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PJ37-W3-ITARO

INTEGRATED TMA, AIRPORT AND RUNWAY OPERATIONS

This Safety Report is Part II of the Demonstration Report, belonging to Contractual Deliverable D1.5, of PJ.37-ITARO for Arrival track PJ37-W3-01A, 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

The present document constitutes Part II of the Demonstration Report (DEMOR), belonging to contractual deliverable (D1.5), of the SESAR2020 project PJ.37 (ITARO). It overviews the results of the various exercises dealing with the Safety aspects of the integrated solutions addressed by ITARO. This project carries out 'VLD-like' exercise activities that focus on the integration of different SESAR solutions and (pre-) deployment items, already validated to high Technological Readiness Levels (TRLs) individually, but being combined and applied for the first time in an operational environment. This first-step integration cannot be performed directly in a real life ATC environment hence requires an integrated Real Time Simulation (RTS) step first, thereby explaining the 'VLD-like' in its IA-naming. As a result, the safety assessment activities have a different character from those usually carried out in VLD exercises. In particular, they do not include the assessment of the Safety Impact of the VLD on current operations, since the exercises take place in a simulation environment only.

There will be four exercises, relating to three Real Time Simulations (Arrival RTS1, Arrival RTS2, and Departures RTS) and a flight trial. The present document details the Safety Report for Arrival RTS1 and Arrival RTS2 (track PJ.37-W3-01A). The Safety Report for Departures RTS is detailed in a separate document (track PJ.37-W3-01B). The Safety Report for the flight trial is detailed in DEMOR Part I.

The main results of the safety assurance strategy to support VLD-like are:

- Regarding OBJ-37-W3-DEMOP-SAF1-0001 (The number of go-arounds due to insufficient spacing shall not be greater than in the reference simulation), the analysis result is: OK (Full).
- Regarding OBJ-37-W3-DEMOP-SAF1-0003 (The interoperability of the different tools in the integrated tool shall not introduce safety issues), the analysis result is: Partial OK (POK).
- Regarding OBJ-37-W3-DEMOP-SAF1-0004 (There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)), the analysis result is: OK (Full).

- Regarding OBJ-37-W3-DEMOP-SAF1-0005 (The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool), the analysis result is: Partial OK (POK).

The report has been progressively updated and expanded as more information became available. It provides input to the full DEMOR report, which in addition to input from this Part II, takes input from Part I, which is the core text that overviews all exercises and SESAR Solutions involved, Part III, which covers the Human Performance, Part IV, which covers Environment Assessment, and Part V, which covers Performance Assessment.



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1 Executive Summary

This document constitutes Part II of the Demonstration Report (DEMOR), belonging to contractual deliverable (D1.5), of the SESAR2020 project PJ.37 (ITARO). It overviews the results of the various exercises dealing with the Safety aspects of the integrated solutions addressed by ITARO. This project carries out 'VLD-like' exercise activities that focus on the integration of different SESAR solutions and (pre-) deployment items, already validated to high Technological Readiness Levels (TRLs) individually, but being combined and applied for the first time in an operational environment. The first-step integration of this new combination of tools cannot be performed directly in a real life ATC environment hence requires an integrated Real Time Simulation (RTS) step first, thereby explaining the 'VLD-like' in its IA-naming.

The project has carried out four exercises, relating to three Real Time Simulations (Arrival RTS1, Arrival RTS2, and Departures RTS) and a flight trial. The present document details the Safety Report for Arrival RTS1 and Arrival RTS2 (track PJ.37-W3-01A). The Safety Report for Departures RTS is detailed in a separate document (track PJ.37-W3-01B). The Safety Report for the flight trial is detailed in DEMOR Part I.

In track PJ.37-W3-01A, RTS1 and RTS2 each consisted of about a dozen runs, which were operated in either a solution scenario (using the new combination of tools) or a reference scenario (without the new combination of tools, but in similar contextual circumstances). The safety assurance strategy to support the VLD-like was formulated in four objectives, which were analysed using data collected during RTS1 and RTS2, observations during the RTSs and their debriefs, and safety observation questionnaires. This provided the following results:

OBJ-37-W3-DEMOP-SAF1-0001: The number of go-arounds due to insufficient spacing shall not be greater than in the reference simulation.

- Safety analysis: Based on the data in RTS1, the fact that more go-arounds occurred in solution runs than in reference runs cannot be related to the new combination of tools. The questionnaires did not reveal a concern regarding this objective either. Therefore, it was concluded that the number of go-arounds due to insufficient spacing is not increased by the combination of tools. This conclusion was confirmed during RTS2, which did not include any go-arounds due to insufficient spacing.
- Safety analysis result: OK (Full).
- Recommendations:
 - For a more accurate representation of the safety objectives being studied, incorporate a runway controller in future simulations to manage traffic on the final approach segment and collaborate with the arrival (ARR) controller in instances that may result in go-arounds.
 - In future simulations it is recommended to incorporate an ACC controller. If a go-around occurs, the ACC or the APP controller should delay the traffic that is still further away from the runway, in order to create some space in the sequence.

OBJ-37-W3-DEMOP-SAF1-0003: The interoperability of the different tools in the integrated tool shall not introduce safety issues.

- Safety analysis: The Flight-deck Interval Management (FIM) system's task is to create spacing between aircraft on fixed routes, but its efficiency depends on the accuracy of the Expected Arrival Time (EAT) provided by E-AMAN (Extended Arrival Management). During a simulation, the actual flight sequence was sometimes different from the planned sequence, resulting in illogical pairings and unpredictable operation. This highlights the need for reliable EAT on the TMA boundary for the FIM system to work properly. However, the likelihood of the E-AMAN system providing unreliable EAT in real-life operations is small and the consequences are likely to be low as the ACC controller and flight crew may detect and resolve any issues before the aircraft arrives in the TMA. Nevertheless, controllers are not informed if the pairing is illogical, resulting in the safety objective not being fully met.
- Safety analysis result: Partial OK (POK).
- Recommendations:
 - For future simulations or demonstrations, implement a safety mechanism to alert controllers in case of any compatibility issues between the FIM system/algorithm and the E-AMAN system/algorithm, such as illogical aircraft pairings.
 - Consider expanding the coverage of the FIM system to include the ACC airspace, in addition to the TMA airspace. This could provide more time and space for the system to maintain appropriate spacing between aircraft and to create gaps in case an aircraft needs to re-sequenced.
 - Enhance the realism of future simulations or demonstrations by incorporating more realistic speed profiles of aircraft. Refining the FIM algorithms and ensuring seamless transitions between them may be necessary to achieve this.

OBJ-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts).

