from HungaroControl	6 ATCos from ENAV
Supported Cmds Types	All of ontology	21	6

16:40

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3. **Results of the experiments**

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Speech-To-Text Performance

	LIT	NOR	BUL
Word Error Rate	5.1% [a]	-	16.9 %
# Words uttered	38,820	-	3,632
# Utterances	2,427	934	454

a. See SID paper for more details

O. Ohneiser, H. Helmke, S. Shetty, M. Kleinert, H. Ehr, Š. Murauskas, T. Pagirys, G. Balogh, A. Tønnesen, G. Kis-Pál, R. Tichy, V. Horváth, F. Kling, W. Rinaldi, S. Mansi, G. Piazzolla, H. Usanovic, "Understanding Tower Controller Communication for Support in Air Traffic Control Displays", SESAR Innovation Days 2022, Budapest, 2022.

Understanding Tower Controller Communication for Support in Air Traffic Control Displays

Oliver Ohneiser; Hartmut Helmke; Shruthi Shetty; Matthias Kleinert; Heiko Ehr
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1185 Budapest, Hungary

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Austro Control (ACG),
Schnirchgasse 17,
1030 Vienna, Austria

Text-To-Concept Performance (Callsigns)

Callsign Recognition Performance [b]	LIT	NOR	*BUL*
Callsign Recognition Rate	98.4% [c]	81.2%	89.8%
Callsign Error Rate	0.9%	7.8%	10.2%
Callsign Rejection Rate	0.7%	11.0%	

b, c: See SID paper for more details

O. Ohneiser, H. Helmke, S. Shetty, M. Kleinert, H. Ehr, Š. Murauskas, T. Pagirys, G. Balogh, A. Tønnesen, G. Kis-Pál, R. Tichy, V. Horváth, F. Kling, W. Rinaldi, S. Mansi, G. Piazzolla, H. Usanovic, "Understanding Tower Controller Communication for Support in Air Traffic Control Displays", SESAR Innovation Days 2022, Budapest, 2022.

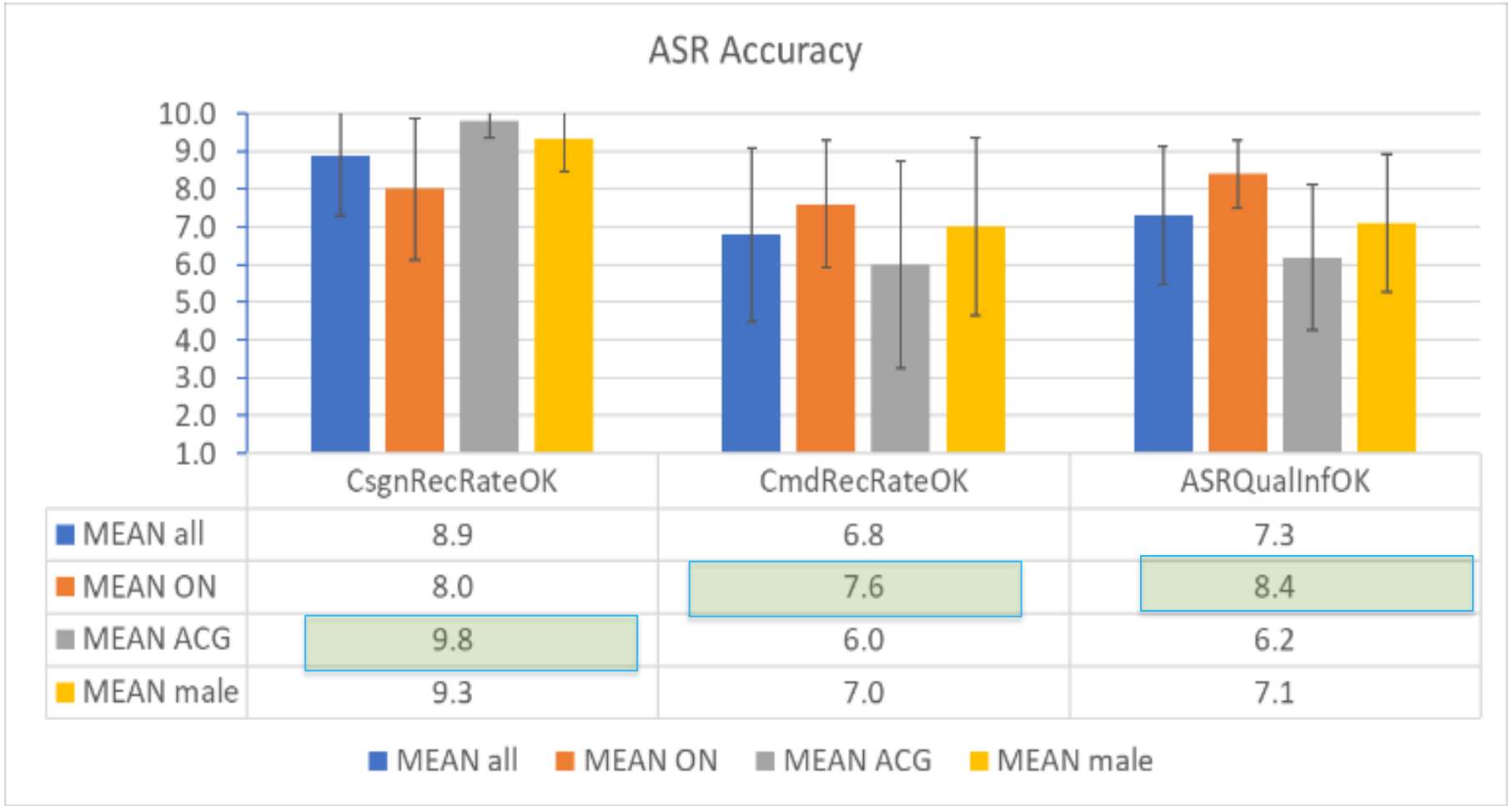
Text-To-Concept Performance (Commands)

