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PJ37-W3-ITARO

INTEGRATED TMA, AIRPORT AND RUNWAY OPERATIONS

This Human Performance Assessment Part III of the DEMO Report (DEMOR) is part of a project that has received funding from the SESAR3 Joint Undertaking under grant agreement No 101017622 under European Union's Horizon 2020 research and innovation programme.



Abstract

This document contains the Human Performance (HP) assessment Part III of the DEMO Report (DEMOR) for the SESAR2020 project PJ37 (ITARO) which consists of the Human Performance (HP) assessment plan, the results of the HP activities conducted according to the HP assessment process, newly identified issues and the HP recommendations & requirements. It corresponds to the completion of the four steps of the Human Performance assessment process, namely: Step 1 – Understand the concept: Baseline, Solution and Assumptions, Step 2 – Understand the Human Performance Implications, Step 3 – Improve and Validate the concept and Step4 – Collate findings & conclude on transition to next V-phase.

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1 Executive Summary

The present document constitutes Part III of the Demonstration Report (DEMOR), belonging to contractual deliverable (D1.5), of the SESAR2020 project PJ.37 (ITARO). It contains the Human Performance (HP) assessment reporting for the project which consists of the HP assessment plan, the results of the HP activities conducted according to the HP assessment process, newly identified issues and the HP recommendations & requirements. It corresponds to the completion of the four steps of the Human Performance assessment process, namely: Step 1 – Understand the concept: Baseline, Solution and Assumptions, Step 2 – Understand the Human Performance Implications, Step 3 – Improve and Validate the concept and Step 4 – Collate findings & conclude on transition to next V-phase.

The main HP findings based on RTS 1 are:

- The acceptability of the concept (OBJ-37-W3-HUP1-0003) was rated Partially OK (POK);
- The ATCOs were successful in achieving the tasks (OBJ-37-W3-HUP1-0008);
- The workload (OBJ-37-W3-HUP1-0009) in the solution and the reference is not significantly different, but was expected to be slightly reduced in the solution compared to the reference, in the long run;
- The ATCOs situational awareness in the solution compared to the reference was not significantly different (OBJ-37-W3-HUP1-0011).

The main HP findings based on RTS 2 are:

- The concept is acceptable for ATCOS, providing:
 - the accuracy of delivery into the TMA is sufficiently accurate (plus or minus 30 seconds),
 - the pilots are timely following up instructions, and
 - equipage levels are substantial (e.g., 80%).
- Controllers had the feeling not to have sufficient time for monitoring the traffic that is turning in for final and being able to instruct interventions when necessary.

This lead to the following recommendations:

- Design arrival routes such that
 - turns are 135 degree or larger
 - routes to parallel runways are not exactly mirrored, (avoid head-on at base leg)
 - merging routes meet in approximately 50 to 70 degree angle
 - a turn in the beginning of the RNP route can serve as a checkpoint whether flight are established on RNP
- Standardise the altitude at IAF or start the RNP at the merge point
- The concept should ensure a minimum separation at the merge point
- Place the IM achieve-by point at the merge point
- Stop IM automatically at FAF

- The integrated concept should ensure a gradual reduction of speeds and should be tested
- Presentation of ghost blip no earlier than just before entering TMA
- Design the HMI, such that
 - It is clear which flights are IM capable and which are not;
 - It is clear which flights are applying IM, and whether it is applied correctly (to the flight preceding on the route);
 - it is clear which flights are established on RNP;
 - that ATCO can change the sequence with a minimal number of actions
- Design sufficient space for the Non Transition Zone (automated monitoring) for traffic established on RNP;
- For the FDR position, consider to divide the work amongst FDR East and FDR West (same number of controllers as in current day operations).

2 Introduction

2.1 Purpose of the document

The purpose of this document is:

- To describe the ITARO (Track PJ.37-W3-01A) results of RTS1 and RTS2 concerning the Human Performance objectives as described in the Human Performance Assessment Plan (D1.4 - PJ37-W3-ITARO, DEMOP – Part IV – Human Performance Plan, Track PJ.37-W3-01A [1]).

2.2 Intended readership

The intended audience for this document are the other team members of the DEMO under investigation. HP practitioners at the level of the transversal areas of SESAR PJ.19 are also expected to have an interest in this document. Other stakeholders that may be interested in this document are to be found among:

- Air navigation service providers (including Air Traffic Controllers)
- Airport owners / providers
- Airline operators (including flight crew) and other airspace users

2.3 Structure of the document

The structure of this document is broken into five sections as follows:

- **Section 1 Executive Summary:** provides a summary of the key information and elements contained in the document.
- **Section 2 Introduction:** presents the purpose and scope of the document, the intended audience, and the main acronyms and terminology used throughout the document.
- **Section 3 Human Performance Assessment Process:** Provides a description of the Human Performance assessment methodology with the main steps to be covered during the activities.
- **Section 4 Human Performance Assessment:** Provides the Human Performance results.
- **Section 5 References** to relevant literature

The first sections are identical to these sections in the DEMOP-HPAP. Therefore, in the current DEMOR we refer to these sections in the DEMOP.