- Safety analysis: The data of RTS1 showed that for both minimum radar separation (MRS) and runway occupancy time (ROT) infringements, the solution runs did not seem to have more cases of loss of separation (LOS) than the reference runs, and even showed much fewer. In the questionnaires and the debriefing, the controllers did have a few concerns with wake turbulence separation (WTS) losses, however. During RTS2, the number of LOSs during solution runs was similar to the number of LOSs in reference runs under comparable circumstances. The controllers did have a few concerns regarding LOSs, but these seemed to be mainly due to the high traffic density, the perceived controllability and the use of IM, rather than due to the combination of tools. Therefore, the results of RTS2 appeared to confirm the RTS1 conclusion.
- Safety analysis result: OK (Full).
- Recommendations:
 - To include a runway controller in the simulations, who controls the traffic on the final approach segment, and who can coordinate with the arrival (ARR) controller regarding situations that may lead up to losses of separation due to WTS, MRS, and ROT. This would provide a more realistic picture regarding the safety objectives studied.
 - The previous recommendation would also create the opportunity to study a safety objective that was omitted from the analysis in this report: OBJ-37-W3-DEMOP-SAF1-0002 (The variability in Clearance to Land margin decreases for ROT constrained pairs).
 - The objectives studied looked at safety up to the level of potential for loss of separation, limited by the nature of real time simulations. In order to assess the risk of a mid-air collision and the risk of wake turbulence related accidents, as is required

in SESAR safety reference material (SRM), in a follow on project it is recommended to use Dynamic Risk Modelling to assess the safety benefits of the combination of tools more accurately.

OBJ-37-W3-DEMOP-SAF1-0005: The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool.

- Safety analysis: At the beginning of RTS1, the controllers did feel less in control during the solution runs, compared to the reference runs. However, this seemed to be mainly due to the use of a single tool rather than to the combination of tools. Moreover, post-experiment they indicated to have grown more positive regarding the solution runs. The execution of RTS2 helped the controllers to become more familiar with and obtain more experience with the integrated tool, resulting in increased trust. However, some simulation issues arose during the runs, leading to concerns about the perceived controllability in real-world operations. In real operational context, controllers must handle various disturbances such as rain clouds, go-arounds, unexpected aircraft behaviour, and aircraft flying too fast or too slow. Some of such types of situations were also encountered during some of the RTS2 runs (grossly unexpected aircraft/pilot behaviour, difference between actual and planned arrival sequence), leading to a rapid loss of control and the need to halt the simulation. The main issue is the integration between AMAN and FIM; the concerns warrant further attention in future testing and simulations. Therefore, at this moment we cannot conclude that objective OBJ-37-W3-DEMOP-SAF1-0005 is fully met.
- Safety analysis result: Partial OK (POK).
- Recommendations:
 - Assess the similarity of simulation issues encountered during RTS2 to real-world operational scenarios. In future testing and simulations, include these types of events in scenarios to gauge the operational efficiency and durability of the tools used.
 - Evaluate the ability of controllers to handle non-typical operational disruptions that occur frequently in real-world practice. Incorporate these events into scenarios for future testing and simulations to assess the efficiency and stability of the tools and overall operation during such situations.



2 Introduction

2.1 VLD-like Objectives, Justification and Scope

A detailed description of the VLD-like demonstration objectives is given in section 4.4 'Demonstration Objectives' of PJ.37-W3-DEMOP Part I [7]. The main objective of ITARO is to integrate SESAR Solutions to optimise the separation and flow of arriving and departing traffic within the TMA that aim to provide greater airport capacity, whilst increasing fuel efficiency, environmental sustainability and cost efficiency, and improving safety and predictability. There will be four exercises, relating to three Real Time Simulations (Arrival RTS1, Arrival RTS2, and Departures RTS) and a flight trial. Each exercise approaches this main objective from a different perspective. The detailed demonstration objectives per exercise are given in Section 5.1.3 (EXE-PJ.37-W3-001), Section 5.2.3 (EXE- PJ.37-W3-002), Section 5.3.3 (EXE-PJ.37-W3-003), and Section 5.4.3 (EXE-PJ.37-W3-004) of DEMOP Part I [7].

- EXE-PJ.37-W3-001 relates to Arrival RTS1 for PJ.37-W3-01A and aims to test the integrated applicable SESAR solutions within PJ.37-W3-01A for the Schiphol Terminal Manoeuvring Area (TMA). The RTS will be performed on the NLR Air traffic management Real-time SIMulator (NARSIM).
- EXE-PJ.37-W3-002 relates to Arrival RTS2 for PJ.37-W3-01A and originally aimed to test the integrated applicable SESAR solutions within PJ.37-W3-01A for outside the Schiphol TMA, i.e. Area Control Centres (ACC) and Upper Area Control (UAC) sectors. After RTS1, the plan for RTS2 was adjusted, aiming to test the integrated applicable SESAR solutions within PJ.37-W3-01A for the Schiphol TMA, but incorporating several improvements in the simulation environment to make it more realistic. This choice was expected to provide more insight into the integration of tools than the extension to ACC and UAC sectors would. RTS2 was performed on NARSIM.
- EXE-PJ.37-W3-003 relates to the flight trial for PJ.37-W3-01A and aimed to live-test the integrated applicable SESAR solutions within PJ.37-W3-01A with an in-flight aircraft pair. The flight trial was done with research aircraft from NLR and DLR.
- EXE-PJ.37-W3-004 investigated the application of reduced, more granular non-wake SID separations on departure with an extended OSD (eOSD) tool. The Departures RTS considered segregated runway operations in the Heathrow environment. The concept also assessed a TMA data-feed into the eOSD tool which aimed to dynamically adjust the departure flow rate into the TMA. The safety assurance activities of that exercise are detailed in the Safety Plan for track PJ.37-W3-01B.

As listed in section 4.4.1.5 of DEMOP part I, the safety demonstration objectives are (Table 1):

[OBJ]	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
OBJ1A	OBJ-37-W3-DEMOP-SAF1-0001	The number of go-arounds due to insufficient spacing shall	The use of the integrated tool shall not increase the number of controller-instructed go-arounds



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[OBJ]	Identifier	Demonstration Exercise Objectives	Demonstration Success criteria
		not be greater than in the reference simulation	
	OBJ-37-W3-DEMOP-SAF1-0002	The variability in Clearance to Land margin decreases for ROT constrained pairs	The integrated tool shall contribute to increasing the consistency in Clearance to Land margin through improved ROT Spacing management
	OBJ-37-W3-DEMOP-SAF1-0003	The interoperability of the different tools in the integrated tool shall not introduce safety issues	Ensure that the functionalities of all solutions complement one another without negative interference
	OBJ-37-W3-DEMOP-SAF1-0004	There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts).	The use of the integrated tool and the Airborne Spacing Flight Deck Interval Management does not lead to an increased number of separation losses in the nominal solution as compared against the reference solution
	OBJ-37-W3-DEMOP-SAF1-0005	The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool.	The design of the Human Machine Interface of the integrated tool for the controller is designed to limit the number of unnecessary interventions. However, it is still the role of the controller to intervene when needed. The tool gives the controller the means to intervene. The use of the tool does not lead to a perceived loss of controllability of the operation by the controller in relation to the conventional operation.
	OBJ-37-W3-DEMOP-SAF1-0006	The use of IM operations shall not result in any unsafe condition during the live trial	No major safety issues are identified both during the test flights and debriefings by the flight crew of the FIM aircraft.
	OBJ-37-W3-DEMOP-SAF1-0007	The FIM system performs its intended function during the live trial (airworthiness related objective)	No functional issues related to the FIM system standard (ED-236A) are identified during the test flights (e.g. non-compliance or other issues with relevant ED-236A requirements).