Command Recognition Performance	LIT	NOR	BUL
Command Recognition Rate	91.4% [d]	76.0% [e]	64.6% [f]
Command Error Rate	4.5%	-	5.1%
Command Rejection Rate	5.0%	-	35.4%
Command Type Recognition Rate	94.0%	93.2%	75.9%
# Commands Uttered	7,560	993	454
# Commands per Utterance	3.11	1.06	1.00

d, e, f: See SID paper for more details

O. Ohneiser, H. Helmke, S. Shetty, M. Kleinert, H. Ehr, Š. Murauskas, T. Pagirys, G. Balogh, A. Tønnesen, G. Kis-Pál, R. Tichy, V. Horváth, F. Kling, W. Rinaldi, S. Mansi, G. Piazzolla, H. Usanovic, "Understanding Tower Controller Communication for Support in Air Traffic Control Displays", SESAR Innovation Days 2022, Budapest, 2022.

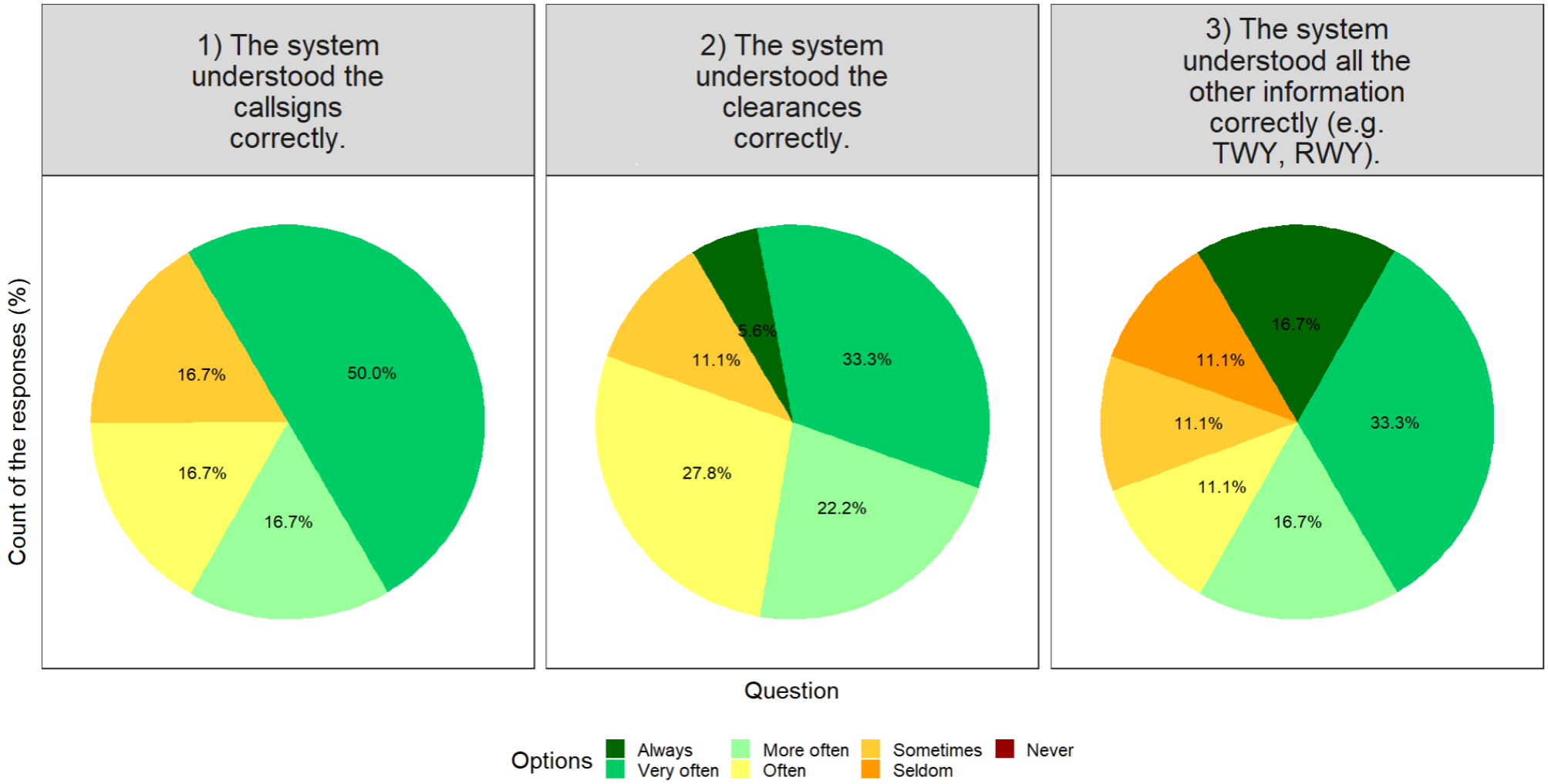
LIT: Perceived Speech Recognition and Understanding Performance