2.4 Acronyms and Terminology

Term	Description
Human Factors (HF)	HF is used to denote aspects that influence a human's capability to accomplish tasks and meet job requirements. These can be external to the human (e.g. light & noise conditions at the work place) or internal (e.g. fatigue). In this way, "Human Factors" can be considered as <i>focussing on the variables that determine Human Performance</i> .
Human Performance (HP)	HP is used to denote the human capability to successfully accomplish tasks and meet job requirements. In this way, "Human Performance" can be considered as <i>focussing on the observable result of human activity in a work context</i> . Human Performance is a function of Human Factors (see above). It also depends on aspects related to Recruitment, Training, Competence, and Staffing (RTCS) as well as Social Factors and Change Management.
HP activity	An HP activity is an evidence-gathering activity carried out as part of Step 3 of the HP assessment process. An HP activity can relate to, among others, task analyses, cognitive walkthroughs, and experimental studies.
HP argument	An HP argument is an HP claim that needs to be proven through the HP Assessment Process.
HP assessment	An HP assessment is the documented result of applying the HP assessment process to the SESAR Solution-level. HP assessments provide the input for the HP case.
HP assessment process	The HP assessment process is the process by which HP aspects related to the proposed changes in SESAR are identified and addressed. The development of this process constitutes the scope of Project 16.04.01. It covers the conduct of HP

	assessments on the Solution-level as well as the HP case building over larger clusters of Solutions.
HP benefit	An HP benefit relates to those aspects of the proposed ATM concept that are likely to have a positive impact on human performance.
HP case	An HP case is the documented result of combining HP assessments from Solutions into larger clusters (SESAR Projects, deployment packages) in SESAR.
HP issue	An HP issue relates to those aspects in the ATM concept that need to be resolved before the proposed change can deliver the intended positive effects on Human Performance.
HP impact	An HP impact relates to the effect of the proposed solution on the human operator. Impacts can be positive (i.e. leading to an increase in Human Performance) or negative (leading to a decrease in Human Performance).
HP recommendations	HP recommendations propose means for mitigating HP issues related to a specific operational or technical change. HF recommendations are proposals that require additional analysis (i.e. refinement and validation). Once this additional analysis is performed, HF recommendations may be transformed into HF requirements.
HP requirements	HP requirements are statements that specify required characteristics of a solution from an HF point of view. HP requirements should be integrated into the DOD, OSED, SPR, or specifications. HF requirements can be seen as the stable result of the HF contribution to the Solution, leading to a redefinition of the operational concept or the specification of the technical solution.

Table 1: Acronyms and terminology

3 The Human Performance Assessment Process: Objective and Approach

The aim of the HP assessment is to provide the necessary ‘evidence’ to show that the HP Arguments impacted have been considered and satisfied by the HP Assessment Process. This includes the identification of HP requirements and recommendations to support the design and development of the concept, which will be defined in the HP Assessment Report.

The HP Assessment Process is a four-step process. Reference [1] provides an overview of these four steps with the tasks to be carried out and the two main outputs (i.e. HP plan and HP assessment report). In addition, an HP Log (see Appendix A) is recommended to be maintained throughout the lifecycle of the DEMO in which all the data/ information obtained from all HP activities conducted as part of the HP assessment is documented. This HP Log is a living document and is continuously updated and / or added to as the SESAR DEMO progresses.

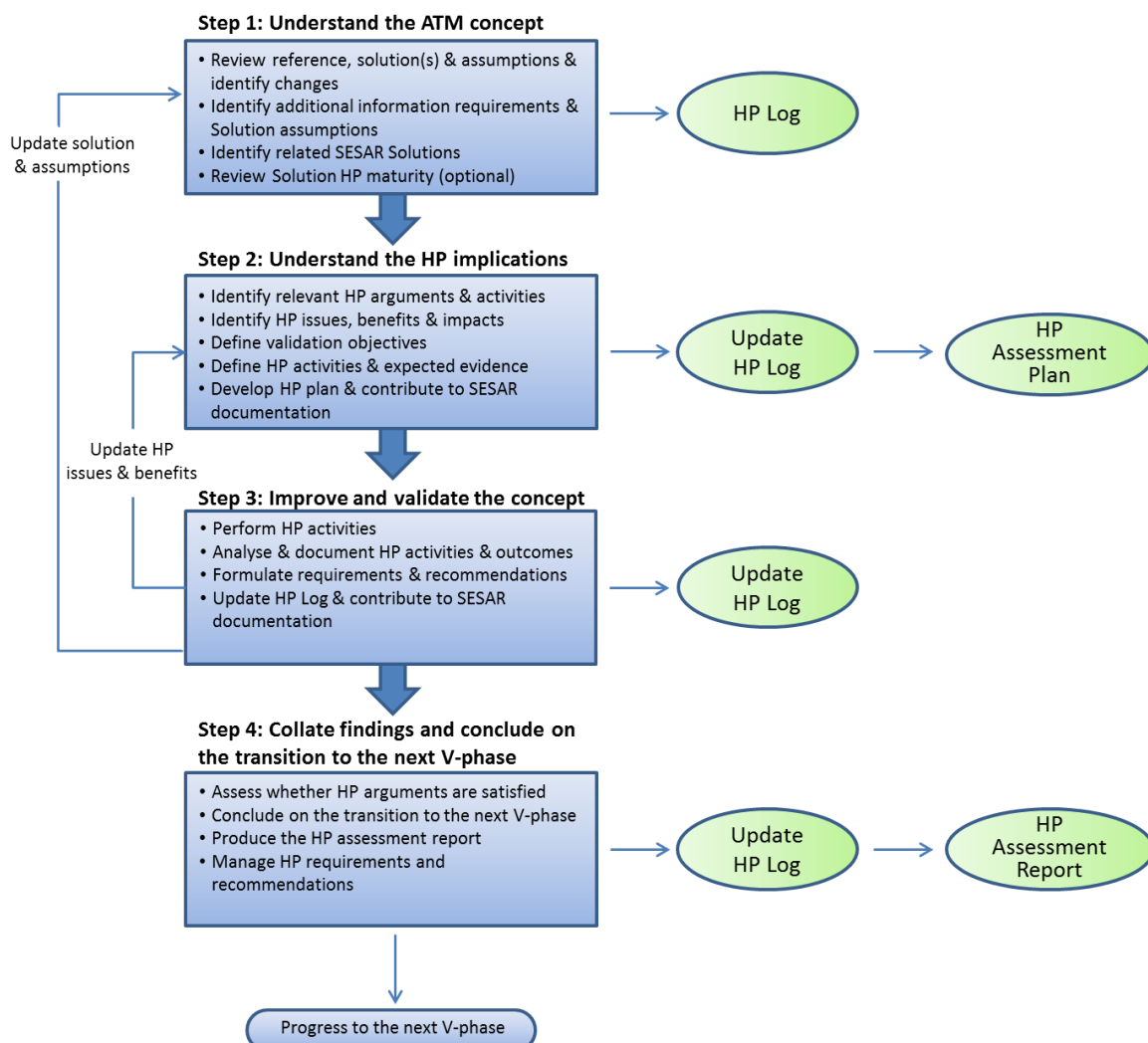


Figure 1: Steps of the HP assessment process

4 Human Performance Assessment

4.1 Step 1 Understand the ATM concept

4.1.1 Description of reference scenario

As described in the Demonstration Plan D1.4, Ref.[2].