Table 1: Safety demonstration objectives



It is noted, however, that during the data analysis of RTS1, it was decided to omit safety demonstration objective OBJ-37-W3-DEMOP-SAF1-0002 from further consideration because:

- The real time simulations did not explicitly include a (real) Runway Controller, therefore no clearance to land margin was included in the simulation, and no data could be collected regarding the variability in Clearance to Land margin.
- In hindsight, this objective is not a safety objective but a capacity / efficiency objective.

2.2 Scope of the VLD Safety Assessment

The scope of the VLD-like safety assessment is demonstrating the suitability of the integrated solution for the deployment.

The concepts being aggregated together and demonstrated in the VLD-like for arrivals (track PJ.37-W3-01A) are:

SESAR Solution	Solution identifier	Operational Improvement (OI)
Extended Arrival Management (E-AMAN) horizon	SESAR 1 Solution #5	TS-0305-A
Enhanced Terminal Airspace Routing using RNP-Based Operations	SESAR 1 Solution #62, #09, #51	AOM-0603 AOM-0605
Airborne Spacing Flight-deck Interval Management (FIM)	SESAR 2020 W1 PJ.01-05	TS-0108
Time Based Separation (TBS)	SESAR 1 Solution #64	AO-0303
Re-CATegorisation (RECAT-EU)	N/A	AO-0326
Optimised Runway Delivery (ORD) on Final Approach	SESAR 2020 W1 PJ.02-01-01	AO-0328
Wake Turbulence Separations (for Arrivals) based on Static Aircraft Characteristics	SESAR 2020 W1 PJ.02-01-04	AO-0306
Increased Runway Throughput based on local Runway Occupancy Time (ROT) categorisation	SESAR 2020 W1 PJ.02-08-03	AO-0337

Table 2: Overview of SESAR solutions demonstrated in PJ.37-W3-01A

The scope of the Safety assessment covers the safety assurance evidence output from the Real-Time Simulations, and the recording of the safety findings from the VLD-like activities.

The VLD-like safety assessment addresses only the safety issues related to the *integration* of the solutions, hence focusing on the interfaces and interactions between the individual solutions. The safety issues related to the individual solutions themselves are already addressed in the safety assurance activities of the respective solutions.

Since the VLD-like is not performed in an operational environment, safety is not compromised during the VLD-like. Therefore, the safety impact on current operations is not within scope.

3 VLD-like safety argument and assurance activities

In a hazard identification workshop, safety issues were identified that could endanger achieving the safety objectives of the VLD-like. These include the issues listed in Table 3. The last column indicates which safety demonstration objectives are linked to these safety issues. For reasons explained in Section 2.1, objective OBJ-37-W3-DEMOP-SAF1-0002 has been omitted from further analysis.

ID	Safety issue	Description	Link with SO
SI-01	Inconsistency between algorithms of Merging Tool (MT) and Flight-deck Interval Management (FIM)	The flight-deck algorithm for merging aircraft onto one route (as part of FIM) and the air traffic control algorithm for merging aircraft onto one route (as part of Merging Tool) may not be the same, leading to potential inconsistencies between aircraft behaviour and controller expectations / perceptions. The controller may be tempted to intervene and disturb the aircraft sequence.	OBJ-37-W3-DEMOP-SAF1-0001 OBJ-37-W3-DEMOP-SAF1-0003 OBJ-37-W3-DEMOP-SAF1-0004 OBJ-37-W3-DEMOP-SAF1-0005
SI-02	Cascading effects in longitudinal separation due to use of various tools in combination	Due to the use of various tools in combination, which give speed instructions to aircraft without the intervention of the controller, the controller may find it difficult to predict how the separation between an aircraft pair further away from the threshold, translates to a separation nearer the threshold.	OBJ-37-W3-DEMOP-SAF1-0001 OBJ-37-W3-DEMOP-SAF1-0003 OBJ-37-W3-DEMOP-SAF1-0004 OBJ-37-W3-DEMOP-SAF1-0005
SI-03	Unexpected large disturbance in the sequence	There are various potential causes for a disturbance in the arrival sequence: pop-up flights, unexpected bad weather requiring increased separation, unexpectedly long runway occupancy time (ROT), go-arounds that need to be re-entered into the sequence, aircraft decreasing speed due to engine failures, emergency flights. This has an effect on the input expected by the different solutions and tools. Some aircraft need to be taken out of the sequence and rerouted.	OBJ-37-W3-DEMOP-SAF1-0003 OBJ-37-W3-DEMOP-SAF1-0004 OBJ-37-W3-DEMOP-SAF1-0005

Table 3: Safety issues to be studied in the VLD-like Safety Assessment.



The following key performance indicators (KPI) have been identified as relevant for the exercise:

ID	KPI to be measured/ quantified	Description	Link with SO	Link with SI
KPI-01	Number of go-arounds instructed by controller	The solutions aim to optimise the landing sequence based on a planned manner. In the RTS environment, a go-around is initiated by controller only if the delivery of the aircraft on certain points might not meet the separation requirements. It is therefore relevant to compare the number of go-arounds with that in the reference scenario.	OBJ-37-W3-DEMOP-SAF1-0001	SI-01 SI-02
KPI-02	Number of losses of separation (wake separation requirements)	The solutions aim to guarantee the minimum separation requirements, including the wake separation requirements. It is therefore relevant to measure the number of losses and compare it to that in the reference scenario.	OBJ-37-W3-DEMOP-SAF1-0004	SI-01 SI-02 SI-03
KPI-03	Number of losses of separation (minimum radar separation requirements)	The solutions aim to guarantee the minimum separation requirements, including the minimum radar separation requirements. It is therefore relevant to measure the number of losses and compare it to that in the reference scenario.	OBJ-37-W3-DEMOP-SAF1-0004	SI-01 SI-02 SI-03

Table 4: Key performance indicators to be measured in the VLD-like Safety Assessment

During the VLD-like Safety assessment, additional hazards for the Safety objectives could be identified. Therefore, the initial safety assurance strategy encompasses the following activities:

- Workshop with solution members to identify, in more detail, the VLD-like objectives/High-level requirements from a safety point of view;
- Prepare and produce safety observation questionnaires to produce the needed data and evidence;
- Provide a safety briefing to participants and solution members;
- Observations during the RTSs to provide the needed data and evidence;
- Develop and run a specific scenario to run in one of the RTSs to produce the needed data and evidence;
- Collect and analyse data of the RTSs of the VLD-like to produce the needed evidence;
- Conduct post VLD-like Safety workshop activities with operational experts (controller, pilots, safety experts) to assess and analyse any safety issues, derive mitigations and assess (if possible) if the safety objectives of this VLD-like are satisfied.
- Making use of operational expert judgement.