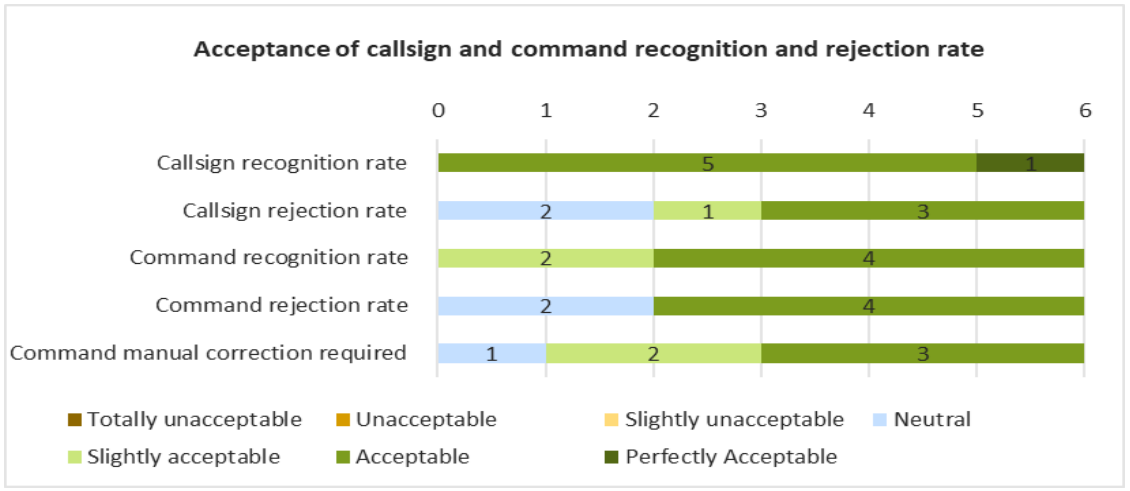
	CsgnRecRateOK	CmdRecRateOK	ASRQualInfOK
MEAN all	8.9	6.8	7.3
MEAN ON	8.0	7.6	8.4
MEAN ACG	9.8	6.0	6.2
MEAN male	9.3	7.0	7.1

ACG = Austro Control, ON = Oro Navigacija

NOR: Perceived Speech Recognition and Understanding Performance



BUL: Perceived Speech Recognition and Understanding Performance



ATCO Questionnaires main findings:

Workload does not noticeably increase with ASR, due to
- Callsign highlighting
- Satisfactory recognition rate
- Acceptable latency of response

- Situational Awareness:
  - ASR supports in keeping adequate levels of SA
  - The «hook» function is reliable and has beneficial effects on SA
- Safety:
  - Overall safety levels at worst left unaltered by ASRU with no detrimental effects observed

SA = Situation Awareness
ASRU = Automatic Speech Recognition and Understanding

21:50

HP Main Changes and Results at solution level

The **role** of the human is **consistent with human capabilities** and limitations:

- ATCO is monitoring recognised clearance instead of manual inputting
- Sometimes manual corrections are needed
- Workload reduction by up to 90%
- ASRU “guarantees” errors

  → the interface is the challenge

HP Main Changes and Results at solution level

The **technical systems** support the **human actors** in performing their tasks:

- Reducing workload
- Reducing head down time
- Improving situational awareness: highlight attention on the flight to be cleared/informed
- Level of trust improved, if the system has a high recognition rate for the callsign and commands utterance:
  - command recognition rate above >90% and
  - a maximum delay of 1 second
- The ASR support might also introduce potential for over-trust.