4.1.2 Description of solution scenario

As described in the Demonstration Plan D1.4, Ref. [2].

4.1.3 Consolidated list of assumptions

As described in the Demonstration Plan D1.4, Ref. [2].

4.1.4 As described in the Demonstration Plan D1.4, Ref.[1].List of related SESAR Solutions to be considered in the HP assessment

As described in the Demonstration Plan D1.4, Ref. [2].

4.1.5 Identification of the nature of the change

A Scoping & Change Assessment workshop was held to systematically identify and capture the nature of the change that may result due to the introduction of the concept under investigation. Following this workshop, a further review by the HP Lead of the relevant SESAR documentation was conducted. The results of these activities are recorded in the “Change & Argument Identification” tab of the HP Log [3].

In summary, two high level HP Arguments are impacted in some way by the integrated arrival concept being developed by PJ.37-W3 Solution Track 1A. These are:

Arg 1: The role of the human is consistent with human capabilities and limitations.

Arg 2: Technical systems support the human actors in performing their tasks.

No changes are foreseen related to arguments 3 and 4 given the applicable maturity level.

4.2 Step 2 Understand the HP implications

4.2.1 Identification of relevant arguments, HP issues & benefits and HP activities

See Appendix F of the demo plan i.e. the HP assessment plan (Table 2: HP Arguments, related HP issues and benefits, and proposed HP activity).

The following tables provide detailed descriptions of the HP activities planned.

HP activity	By when
Risk & Benefit Analysis	September-October 2021
Human Centred Design Sessions	October-December 2021
Real Time Simulation #1 (RTS 1)	December 2021 January-February 2022
Real Time Simulation #2 (RTS 2)	July, October, November, December 2022

Table 2 Table of proposed HP activities and their priority

4.3 Step 3 Improve and validate the concept

4.3.1 Description of HP activities conducted

ACTIVITY 1.	Issue & Benefit Analysis
Description	Expert sessions to assess the credibility of the issues and benefits identified in the HP log, add additional issues and benefits if required and identify potential mitigations to reduce the risk of human error introduced by the integrated solutions.
HP OBJECTIVES	See HP Log
Tool selected out of the HP repository	Not Applicable
Planning and Approach	A list of credible issues and benefits has been produced. A plan for managing these risks and benefits has been produced.
timeline	September-October 2021

Table 3: Description of Activity 1

ACTIVITY 2	Human Centred Design Sessions
Description	Various sessions to design Human-Machine Interface of the integrated arrival concept with end users.
HP objectives	See HP Log.
Tool selected out of the HP repository	ISO 9241: Ergonomics of Human-System Interaction; Guidelines for the Use of Colour in ATC Displays.

Planning and Approach	Using a range of HP related international standards and guidance, the design of the HMI supporting the integrated arrival concept has been reviewed and recommendations made to further optimise its design.
timeline	October-December 2021

Table 4: Description of Activity 2

ACTIVITY 3	Real Time Simulation 1
Description	Assessment of whether the Integrated Arrival Concept (IAC) being developed by PJ37 W3 Sol1A meets relevant HP Arguments.
Arguments	Arg 1: The role of the human is consistent with human capabilities and limitations. Arg 2: Technical systems support the human actors in performing their tasks.
HP objectives	See HP Log
Tool selected out of the HP repository	SHAPE (SASHA, SATI), NASA TLX
Planning and Approach	Using a range of quantitative and qualitative metrics, evidence shall be gathered from users on the validity of the Integrated Arrival Concept from an HP perspective.
timeline	January - February 2021

Table 5: Description of Activity 3

ACTIVITY 4	Real Time Simulation 2
Description	Assessment of whether the Integrated Arrival Concept (IAC) being developed by PJ37 W3 Sol1A meets relevant HP Arguments.
Arguments	Arg 1: The role of the human is consistent with human capabilities and limitations. Arg 2: Technical systems support the human actors in performing their tasks.
HP objectives	See HP Log. In addition: • Validate the concept with the optimised routes and HMI changes • Robustness of the concept to inaccurate delivery of flights at IAF, and transition issues such as varying levels flight equipped with Interval Management systems.
Tool selected out of the HP repository	SHAPE (SASHA, SATI), NASA TLX
Planning and Approach	Using a range of quantitative and qualitative metrics, evidence shall be gathered from users on the validity of the Integrated Arrival Concept from an HP perspective.
timeline	October-December 2022

Table 6: Description of Activity 4

4.4 Step 4 Collate findings & conclude on transition to next V-phase

4.4.1 Summary of HP activities results & recommendations / requirements

The Table 6 below provides the results of the (run and debriefing) questionnaires used inside the RTS1 and RTS2, and the consolidated results for each HP issue/benefit.

Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
Arg. 1.2.1: Operating methods cover operations in normal operating conditions.							
1.2.1-1	The arrival management process is found acceptable by the ATCOs present in the RTS.	POK	OBJ-37-W3-DEMOP-HUP1-0003	RTS 1 and 2, questionnaire and debriefing	The post-run question on the acceptability of the concept were on average rated 4.5 (scale 1-7), with high variation in the ratings. One ATCO rated the statement 1 or 2 in four instances. The explanation provided pertained to different reasons: the low equipage level (20%), the sequence of delivery into TMA (as a result of less accurate EAT adherence) and simulator issues in nominal runs. Concluding, the acceptability is only sufficient provided that the flights are delivered accurately, pilots are timely following up instructions and the equipage level is substantial.		
1.2.1-1	Working procedures regarding transition between IM/merge tool and PWS/ORD tool are neither complete nor acceptable.	POK	OBJ-37-W3-DEMOP-HUP1-0004	RTS 1 and 2, questionnaire and debriefing	In RTS 1, all controllers rated the completeness and acceptability of the working procedures 4 (on a scale of 1 to 5) in the post-experiment questionnaire. It is concluded that both completeness and acceptability of working procedures are at an acceptable level. Nevertheless, there is room for further improvement.	REC-37-W3-R4.1: Design arrival routes such that turns are 135 degree or larger and that routes to parallel runways are not exactly mirrored (avoid head-on base legs). Validated in RTS2. REC-37-W3-R4.2: Standardise the altitude at IAF or start the RNP approach at the merge point. Standardised altitude was validated in RTS2	

Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
					In RTS 2, the ATCOs rated the completeness 2.7 and acceptability 3 (scale 1-5). The completeness and acceptability apparently reduced in comparison to the first RTS. In RTS 2 the concept was evaluated against more challenging situations that required more controller actions. For example, merging a go-around, which was rather challenging in the high volume of traffic. Also some unexpected simulation and technology behaviours may have had an effect. Overall, working procedures seem not fully acceptable and complete. Certain aspects require further attention, e.g. how to deal with (inevitable) unexpected traffic behaviour, but still fall under normal operations.	REC-37-W3-R4.3: The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can be placed at the merge point. This was validated in RTS 2 REC-37-W3-R4.4: The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.	
Arg. 1.2.4: The content of operating methods is clear and consistent.							
1.2.4-1	Working procedures regarding the transition from IM to PWS/ORD operations are not	POK	OBJ-37-W3-DEMOP-HUP1-0005	RTS 1 and 2, questionnaire and debriefing	In RTS 1, the controllers rated the clarity and consistency of the procedures at 3 or 4 (scale 1 to 5) in the post-experiment questionnaire. The average on clarity was 3.7 and on	See REC-37-W3-R4.3 See REC-37-W3-R4.4	



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Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
	clear and consistent				consistency 3.3, which indicates the controllers rated it neutral to positive. In RTS2, the ATCO rating regarding clarity and consistency of the procedures did not increase compared to RTS 1. In contrary, the consistency was reduced to 2.8. It is believed that the inconsistency due to technology aspects, that resulted in some flights increasing speeds at final approach, led to this decreased rating. Overall, working procedures clarity and consistency were neutrally rated in RTS 2. It seems that this requires further attention.		
Arg. 1.2.5: Operating methods can be followed in an accurate, efficient and timely manner.							
1.2.5-1	New working procedures & practices associated with the transition from IM to PWS/ORD are not usable / suitable or acceptable, i.e. they cannot be followed and executed in an accurate, efficient	POK	OBJ-37-W3-DEMOP-HUP1-0006	RTS 1 and 2, questionnaire and debriefing	In RTS 1, ATCOs stated that there was insufficient time to also monitor the traffic that is turning in for the final stretch. The high speeds at final seem to increase the above mentioned aspect. These findings concern both reference and solution. In addition, changing IM targets (only performed in	REC-37-W3-HUP-R6.1: In case of changes in the inbound sequence it is recommended to update the inbound planning (AMAN/Supervisor) or cancel the IM for one (or several) flights, instead of changing IM targets. REC-37-W3-HUP-R6.2: It is recommended to take a closer look at responsibilities such as monitoring the traffic at final,	





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Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
	and manner.	timely			rare cases) was found too cumbersome. For RTS 2, the above finding also applies but to a lesser extent as speeds were in general lower and the routes towards the parallel runways were no longer head-on. Overall, ATCOs were able to follow the working procedures but meanwhile mentioned that high traffic volumes and high speeds make it difficult to monitor the traffic at all route segments in the same way it is done in current operations. Also, the task of changing IM targets should be avoided.	with high volumes of traffic. Can this reasonably be expected from the ATCO?	
Arg. 1.3.1: The potential for human error is reduced as far as possible.							
1.3.1-1	The combined presentation of ITD and FTD indications and merge tool indications may lead to human errors.	OK	OBJ-37-W3-DEMOP-HUP1-0007	RTS 1 and 2, questionnaire and debriefing	In RTS 1, ATCOs did not indicate to have experienced any confusion between the tools in the post-run ratings of the Solution concept (for the Reference this was indicated once (1 in 8 runs)). One of the three ATCOs rated the HMI's robustness against error negatively. Several potential HMI improvements were identified in RTS 1 (under recommendations). In RTS 2, the combined presentation did not lead to confusion. ATCOs did not	REC-37-W3-HUP-R7.1: Design the HMI, such that: • It is clear which flights are IM capable and which are not; validated in RTS2 • It is clear which flights are applying IM validated in RTS2, and whether it is applied correctly (to the flight preceding on the route); • it is clear which flights are established on RNP; Validated in RTS2	





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
					mention this as a problem. Increased confusion was reported in runs where simulation/automation generated illogical sequences and IM settings. It was concluded that the combined presentation of ITD, FTD and merge tool indications do not lead to confusion and the probability of human error is not increased. A potential point of attention was identified (see recommendations).	that ATCO can change the sequence with a minimal number of actions REC-37-W3-HUP-R7.2: When the actual sequence is different from the planned sequence, the planning is preferably updated (automatically ensuring the right IM target for each flight). If a mix up of IM targets is a possible occurrence, the controller could be made aware of such mix-ups.	
1.3.1-1	The tasks of the ATCO are not clear with regard to actions required in relation to the IAC concept, for the transition from IM/merge tool to PWS/ORD tool, on RNAV/RNP-based fixed approach procedures (including initial, intermediate and final approach segments). This may result in tasks not adequately performed and potentially human errors.	POK	OBJ-37-W3-DEMOP-HUP1-0007	RTS 1 and 2, questionnaire and debriefing	In RTS 1, task performance self-ratings were not reduced in the solution compared to the reference. ATCO ratings on task performance were sufficiently stable and on average 5.9 (scale 1 – 7). Also confidence levels were high and confusion on what to do was low. In RTS 2 the above results are very similar. The effect of the concept on task performance and potential for human error was rated neutrally to slightly negative in comparison to the current concept of operations (vectoring). The working procedures are not absolutely clear and	Further refinement on the integrations of tools	