Table 5 and Table 6 show which safety assurance strategy is used to provide the needed evidence per identified safety issue and KPI, respectively.

ID	SI	Strategy
SI-01	Inconsistency between algorithms of Merging Tool (MT) and Flight-deck Interval Management (FIM)	• Observations during the RTSS • Safety observation questionnaires
SI-02	Cascading effects in longitudinal separation due to use of various tools in combination	• Collect and analyse data of the RTSS of the VLD-like • Observations during the RTSS • Safety observation questionnaires
SI-03	Unexpected large disturbance in the sequence	• Develop and run a specific scenario to run in one of the RTSS to produce the needed data and evidence • Collect and analyse data of the RTSS of the VLD-like • Observations during the RTSS

Table 5: Safety assurance activities to be conducted to provide the necessary evidence per pre-VLD-like identified safety issue

ID	KPI	Strategy
KPI-01	Number of go-arounds instructed by controller	• Collect and analyse data of the RTSS of the VLD-like • Observations during the RTSS • Safety observation questionnaires
KPI-02	Number of losses of separation (wake separation requirements)	• Collect and analyse data of the RTSS of the VLD-like • Observations during the RTSS • Safety observation questionnaires
KPI-03	Number of losses of separation (minimum radar separation requirements)	• Collect and analyse data of the RTSS of the VLD-like • Observations during the RTSS • Safety observation questionnaires

Table 6: Safety assurance activities to be conducted to provide the necessary evidence per pre-VLD-like identified KPI



4 VLD-like Safety Results

4.1 Suitability of the SESAR solution(s) for deployment

The tables below provide an analysis of the RTS1 and RTS2 results per safety demonstration objective. For justification and full details, please refer to the appendix.

Identifier	OBJ-37-W3-DEMOP-SAF1-0001	KPA Category	Safety
Title	Number of go-arounds		
Objective	The number of go-arounds due to insufficient spacing shall not be greater than in the reference scenario		
Success Criterion	CRT-37-W3-DEMOP-SAF1-0001	The use of the integrated tool shall not increase the number of controller-instructed go-arounds.	
Results	Based on the data in RTS1, the fact that more go-arounds occurred in solution runs than in reference runs cannot be related to the new combination of tools. The questionnaires did not reveal a concern regarding this objective either. Therefore, it was concluded that the number of go-arounds due to insufficient spacing is not increased by the combination of tools. This conclusion was confirmed during RTS2, which did not include any go-arounds due to insufficient spacing. Recommendations REC-37-W3-SAF-R1.1: For a more accurate representation of the safety objectives being studied, incorporate a runway controller in future simulations to manage traffic on the final approach segment and collaborate with the arrival (ARR) controller in instances that may result in go-arounds REC-37-W3-SAF-R1.2: In future simulations it is recommended to incorporate an ACC controller. If a go-around occurs, the ACC or the APP controller should delay the traffic that is still further away from the runway, in order to create some space in the sequence.		OK (Full)
Reference	Post-run questionnaire Data analysis on KPI-01		

Table 7: Results for OBJ-37-DEMOP-SAF1-0001: The number of go-arounds due to insufficient spacing shall not be greater than in the reference simulation



Identifier	OBJ-37-W3-DEMOP-SAF1-0003		KPA Category	Safety	
Title	Interoperability				
Objective	The interoperability of the different tools in the integrated tool shall not introduce safety issues.				
Success Criterion	CRT-37-W3-DEMOP-SAF1-0003	Ensure that the functionalities of all solutions complement one another without negative interference.			
Results	The FIM system's task is to create spacing between aircraft on fixed routes, but its efficiency depends on the accuracy of the EAT provided by E-AMAN. During a simulation, the actual flight sequence was sometimes different from the planned sequence, resulting in illogical pairings and unpredictable operation. This highlights the need for reliable EAT on the TMA boundary for the FIM system to work properly. However, the likelihood of the E-AMAN system providing unreliable EAT in real-life operations is small and the consequences are likely to be low as the ACC controller and flight crew may detect and resolve any issues before the aircraft arrives in the TMA. Nevertheless, controllers are not informed if the pairing is illogical, resulting in the safety objective not being fully met. The overall score for this system is "Partial OK." Recommendations REC-37-W3-SAF-R3.1: For future simulations or demonstrations, implement a safety mechanism to alert controllers in case of any compatibility issues between the FIM system/algorithm and the E-AMAN system/algorithm, such as illogical aircraft pairings. REC-37-W3-SAF-R3.2: Consider expanding the coverage of the FIM system to include the ACC airspace, in addition to the TMA airspace. This could provide more time and space for the system to maintain appropriate spacing between aircraft and to create gaps in case an aircraft needs to re-sequenced. REC-37-W3-SAF-R3.3: Enhance the realism of future simulations or demonstrations by incorporating more realistic speed profiles of aircraft. Refining the FIM algorithms and ensuring seamless transitions between them may be necessary to achieve this.			Partial (POK)	OK
Reference	Post-run questionnaire Remarks end-of-run debrief-sessions Remarks end-of-experiment debrief session				

Table 8: Results for OBJ-37-W3-DEMOP-SAF1-0003: The interoperability of the different tools in the integrated tool shall not introduce safety issues



Identifier	OBJ-37-W3-DEMOP-SAF1-0004	KPA Category	Safety
Title	Loss of separation		
Objective	There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts).		
Success Criterion	CRT-37-W3-DEMOP-SAF1-0004	The use of the integrated tool and the Airborne Spacing Flight Deck Interval Management does not lead to an increased number of separation losses in the nominal solution as compared against the reference scenario.	
Results	The data of RTS1 showed that for both MRS and ROT, the solution runs did not seem to have more cases of LOS than the reference runs, and even showed much fewer. In the questionnaires and the debriefing the controllers did have a few concerns with wake turbulence separation losses, however. During RTS2, the number of LOSs during solution runs was similar to the number of LOSs in reference runs under comparable circumstances. The controllers did have a few concerns regarding LOSs, but these seemed to be mainly due to the high traffic density, the perceived controllability and the use of IM, rather than due to the combination of tools. Therefore, the results of RTS2 appeared to confirm the RTS1 conclusion. Recommendations REC-37-W3-SAF-R4.1: To include a runway controller in the simulations, who controls the traffic on the final approach segment, and who can coordinate with the arrival (ARR) controller regarding situations that may lead up to losses of separation due to WTS, MRS, and ROT. This would provide a more realistic picture regarding the safety objectives studied. REC-37-W3-SAF-R4.2: The previous recommendation would also create the opportunity to study a safety objective that was omitted from the analysis in this report: OBJ-37-W3-DEMOP-SAF1-0002 (The variability in Clearance to Land margin decreases for ROT constrained pairs). REC-37-W3-SAF-R4.3: The objectives studied looked at safety up to the level of potential for loss of separation, limited by the nature of real time simulations. In order to assess the risk of a mid-air collision and the risk of wake turbulence related accidents, as is required in SESAR safety reference material (SRM), in a follow on project it is recommended to use Dynamic Risk Modelling to assess the safety benefits of the combination of tools more accurately.		OK (Full)
Reference	Post-run questionnaire Data analysis on KPI-02, KPI-03		