HP Main Changes and Results at solution level

Team structure and team communication support the human actors in performing their tasks

- No changes are expected in communication among human actors (TWR and cockpit) in terms of both means and phraseology.
- However, ATCOs might improve the adherence to the phraseology, if they have a good user experience through ASR support

HP Main Changes and Results at solution level

Human Performance related **transition factors** are considered:

- ASRU tool support improves job acceptance and satisfaction
  - in case of a good system performance and
  - interaction means that is intuitive

- Changes will be required in terms of content of training
  - no significant changes

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1. Overview of Solution 97 of Project DTT (Digital Tower Technology)

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   a. Lithuanian airspace (Exe-006)
   b. Norwegian airspace (Exe-004)
   c. Bulgarian airspace (Exe-007)

3. Results of the experiments

4. **Summary**



Outcome of all three exercises

- Agreement on common transcription rules and common annotation rules (and used in 3 different exercises)
- Callsign highlighting much appreciated
- Connect ASRU solutions to systems closer to industry (interface)
- Use (a huge amount of) data from operations room to make the step to TRL6.

O. Nunez (SID, 6.12.2022):
Planning is essential,
…but plans are worthless.

Simulations are essential,
…but simulations burn money.

- ASRU = Automatic Speech Recognition and Understanding
- TRL = Technology Readiness Level

Solution 97.2 Main Results

- Validation objectives broadly met
- Feasibility for all validation exercises
- No technological showstoppers found
- Technologies appear stable



- Promising performance levels, only in need of longer term adoption
- Cost efficiency improvement shown through ATCO workload reduction

27:10

Solution 97.2 – Confidence in the results

- Limitations
  - Prototypes entailed the need for ATCOs to adapt to different environment
  - Training sometimes not comprehensive (longer and flatter learning curve)
- Quality
  - Coverage of command types can be widened
- Statistical Significance
  - No statistical significance for subjective questionnaire based measurements
  - Thorough measurements of ASRU performance



Solution 97.2 - Conclusions

- Maturity: targeting TRL4, waiting for SJU feedback to assessment

- Technological Feasibility: ASRU technology solid and of proven feasibility now also in **tower environment**

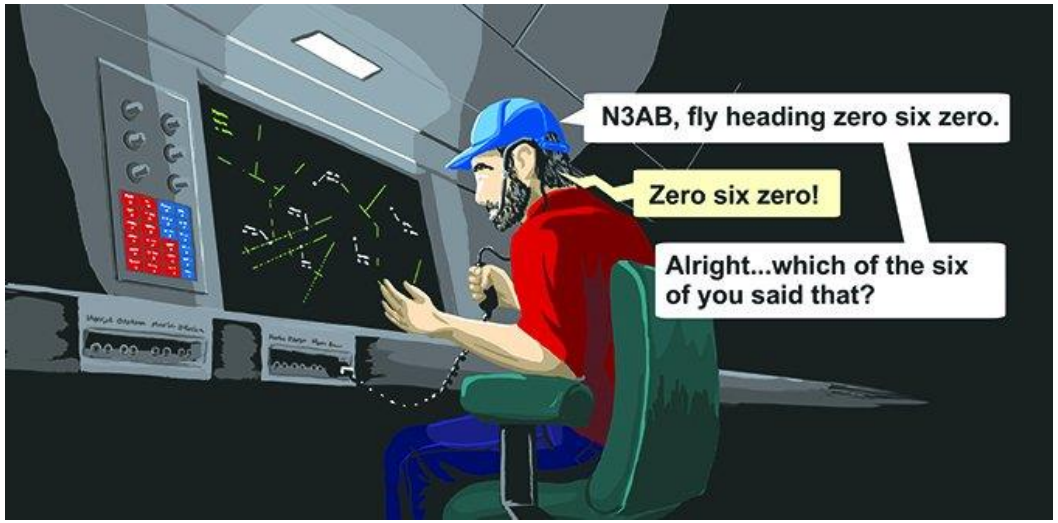
- Performance: Human Performance and Safety assessments had positive results

	EXE-004	EXE-006	EXE-007
FEASIBILITY			
ASR impact on ATCO tasks			
ASR impact on ATCO role			
ASR impact on job satisfaction			
ASR impact on Safety			

- Cost Efficiency assessment where applicable yielded positive results

Solution 97.2 – Towards SESAR3

- For Next Phase:
  - Enlarge training data (ATM ops rooms)
  - Pilot utterances (readback and more)
  - Incident analysis
  - Training for different roles
  - Intensify use of SESAR Ontology for all exercises and standardize



30:30

sesar
JOINT UNDERTAKING

THANK YOU FOR YOUR ATTENTION

EUROPEAN PARTNERSHIP

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