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
					consistent. Some further refinement on the integration of algorithms was deemed necessary.		
Arg. 1.3.2: Tasks can be achieved in a timely manner.							
1.3.2-1	Merging and spacing tasks cannot be undertaken in a timely manner whilst transitioning from IM/merge tool to PWS/ORD tool (e.g. scanning the merging and spacing of a/c; updating the spacing according to the envisaged arrival flow cannot be done in a timely manner)	OK	OBJ-37-W3-DEMOP-HUP1-0008	RTS 1 and 2, post-experiment rating	In RTS 1, merging and spacing was performed in a timely manner. The post-run ratings of 'the successfulness in achieving the task' was rated 5.9 (scale 1-7) for both conditions, which is concluded to be acceptable. Nevertheless, one ATCO mentioned it was difficult to monitor the aircraft turning in for final and meanwhile dealing with aircraft separation before the merge point. In addition, ATCOs mentioned it to be cumbersome to change all IM targets when a sequence change was required. They tended to prefer to revert to vectoring. For RTS 2, the above mentioned results apply and ATCOs were slightly more pessimistic. Overall it was concluded that merging and spacing were performed timely. Nevertheless, meanwhile	REC-37-W3-HUP-R8.1: Consider automated adherence monitoring of the NTZ	





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
					monitoring the traffic turning in for final was difficult.		
1.3.2-2	The tasks of the ATCO are not clear with regard to actions required in relation to the IAC concept, for the transition from IM/merge tool to PWS/ORD tool, on RNAV/RNP-based fixed approach procedures (including initial, intermediate and final approach segments). This may result in tasks not adequately performed, hence not timely.	OK	OBJ-37-W3-DEMOP-HUP1-0008	RTS 1 and 2, post-experiment rating	Overall, tasks are not unclear but it is not possible to devote the same amount of attention to monitoring traffic in the way it is done today, and adequate or timely intervening when it is necessary is difficult.	See REC-37-W3-HUP-R8.1: Consider automated adherence monitoring of the NTZ REC-37-W3-HUP-R8.2: the concept should ensure the gradual reduction of speeds of arriving traffic.	
Arg. 1.3.3: The level of workload (induced by cognitive and/or physical task demands) is acceptable.							
1.3.3-1	The level of APP ATCO workload has increased due to negative interaction between IM and PWS/ORD (increased executive control, increased time for monitoring conformance to instruction and monitoring spacing).	OK	OBJ-37-W3-DEMOP-HUP1-0009	RTS 1 and 2, questionnaire and debriefing (NASA-TLX, post experiment rating).	In RTS 1, the NASA-TLX ratings of controllers in the overall analysis result in an average rating of 35 (on scale 0-100) and no significant differences between the solution and the reference. The post-experiment controller ratings showed that the controllers expected a positive influence of the solution concept on workload in comparison to the current way of working (m=4 (on	REC-37-W3-HUP-R9.1: Divide the work of the FDR between two ATCOs (TWEC/TOC) Validated in RTS 2. REC-37-W3-HUP-R9.2: Expand Non Transition Zone (automated monitoring) for traffic established on RNP (18/18). Validated in RTS 2	





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
					scale 1-5)). Meanwhile it was said it was impossible to also check if the turn towards final was performed properly the scenarios with RWY 18/18. In RTS 2, the NASA-TLX ratings were between 30 and 40. The ratings of the runs with 100% equipage were increased compared to all other runs, contrary to what was expected. This is most likely due to simulation problems. For runs with more variation and with a go-around the workload rating was increased, as expected, but only slightly. For MRS 2.0 no increase was measured. For equipages of 20% and 80%, no increases in average ratings were found. The strong wind did not lead to increased workload, neither in the reference nor in the 100% equipage run, while the number of aircraft per hour remained at the level of 40/40. Concluding, the average workload ratings seem to be at acceptable levels. Nevertheless, ATCOs mentioned that that small disturbances have an impact on workload and that insufficient time remained to		





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
					monitor the traffic turning towards final. The reduction of MRS to 2.0 does not seem to contribute to ATCO workload.		
Arg. 1.3.4: The level of trust in the new concept/the new procedures is appropriate.							
1.3.4-1	ATCOs do not trust the new working practices and related tools in relation to the transition from IM to PWS/ORD. This may lead to them adding extra buffers, interventions, not using the TDI's appropriately or not using all/most opportunities for IM procedures.	-	OBJ-37-W3-DEMOP-HUP1-0010	RTS 1 and 2, questionnaire and debriefing	In RTS 1, the average ATCO rating of confidence was around 6.2 (on scale 1-7) with no significant difference between the solution (6.1) and the reference (6.3). ATCO's mentioned that the confidence is strongly related to the confidence in the pilots to follow the routes, which will in reality be different. In RTS 2, the average confidence in the concept was 4.8 (scale 1-.9, in the end-of-day questionnaire, but was also once rated value 1 and 2 (in day 2) and mentioned it was caused by the unexpected behaviour due to simulator issues. Results were not conclusive.. The ATCOs' confidence in the concept was rated neutrally, with the remark that in de simulation the pilots were very collaborative and timely following up instructions, which is not the case in current day operations.	REC-37-W3-HUP-R10.1: Trust should develop with more experience. Test the concept with, for example: - Go-arounds: Validated in RTS2 - Provide a gap for runway inspection - Change sequence (e.g. emergency): Validated in RTS2 - Runway closure - Runway change	
Arg. 1.3.5: Human actors can maintain a sufficient level of situation awareness.							