Table 9: Results for OBJ-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)



Identifier	OBJ-37-W3-DEMOP-SAF1-0005		KPA Category	Safety
Title	Controllability			
Objective	The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool.			
Success Criterion	CRT-37-W3-DEMOP-SAF1-0005	The tool gives the controller the means to intervene. The use of the tool does not lead to a perceived loss of controllability of the operation by the controller in relation to the conventional operation.		
Results	At the beginning of RTS1, the controllers did feel less in control during the solution runs, compared to the reference runs. However, this seemed to be mainly due to the use of a single tool rather than to the combination of tools. Moreover, post-experiment they indicated to have grown more positive regarding the solution runs. The execution of RTS2 helped the controllers to become more familiar with and obtain more experience with the integrated tool, resulting in increased trust. However, some simulation issues arose during the runs, leading to concerns about the perceived controllability in real-world operations. In real operational context, controllers must handle various disturbances such as rain clouds, go-arounds, unexpected aircraft behaviour, and aircraft flying too fast or too slow. Some of such types of situations were also encountered during some of the RTS2 runs (grossly unexpected aircraft/pilot behaviour, difference between actual and planned arrival sequence seen as abnormal behaviour), leading to a rapid loss of control and the need to halt the simulation. The main issue is the integration between AMAN and FIM; the concerns warrant further attention in future testing and simulations. Therefore, at this moment we cannot conclude that objective OBJ-37-W3-DEMOP-SAF1-0005 is fully met. Recommendations REC-37-W3-SAF-R5.1: Assess the similarity of simulation issues encountered during RTS2 to real-world operational scenarios. In future testing and simulations, include these types of events in scenarios to gauge the operational efficiency and durability of the tools used. REC-37-W3-SAF-R5.2: Evaluate the ability of controllers to handle non-typical operational disruptions that occur frequently in real-world practice. Incorporate these events into scenarios for future testing and simulations to assess the efficiency and stability of the tools and overall operation during such situations.			Partial OK (POK)
Reference	Post-run questionnaire RTS2 End of Day questionnaire Additional input from Post-experiment questions on perceived workload, situation awareness and potential for human error.			

Table 10: Results for OBJ-37-W3-DEMOP-SAF1-0005: The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool

4.2 Safety impact of the VLD-like on current operations

This is out of scope for the VLD-like.



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5 Acronyms and Terminology

Acronym	Definition
ACC	Area Control Centre
AIS	Aeronautical Information Service
ATC	Air Traffic Control
ATS	Air Traffic Services
CDO	Continuous Descent Operation
CNS	Communication, Navigation, Surveillance
DEMOP	Demonstration Plan
E-AMAN	Extended Arrival Management
EAT	Expected Approach Time
eOSD	extended OSD
FIM	Flight-deck Interval Management
FIR	Flight Information Region
GA	Go-Around
IA	Innovation Action
IAF	Initial Approach Fix
IM	Interval Management
ITARO	Integrated TMA, Airport and Runway Operations
LOS	Loss of Separation
MRS	Minimum Radar Separation
MT	Merging Tool
NARSIM	NLR Air traffic management Real-time SIMulator
ORD	Optimised Runway Delivery
PWS	Pair Wise Separations
R&D	Research and Development




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RECAT	Re-Categorisation
RNP	Required Navigation Performance
ROT	Runway Occupancy Time
RSP	Required Surveillance Performance
RTS	Real Time Simulation
SESAR	Single European Sky ATM Research Programme
SID	Standard Instrument Departure
SRM	Safety Reference Material
TBS	Time-Based Separation
TMA	Terminal Manoeuvring Area
TRL	Technological Readiness Level
UAC	Upper Area Control centre
VLD	Very Large Demonstration
WTS	Wake Turbulence Separation
XMAN	Cross Border Arrival Management

Table 11: Acronyms


6 References

Safety

- [1] DEMO Plan Part II Safety Assessment Plan - latest edition accessible in STELLAR Program Library
- [2] SESAR Safety Reference Material - latest edition accessible in STELLAR Program Library
- [3] Guidance to Apply SESAR Safety Reference Material - latest edition accessible in STELLAR Program Library
- [4] STELLAR Slideboard, Safety part (complementary guidance)
- [5] (EU) No 2017/373 laying down common requirements for service providers and the oversight in air traffic management/air navigation services and other air traffic management network functions, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 1034/2011 and (EU) No 1035/2011 and amending Regulation (EU) No 677/2011 (and associated AMC and GM)
- [6] SESAR P16.01.04, Final Guidance Material to Execute Proof of Concept, Ed00.04.00, August 2015
- [7] SESAR Project PJ37-W3-ITARO, PJ.37-W3-DEMOP, Part I - latest edition accessible in STELLAR Program Library
- [8] SESAR Solution PJ.02-01 SPR-INTEROP/OSED for V3 - Part II - Safety Assessment Report
- [9] SESAR Solution 02.03 SPR-INTEROP/OSED for V3 - Part II - Safety Assessment Report
- [10] SESAR Solution 02.08 SPR-INTEROP/OSED for V3 - Part II - Safety Assessment Report
- [11] ED-195B/DO-328B, Safety, Performance, and Interoperability Requirements Document for Airborne Spacing – Flight-deck Interval Management (ASPA-FIM), 2020.

Appendix A Analysis of Safety Objectives

This appendix provides more detailed analysis regarding the safety demonstration objectives, as input to chapter 4. This includes an analysis for RTS1 as well as an analysis for RTS2.

A.1 List of simulation runs in RTS1 and RTS2

RTS1 included 11 simulation runs:

ID of run in RTS1	Reference (REF) or Solution (SOL)	Runway combination	Nr of a/c per hour per rwy	Wind
#2	REF	06/36R	35/35	Calm wind
#1	SOL	06/36R	35/35	Calm wind
#4	REF	18R/18C	35/35	Strong headwind on final
#3	SOL	18R/18C	35/35	Strong headwind on final
#7	REF	06/36R	40/40	Calm wind
#6	SOL	06/36R	40/40	Calm wind
#8	REF	18R/18C	35/35	Light-moderate headwind on final
#5	SOL	18R/18C	35/35	Light-moderate headwind on final
#10	REF	18R/18C	40/40	Light-moderate headwind on final
#9	SOL	18R/18C	40/40	Light-moderate headwind on final
#11	SOL*	06/36R	40/40	Calm wind, MRS 2.0 NM, IM +/-10%

Table 12: List of simulation runs during RTS1

As one may notice, run #1 is a solution run, but was executed in similar circumstances (similar runway combination, capacity and wind) as done for run #2. Therefore, the results for runs #1 and run #2 are compared to analyse the safety demonstration objectives for solution runs compared to reference runs. Similar for run #4 (REF) and run #3 (SOL), run #7 (REF) and run #6 (SOL), run #8 (REF) and run #5 (SOL), run #10 (REF) and run #9 (SOL). Finally, run #11 was a solution run, but with unique circumstances for the minimum radar separation (MRS) and IM.