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Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
1.3.5-1	ATCO level of SA may reduce due to negative interaction between PWS/ORD tool and IM/merge tool, e.g. indications of ORD and merge tools are mixed up.	OK	OBJ-37-W3-DEMOP-HUP1-0011	RTS 1 and 2, questionnaire and debriefing	In RTS 1, The post-run SASHA ratings show differences between the solution (4.6) and reference (5.1) (on the SASHA scale 0-6). Thus the SA is slightly reduced in the solution concept. Especially the statement 'there was a risk of forgetting something important' is responsible for the difference. ATCOs mentioned that when an IM alert was given they were searching for the reason. In RTS 2, the average SASHA ratings varied between 4.4 and 5.5 (scale 0 – 6). For the 20% equipage the rating was highest and lowest for 100% equipage with increased variation at TMA entry. On average the ATCO SA seems sufficient. Partial equipage of the traffic does not seem to give severe problems of SA. The variation of accuracy of TMA entry seems to have a higher impact on SA.	REC-37-W3-HUP-R11.1: Improve IM alert: Validated in RTS2 REC-37-W3-HUP-R11.2: Improve HMI to provide an indication when a flight is established on RNP: Validated in RTS2 REC-37-W3-HUP-R11.3: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: Validated in RTS2	
Arg. 2.3.3: Visual displays and other types of output devices adhere to HF principles. [V1: AIR only]							
2.3.3-1	Controllers may misidentify /mistake IM information and	POK	OBJ-37-W3-DEMOP-HUP1-0012	RTS 1 and 2, debriefing	In RTS 1, ATCOs did not indicate to have experienced any confusion between the tools in the post-run ratings	See REC-37-W3-HUP-R11.2: Improve HMI to provide an indication when a flight is (not)	





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
	merge tool indicators with ORD tool indicators (and other information) on the radar screen due to their visual channels already heavily loaded.				of the Solution concept (for the Reference this was indicated once (1 in 8 runs)). The consistency of the design of the tools was rated negative by two of the three controllers. The inconsistencies between the ghost and the IM activation was mentioned to be confusing at first. In addition, the end-of-day questionnaires revealed that the potential for Human Error might increase with the Solution concept. In RTS 2, the results show similar trends (with several negative ratings due to the unpredictable behaviour of IM). Overall it is concluded that the HMI was adequately improved for RTS 2.	established on RNP: validated in RTS2 See REC-37-W3-HUP-R11.3: Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: Validated in RTS2.	
Arg. 2.3.6: The usability of the user interface (input devices, visual displays/output devices, alarm& alerts) is acceptable.							
2.3.6-1	Usability of the HMI (input devices, visual displays, output devices, alerts and alarms) for combined use of IM and PWS/ORD is poor, not intuitive nor easy to use/interpret and reduces	OK	OBJ-37-W3-DEMOP-HUP1-0013	RTS 1 and 2, questionnaire and debriefing	In RTS 1, several HMI improvements were identified and implemented. Validated in RTS2. The consistency of the design of the tools was rated negative by two of the three controllers.. The inconsistency between the IM activation and the ghost presentation was one of the reasons.		





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
	situational awareness.				In RTS 2, the HMI usability was rated 4.7 to 6.0 on average (scale 1-7). The HMI usability was rated positively. Both in RTS 1 and 2 potential HMI improvements were identified. Even though the SA ratings reduced between RTS 1 and RTS 2, ATCOs mentioned the HMI had improved. Lower SA ratings are explained by the more challenging scenarios with more variation in the accuracy of delivered flight.		
2.3.6-2	The usability of the (combined) IM information, merge tool and ORD tool indications is not acceptable for APP ATCOs including input devices, output devices/displays, and alarms & alerts, (e.g. as there is too much clutter on the screen).	OK	OBJ-37-W3-DEMOP-HUP1-0013	RTS 1 and 2, questionnaire and debriefing	In RTS 1, several HMI improvements were identified and implemented for RTS 2. In RTS 2, the HMI usability of 4.7 to 6.0 on average (scale 1-7). ATCOs did not mention to have experienced clutter, except for the area of the final approach (for RTS 1). This was improved for RTS 2. Overall it was concluded that the HMI does not negatively impact the human performance.	Improve HMI, Validated in RTS2.	



Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
Arg. 2.3.7: The user interface design reduces human error as far as possible.							
2.3.7-1	IM information, merge tool and ORD tool indications negatively interact such that it increase human error potential.	OK	OBJ-37-W3-DEMOP-HUP1-0004	RTS 1 and 2, questionnaires	In RTS1, the end-of day questionnaire revealed that the controllers estimated the potential for human error negatively for the solution (not decreased). The post-run question on the successfulness in accomplishing the task was on average rated 5.9 (scale 1 to 7) both for the reference and the solution runs. This could mean the human performance was not decreased. For RTS2, the ATCOs answered in the post-run questionnaire quite a few times to be confused on what to do. The explanations concerned sequence failures (simulator issue). The HMI usability was rated positively. In conclusion, the HMI supported the ATCOs in performing their task. Some simulator anomalies caused confusion. These situations were not highlighted by the HMI, but it was felt that the anomaly will not occur in reality.		

Arg. 2.3.8: The user interface supports a sufficient level of individual situation awareness.



Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
2.3.8-1	Combined use of IM information, merge tool and ORD tool indications may lead to an inadequate level of individual situation awareness, e.g. deteriorates the monitoring & identification of separation infringements, so decreases ATCO SA.	OK	OBJ-37-W3-DEMOP-HUP1-0011	RTS 1 and 2, questionnaires	In RTS 1, the SA was slightly reduced in the Solution compared to the reference. The ATCOs rated the influence of the solution concept (in comparison to the current way of working) neutral to positive regarding HP aspects of Situational Awareness, in the post-experiment questionnaire. The post-run ratings of 'the successfulness in achieving the task' was rated 5.9 (scale 1-7) for both conditions. Controllers mentioned that the IM alert made it not immediately evident what was wrong. It was concluded that the HMI does not negatively impact the human performance. Nevertheless room for improvement exists. In RTS 2, several improvements were implemented. The SA ratings were sufficient and post-run ratings of HMI usability were on average between 4.4 and 5.5 (scale 1 – 7), which is positive. Overall the SA was rated sufficient.		
Arg. 2.3.9: The user Interface design supports a sufficient level of team situational awareness. [V1: AIR only]							





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Valid. Obj. ID	activity conducted	results / evidence	recommendations	requirements
2.3.9-1	The design of the HMI should support the level of individual situation awareness for all terminal controllers in order to support sufficient levels of team SA. Failure to do so could impact the efficiency and effectiveness of the team.	OK	OBJ-37-W3-DEMOP-HUP1-0014	RTS 1 and 2, questionnaire and debriefing	In RTS 1, the team SA was not significantly different between the two conditions considering the post-run ratings as well as the post-experiment ratings. It may be the case that for the FDR/DCO the Team SA is reduced in the Solution. In RTS 2, the team SA was rated on average 5.7 (scale 1-7). Nevertheless, the expected effect of the concept on Team SA was on average rated slightly negative (2.6 on scale 1-5, end-of-day questionnaire). It was concluded that Team SA may reduce slightly in comparison to current day operations but will remain at sufficient levels.	REC-37-W3-HUP-R14.1: Provide a ghost symbol only for flights almost in TMA. Validated in RTS2.	
	The integrated concept deteriorates the arrival management process	POK	OBJ-37-W3-HUP1-0015	RTS1 and 2 observations and simulation data	In RTS 1, the number of flights vectored was not higher in the solution in comparison to the reference. In the condition with strong wind the ATCOs decided to apply a larger separation distance. In RTS 2, abnormal system behaviour was deteriorating the arrival management process in a few runs. This abnormal behaviour was in		





Issue ID	HP issue / Benefit	HP Issue/ Benefit Status	HP/ Obj. ID	Valid. activity conducted	results / evidence	recommendations	requirements
					itself an integration issue but is believed to be solvable in next iterations. Overall it is concluded that the integration is complex. Small changes meant to improve the integration proved to have unexpected results. Nevertheless, it is expected that if flights are delivered accurately into the TMA the concept could work, allowing continuous descents at high throughput.		

Table 6: Summary of the HP results and recommendations/ requirements for each identified issue & related argument



4.4.2 Maturity of the DEMO

RTS1 revealed that ATCOs were able to work with the concept under normal circumstances, after a day of training. Most of the HP objectives were (partially) met. Several potential suggestions for improvement of the concept were identified, making it possible to further refine the concept, the routes and HMI. This improved concept was tested in RTS2. In RTS 2 more challenging circumstances were simulated. This led to the conclusion that the concept is acceptable when the number of equipped aircraft is substantial (e.g., 80%), that the accuracy of delivery at TMA entry is sufficient (plus or minus 30 seconds).

5 References

- [1] SESAR (2020). SESAR Human Performance Assessment Process V1 to V3 – including VLD, ed. 00.03.01
- [2] SESAR 2020 Project PJ37-W3-ITARO, D1.4 Demonstration Plan – Part I, Edition 01.00.00, January 2023.
- [3] SESAR 2020 Project PJ37-W3-ITARO, D1.4 Demonstration Plan – Part IV – Human Performance Plan, Track PJ.37-W3-01A, Edition 01.00.00, January 2023.

Appendix A – Additional HP activities conducted

With regard to the HUP 0015 the flights that were vectored were counted in the solution as well as in the reference.

The table below presents a list of callsigns of the flights that have been vectored and the observation why they were vectored. Most flights received a dog-leg instructions to (slightly) increase the flight path or a shortcut to (slightly) decrease the flight path. Another reason to vector was to anticipate on a go-around (increasing separation such that the go-around aircraft can be re-inserted in the sequence). In one occurrence, a simulation error delivered two aircraft with similar planned time at the IAF, resulting in a conflict. The controller required to vector to resolve the conflict.

Since the 4th Schiphol IAF is not published, for the sake of this research it has been indicatively named as [XXXXX].

Run	Nr of vectored flights	Callsigns	Reason
1	0		
2	1	AZA11Y	Dog-leg after TEPKI
4	14	AZA11Y	Dog-leg from MASKA to SISEK
		BAW81HM	Dog-leg from SUGOL to EDDIE
		DLH7AK	After XXXXX flew to the north where after flying west towards FAR before a direct to CEFAF
		EJU7934	Inverted S-pattern after SEFIS to SISEK, first flying parallel the left of the FAR, followed by flying parallel to the right of the FAR before proceeding to the merge point
		ELY339	Shortcut before CEFAF to TOTOZ
		KLM16V	Dog-leg after AM805 to AM842, merging after the merge point.
		KLM37D	Dog-leg from SUGOL to EDDIE
		KLM84Q	Dog-leg before SUGOL to NIKOS
		KLM876	After XXXXX flew to the south-west where after flying north towards the FAR before a direct to CEFAF, and dog-leg from TOTOZ to SISEK
		KLM87H	Dog-leg after SEFIS to CEFAF
		KLM882	Dog-leg from ARTIP to OTFUZ