RTS2 included 12 simulation runs, but the results of one of them (#7) are not included in the analysis, which leaves 11 runs remaining. Clarification:

- In runs #8, #9, #4, and #5, due to logistics, only the West-side of the operation (approach for runway 18R) was operated, but these runs still have valuable results. Run #4 was later repeated including the West and the East side; this run is named #4bis.
- In runs #2 and #7 there were technical problems and they were stopped before the planned ending (i.e. they were stopped after about 45-50 minutes). Both were later repeated, named #2bis and #7bis. The original run #2 still has valuable results up until a few minutes before the simulation was stopped. Run #2bis also experienced technical problems, but its results can be used to an extent. Run #7 had problems right from the beginning hence its results are not used for this safety analysis.

ID of run in RTS2	Reference (REF) or Solution (SOL)	Runway combination	Nr of a/c per hour per rwy	Wind
#8	REF (strong wind)	18R/18C	40/40	Strong wind
#9	SOL (100% IM, strong wind)	18R/18C	40/40	Strong wind
#1	REF	18R/18C	40/40	Calm wind
#3	SOL (20% IM)	18R/18C	40/40	Calm wind
#4	SOL (80% IM)	18R/18C	40/40	Calm wind
#4bis	SOL (80% IM)	18R/18C	40/40	Calm wind
#2	SOL (100% IM)	18R/18C	40/40	Calm wind
#2bis	SOL (100% IM)	18R/18C	40/40	Calm wind
#5	SOL (100% IM, go-arounds, landing sequence change)	18R/18C	40/40	Calm wind
#7bis	SOL (100% IM, EAT adherence)	18R/18C	40/40	Calm wind
#10	SOL* (100% IM, MRS 2.0 NM)	18R/18C	43/43	Calm wind

Table 13: List of simulation runs during RTS2

As one may notice, run #9 is a solution run, but was executed in similar circumstances (similar runway combination, capacity and wind) as reference run #8 was. Therefore, the results for run #9 and run #8 are compared to analyse the safety demonstration objectives for solution runs compared to reference runs in strong wind.

Similar for run #1 (REF), which can be directly compared with run #3 (SOL with 20% IM), run #4 and #4bis (SOL with 80% IM), run #2 and #2bis (SOL with 100% IM), to analyse various levels of IM equipage in calm wind conditions.

Run #1 (REF) can also be compared with run #5 (SOL with two scripted go-arounds and a scripted landing sequence change), and run #7bis (SOL with some deviations in expected approach times (EAT) in the TMA), but it is noted that #5 and #7bis included a few scripted non-nominal events while #1 did not, which will have created some bias.

Finally, run #10 was a 'demo' solution run, with unique circumstances for the minimum radar separation (MRS 2.0 NM on final, rather than 2.5 NM) and traffic density (43 flights per hour for each runway, rather than 40).

Differences between RTS1 and RTS2

The set-up for RTS1 was different from that of RTS2.

- There were some differences in the ConOps. These have been incorporated based on feedback from the participating controllers and pseudo-pilots, in order to improve the operation, including the airspace layout and routes, the location of the merging points and achieve-by points, etc. These differences have been detailed in [DEMOP Part I] and the reader is referred to that overview.
- In RTS1 there was an equal number of REF runs and SOL runs, and the results could be compared pairwise. In RTS2 there were only 2 REF runs, which could be directly compared with 5 SOL runs. In addition there were 3 SOL runs with scripted non-nominal events or

circumstances. Using feedback and lessons learned from RTS1, the questionnaire for RTS2 was also updated. Some of the questions were reformulated in such a way that their answers could be interpreted on their own, rather than through a comparison of SOL and REF answers.

A.2 Analysis of OBJ-37-W3-DEMOP-SAF1-0001

A.2.1 Analysis for RTS1

Objective	OBJ-37-W3-DEMOP-SAF1-0001: The number of go-arounds due to insufficient spacing shall not be greater than in the reference simulation
Success criterion	CRT-37-W3-DEMOP-SAF1-0001: The use of the integrated tool shall not increase the number of controller-instructed go-arounds.
Analysis result	A detailed analysis of this objective is provided below this table. It is summarised as follows: During the 11 simulation runs in RTS1, there were 7 go-arounds (A-G). Five of these go-arounds (B, C, D, E, G) occurred in SOL runs, and two (A, F) occurred in a REF run. • In 2 of the cases (A, G) the pilot forgot to arm the ILS or to enter an altitude and did not even attempt a landing or a GA. • In 1 of the cases (B), the GA was initiated by the pilot. • In 2 of the cases (D, F), the GA was instructed by the controller, but because the aircraft was too high on approach, not because there was insufficient spacing. • Only in 2 cases (C, E), the controller instructed a GA because the aircraft was flying too fast, which may have led to insufficient spacing if the controller had not intervened. Both cases occurred in SOL runs; however, the first GA (C = #6 (SOL)) was due to a simulation issue, and the second (E = #9 (SOL)) was because the pilot forgot to arm FIM. Neither was caused by the combination of tools. Based on the data, the fact that more go-arounds occurred in SOL runs than in REF runs can therefore not be related to the new combination of tools. The questionnaires did not reveal any concern regarding this objective either. Therefore, we conclude at this moment that the number of go-arounds due to insufficient spacing is not increased by the combination of tools. It is recommended to confirm this conclusion during RTS2.
Results	OK (Full) but to be confirmed during RTS2
Reference	RTS1 Post-run Question 22 (<i>"I think that the combination of tools will improve (i.e. decrease, or not increase) the number of go-arounds that need to be instructed by the controller"</i>) Data analysis on KPI-01

Table 14: Extended results after RTS1 for OBJ-37-W3-DEMOP-SAF1-0001: The number of go-arounds due to insufficient spacing shall not be greater than in the reference simulation

Detailed analysis:

The detailed analysis is based on the results of the questionnaires (post-run question 22), and on data analysis.

In the questionnaires, the controllers were asked whether they thought that the combination of tools will improve (i.e. decrease, or not increase) the number of go-arounds due to insufficient spacing that need to be instructed by the controller. The responses for the SOL runs were compared with the responses for the corresponding REF runs.

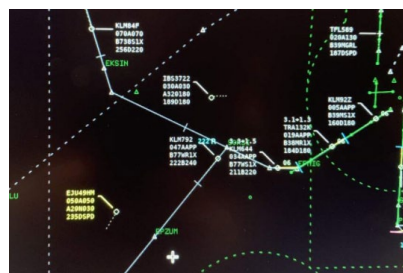
For multiple runs, the comparison of the answers to the question appeared to be inconclusive due to high dependencies on the context of each run. In run #1 (SOL), aircraft behaviour was indicated to be unrealistic, which was repaired in later runs, due to which a good comparison with the corresponding run #2 (REF) was not possible. In runs #4 (REF) (to be compared with #3 (SOL)), #5 (SOL) (to be compared with #8 (REF)) and #6 (SOL) (to be compared with #7 (REF)), one controller was critical about the way that aircraft and their ghosts were not separated by ACC before they entered the TMA, which gave bias to the responses by this controller. In run #9 (SOL) (to be compared with #10 (REF)), another controller was critical with respect to the number of go-arounds, but he also noted that this was partially due to pilot errors, and due to some medium-heavy aircraft flying too close behind a heavy, which gives a higher chance of a GA due to occupied runway. In the remaining comparisons (i.e. answers from controllers who were not critical regarding a specific issue), the scores for the reference run and the solution run regarding question 22 were similar.

From the data analysis: There were seven go-arounds in the simulation runs for RTS1:

- A. In #4 (REF): FIN2XL received an approach clearance, but the pilot forgot to arm the ILS approach. The aircraft did not land but continued flying and left the TMA while at 3000 ft altitude. This was a pilot error and not caused by the combination of tools. In any case, it was not an instructed GA due to insufficient spacing.
- B. In #6 (SOL): BEE6CP was delivered at the TMA entry fix close to the ghost symbol of KLM1566, and vice versa. The controller intervened by giving speed instructions to both aircraft. In the end, KLM1566 was 3500 ft above the fixed descent path and the pilot initiated a GA. Analysis revealed that the AMAN/TP calculations of the flying time for these aircraft types were not correct, which led to the plot-on-ghost issue. Hence this was primarily a simulation issue that triggered controller actions that triggered the pilot to initiate a GA. The controller actions may have been unnecessary since FIM might have been able to solve the separation issue in time (before the merge point), but this cannot be confirmed in hindsight. In any case, the GA was initiated by the pilot and it was not an instructed GA due to insufficient spacing. The GA was not caused by the combination of tools.
- C. In #6 (SOL): ARR1 provided speed instructions to KLM56C (leader), starting at 220 KIAS, and reducing in steps down to 160 KIAS. KLM54J (trailer) was flying behind it, controlled by FIM. ARR1 instructed KLM54J to reduce to Final Approach Speed as well, but KLM54J kept on flying at 190 kts. The controller instructed a GA. After analysis, it appeared that the simulation worked with a FAS of 190 kts, instead of a realistic speed. Therefore, even though the GA was instructed by the controller due to high speed of the aircraft and to avoid a loss of separation, it was due to a simulation issue, and not caused by the combination of tools.



- D. In #9 (SOL): KLM69B pilot entered a wrong R/T frequency and was not in contact with the controller until late. After the pilot armed the ILS approach, the aircraft did not descend, due to a simulator issue, and kept flying just below FL100. The controller instructed a GA. This was a simulator issue, the GA was not caused by the combination of tools
- E. In #9 (SOL): KLM1018 pilot forgot to arm FIM and did not reduce speeds, even when in final approach. The controller did not properly monitor this due to being busy with monitoring elsewhere, while assuming that FIM would solve any separation issues. The controller instructed a GA due to the aircraft flying too fast. This GA was therefore due to pilot error, combined with controller not properly monitoring. It can be argued that the GA was not caused by the combination of tools. However, the fact that the controller was distracted and was not properly monitoring may have been indirectly caused by the combination of tools: For example, if the controller had limited trust in the combination of tools, he may have been tempted to monitor how the operation unfolded more closely and become distracted. It is recommended to study this issue during RTS2. For now, we preliminarily conclude that there is no evidence that the GA was due to the combination of tools.
- F. In #7 (REF): IBS3722 was correctly established on RNP, descending to FL70, but the controller forgot to give the approach clearance. The pilot never challenged this. The controller instructed a GA due to the aircraft being too high. The next aircraft on approach was vectored to make space for IBS3722 in the sequence. This GA was due to a controller error combined with pilot not challenging. Because this GA was in a REF run, it was not caused by the combination of tools.



- G. In #11 (SOL*): TAP674 pilot got an instruction to descend to FL70 but forgot to enter the altitude. After having been given the approach clearance, the aircraft did descend but not nearly fast enough due to a simulator issue. The aircraft passed the threshold at 3300 ft; neither the pilot nor the controller noticed this. Hence this was a simulator issue; contributing factor was pilot error. It is unlikely this GA was related to the usage of the new combination of tools.

A.2.2 Analysis for RTS2

Objective	OBJ-37-W3-DEMOP-SAF1-0001: The number of go-arounds due to insufficient spacing shall not be greater than in the reference simulation
Success criterion	CRT-37-W3-DEMOP-SAF1-0001: The use of the integrated tool shall not increase the number of controller-instructed go-arounds.
Analysis result	During the 11 simulation runs in RTS2, there were 2 go-arounds. Both of them occurred in run #5. They were planned (scripted) by the RTS2 organisation and were initiated by the pilot. Therefore, the RTS2 simulation did not include go-arounds that were initiated by the controller. From observations during the simulations, one controller noted that there was one 'almost go-around', in run #1. The separation was tight, but the aircraft



	still landed. Run #1 was a reference run. In other runs, there were also a few losses of separation on final approach, which in normal circumstances might have led to an instructed go-around, but did not in this simulation. The questionnaires did not reveal major concerns regarding this objective. The controllers provided a neutral to positive scoring and in their comments they noted that the combination of tools provides some predictability for both the pilots and the controllers. One controller noted that a condition is that the pilots understand the procedure; if they don't, the controller's workload gets too high. The detailed analysis below this table outlines several potential reasons why RTS1 did include controller-instructed go-arounds and RTS2 did not. One of the possible reasons was that due to the high traffic density in RTS2, the controllers may have been more hesitant to instruct a go-around to avoid a (minor) loss of separation, because they knew it would be challenging to avoid such loss in the second approach anyway. Since the solution runs did not include a controller-initiated go-around, we cannot conclude from the RTS2 results that the number of go-arounds due to insufficient spacing is increased by the combination of tools.
Results	OK (Full)
Reference	Post-run Question 24 (<i>"I think that the combination of tools will reduce the number of controller-instructed Go-arounds (i.e. go-arounds that need to be instructed to avoid loss of separation)."</i>) RTS2 Post-run Question 30 and 30a (<i>"Did your run include a Go-around? If yes, who (you, other controller, pilot) initiated the go-around(s) and why?"</i>) Data analysis on KPI-01

Table 15: Extended results after RTS2 for OBJ-37-W3-DEMOP-SAF1-0001: The number of go-arounds due to insufficient spacing shall not be greater than in the reference simulation

Detailed analysis:

The detailed analysis is based on the results of the questionnaires (post-run questions 24, 30 and 30a), and on data analysis.

In the questionnaires (Question 24), the controllers were asked whether they thought that the combination of tools will improve (i.e. decrease, or not increase) the number of go-arounds due to insufficient spacing that need to be instructed by the controller.