Run	Nr of vectored flights	Callsigns	Reason
		KLM896	Dog-leg from ARTIP to OTFUZ
		SWR736	Shortcut from SEFIS to TOTOZ
		SWR734	Dog-leg after SEFIS, then deleted/simulation-stop
5	1	KLM1634	Shortcut before KILNU to HANSI
6	2	KLM32Z	Holding at RIVER and then shortcut before EPZUM to EFMIG. Due to simulation issue, KLM32Z was planned 11 seconds before EJU9043 at the IAF. To resolve the conflict, the controller instructed to hold one lap, followed by a direct to EFMIG on the extended centreline to solve a conflict with the next aircraft (TAP678).
		KLM1670	Dog-leg near EPZUM
7	2	EJU49HM	Dog-leg near EPZUM, to make space for IBS3722 to get back into sequence after a GA
		IBS3722	Controller instructed go-around, diverted from ILS: aircraft was flying too high because controller did not give approach clearance
8	1	KLM1688	Shortcut before KILNU to HANSI: aircraft is given direct to HANSI to solve a conflict with ghost blip
9	2	BEE4RJ	Maintained present heading near AM829 to create a gap to re-insert KL1018 which performed a go-around
		KLM1018	Go-Around, diverted from ILS: pilot did not arm IM and did not reduce speeds, therefore controller instructed a GA
10	5	BEE1015	Dog-leg between AM829 and EDDIE
		KLM1524	Dog-leg between AM829 and EDDIE
		KLM80X	Dog-leg between ARTIP and OTFUZ: aircraft is given a dog-leg to solve a separation issue
		CGJCY	Dog-leg between ARTIP and OTFUZ: aircraft is given a dog-leg to solve a separation issue
		KLM52G	Dog-leg between ARTIP and OTFUZ: aircraft is given a dog-leg to solve a separation issue
3	0		
11	0		

Table 7 : OBJ-37-W3-DEMOP-HUP1-0015 Full list of vectored flights/callsigns

Appendix B – HP Recommendations Register

HP Recommendations Register									
Reference	Type of recommendation	Recommendation	Rationale	Assessment source + Reference report	Scope (Air, Air/Ground, Ground)	Concept/solution Involved	Recommendation status	Rationale in case of rejection	Comments
REC-37-W3-HUP-R4.1	Route	Design arrival routes such that turns are 135 degree or larger and that routes to parallel runways are not exactly mirrored (avoid head-on base legs). <i>Validated in RTS2.</i>		RTS	Air/Ground		Closed		
REC-37-W3-HUP-R4.2	Route	Standardise the altitude at IAF or start the RNP approach at the merge point. <i>Standardised altitude was validated in RTS2.</i>		RTS	Air/Ground		Closed		
REC-37-W3-HUP-R4.3	Concept	The concept should ensure a minimum separation at the merge point. As a solution the IM achieve-by point can		RTS	Air/Ground		Closed		

		be placed at the merge point. <i>This was validated in RTS 2.</i>						
REC-37-W3-HUP-R4.4	Concept	The integrated concept ideally ensures a gradual reduction of speeds. This requires sufficient testing of the integrated tools and investigate at what point to (automatically) terminate IM earlier.		RTS	Air/Ground		Open	
REC-37-W3-HUP-R6.1	Concept	In case of changes in the inbound sequence it is recommended to update the inbound planning (AMAN/Supervisor) or cancel the IM for one (or several) flights, instead of changing IM targets.		RTS	Air/Ground		Open	
REC-37-W3-HUP-R6.2	Roles and responsibilities	It is recommended to take a closer look at responsibilities such as monitoring		RTS	Air/Ground		Open	

		the traffic at final, with high volumes of traffic. Can this reasonably be expected from the ATCO?						
REC-37-W3-HUP-R7.1	HMI design	Design the HMI, such that: - It is clear which flights are IM capable and which are not; Validated in RTS2 - It is clear which flights are applying IM (validated in RTS2), and whether it is applied correctly (to the flight preceding on the route); - It is clear which	RTS	Ground		Open		

		flights are established on RNP; <i>Validated in RTS2</i> That ATCO can change the sequence with a minimal number of actions						
REC-37-W3-HUP-R7.2	Concept	When the actual sequence is different from the planned sequence, the planning is preferably updated (automatically ensuring the right IM target for each flight). If a mix up of IM targets is a possible occurrence, the controller could be made aware of such mix-ups.		RTS	Air/Ground		Open	
REC-37-W3-HUP-R8.1	Concept/ Roles and responsibilities	Consider automated adherence		RTS	Air/Ground		Open	



		monitoring of the NTZ.							
REC-37-W3-HUP-R8.2	Concept	The concept should ensure the gradual reduction of speeds of arriving traffic.		RTS	Air/Ground		Open		
REC-37-W3-HUP-R9.1	Roles and responsibilities	Divide the work of the FDR between two ATCOs (TWEC/TOC). <i>Validated in RTS 2.</i>		RTS	Ground		Closed		
REC-37-W3-HUP-R9.2	Concept	Expand Non Transition Zone (automated monitoring) for traffic established on RNP (18/18). <i>Validated in RTS 2</i>		RTS	Air/Ground		Closed		
REC-37-W3-HUP-R10.1	Further research	Trust should develop with more experience. Test the concept with, for example: - Go-arounds: <i>Validated in RTS2</i> - Provide a gap for		RTS	Air/Ground		Open		



		runway inspection • Change sequence (e.g. emergency). <i>Validated in RTS2</i> • Runway closure • Runway change						
REC-37-W3-HUP-R11.1	HMI desing	Improve IM alert: <i>Validated in RTS2</i>		RTS	Ground		Closed	
REC-37-W3-HUP-R11.2	HMI design	Improve HMI to provide an indication when a flight is established on RNP: <i>Validated in RTS2</i>		RTS	Ground		Closed	
REC-37-W3-HUP-R11.3	Route	Alternatively, a turn in the designed route may serve as a checkpoint whether a flight is established: <i>Validated in RTS2</i>		RTS	Air/Ground		Closed	
REC-37-W3-HUP-R14.1	Concept	Provide ghost indicator only for flights almost in		RTS	Ground		Closed	

		TMA. <i>Validated in</i> <i>RTS 2</i>							
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Table 8: HP recommendations

Appendix C – HP Requirements Register

HP Requirements Register									
Reference	Type of requirement	Requirement	Rationale	Assessment source + Reference report if available	Scope (Air, Air/Ground, Ground)	Concept/ solution Involved	Requirement status	Rationale in case of rejection	Comments
NA	NA	NA							

Table 9: HP Requirements

Appendix D – HP Log

See DEMOP Part IV, Human Performance Plan [3]

-END OF DOCUMENT-