For almost all runs, the controllers either gave a neutral response ("4", i.e. in the middle between "1 = Strongly disagree" and "7 = Strongly agree"), or a slightly positive response ("5" or "6"). The one exception was run #2 (SOL), in which one controller gave the score "2" with the comment that it all depends on whether the pilots understand the IM procedure; if they don't, the controller's workload gets too high. Note that in run #2 there were several simulation issues, and the other controllers gave the scores of "4" and "6" in this run. Nevertheless, if the disturbances would have been due to pilots not listening to instructions, rather than due to simulation issues, the comment is a valid point.

The comment was made in the questionnaire that with the use of IM, pilots have a clearer understanding of what is expected from them. The combination of tools also allows controllers to have more time for separation monitoring due to the reduced (R/T) workload, but can also distract their attention from the situation on final approach, causing delays in solving (potential) separation issues. One controller reported that using speed instructions instead of IM increases their control over separation assurance and reduces the likelihood of go-arounds.

There were also a few comments that were related to this being a simulation environment: One controller noted that in this simulation environment, he instructs fewer go-arounds than normal, in order to not overload the pseudo-pilots (who were in charge of multiple aircraft at the same time). Another controller noted that in real operational practice, some go-arounds are due to other reasons than separation assurance, for example, due to cabin crew not yet being ready for landing, or technical problems, which makes judging the answer difficult.

In questions 30 and 30a the controllers were asked whether their run in fact included a go-around. In their replies, the controllers referred to the two go-arounds in run #5 only, which were scripted by the RTS2 organisation. Indeed, according to the data, and in contrast with RTS1, RTS2 did not include any go-arounds other than the two scripted ones. There may be several reasons for this. One reason is the reduced radar separation minimum on final (MRS = 2.5 NM) that was used for RTS2. Another is that the controllers did not wish to overload the pseudo-pilots in this simulation. A third possibility is that the traffic density in this simulation was very high: 40 aircraft per runway per hour. After a go-around, the number of approaches is increased even further, since the aircraft needs to be re-sequenced. Therefore the probability of a LOS in the second attempt may be even higher. Indeed, it appears that both of the scripted go-arounds led to a LOS after resequencing (see appendix A.4.2 for details). Therefore, the controllers may have been hesitant to instruct a go-around to avoid a (minor) loss of separation, because they knew it would be challenging to avoid such loss in the second approach anyway.

One of the controllers did make a suggestion to mitigate this problem: If a go-around occurs, the ACC or the APP controller should delay the traffic that is still further away from the runway, in order to create some space in the sequence. The aircraft executing the go-around can be re-sequenced immediately if necessary, but the aircraft following it can be delayed a few minutes until the extra space reaches them. Proper controller training should help to give the controller more trust in this procedure.

A.2.3 Conclusions on OBJ-37-W3-DEMOP-SAF1-0001

During RTS1, based on the data, the fact that more go-arounds occurred in SOL runs than in REF runs could not be related to the new combination of tools. The questionnaires did not reveal any concerns regarding this objective either. Therefore, after RTS1 it was concluded that the number of go-arounds due to insufficient spacing is not increased by the combination of tools. The results of RTS2 appeared to confirm (or at least did not contradict) this conclusion.

Recommendations for future research are:

- For a more accurate representation of the safety objectives being studied, incorporate a runway controller in future simulations to manage traffic on the arrival segment and collaborate with the arrival controller in instances that may result in go-arounds.



A.3 Analysis of OBJ-37-W3-DEMOP-SAF1-0003

A.3.1 Analysis for RTS1

Objective	OBJ-37-W3-DEMOP-SAF1-0003: The interoperability of the different tools in the integrated tool shall not introduce safety issues
Success criterion	CRT-37-W3-DEMOP-SAF1-0003: Ensure that the functionalities of all solutions complement one another without negative interference.
Analysis result	A detailed analysis on this objective is provided below this table. It is summarised as follows: One issue has been identified in which the interoperability of the different tools might be a factor. During RTS1, traffic on two RNP routes ('transitions') that merged further along the route often arrived at the IAF unseparated: the 'merge support ghost blip' of one aircraft was projected on or near the plot of the actual aircraft to which the merge had to be performed. This was an undesirable situation from the perspective of the controller, because in normal operations, the controller would expect ACC to deliver the aircraft without conflict. A combination of multiple factors contribute to the discomfort of the controller. The following SESAR solutions are involved: • E-AMAN (SESAR 1 Solution #5) • Airborne Spacing Flight Deck Interval Management (SESAR 2020 W1 PJ.01-05) • Enhanced Terminal Airspace Routing using RNP-based Operations (SESAR 1 Solution #62, #09, #51) In addition, the merge tool and associated ghost blip plays a significant role. However this is not a SESAR solution to be validated in ITARO. After RTS1, it is unclear what exact role is played by the interoperability of the different tools due to the many contributing factors. Some of these are due to simulation design and some are due to functionalities and tools that are not part of the SESAR solutions to be validated in ITARO. In RTS2, some changes are made to the design of the simulation (route, algorithms) and functionality of the merge tool. This aims to reduce the contribution of the factors that are not related to the interoperability of the SESAR solutions. In RTS2, this issue can then be further investigated.
Results	Based on the results of RTS1, a final and valid conclusion cannot be given. It will be formulated after RTS2.
Reference	RTS1 Post-run Questions 18-28 and RTS1 Post-experiment Question 5 Remarks end-of-run debrief-sessions Remarks end-of-experiment debrief session

Table 16: Extended results after RTS1 for OBJ-37-W3-DEMOP-SAF1-0003: The interoperability of the different tools in the integrated tool shall not introduce safety issues

Detailed analysis:

Interoperability describes the interaction between different components in a single system. Within ITARO, it is about how the individual solutions work together, and how the information provided by one tool is accurately used and interpreted by the users or by a different system. The safety aspect of interoperability is acceptable if the functionalities of all solutions complement one another without negative interference. This is assessed by qualitative means, based on the results of the questionnaires and in particular, in the explanation fields, observations by the safety experts, and in post-run and post-experiment debrief sessions.

Question 18 asked the controllers to rate the overall level of safety for the combination of tools used in the reference or solution run, compared to the current situation at Schiphol. These results can be used to compare solution runs with reference runs executed under the same circumstances. In these comparisons, it is noticed that overall, the reference runs received slightly (not significantly) higher scores than the solution runs: 3.9 over 3.6 on a scale of 1 to 5. In several of the debrief sessions one of the controllers indicated to be concerned about the delivery of aircraft at the Initial Approach Fix (IAF) by ACC. Traffic on two RNP routes ('transitions') that merged further along the route often arrived at the IAF 'unseparated': the 'merge support ghost blip' of one aircraft was projected on or near the plot of the actual aircraft to which the merge had to be performed (see pictures to the right, from run #4 (REF) (top picture) and #3 (SOL) (bottom picture)). This was an undesirable situation from the perspective of the controller, because in normal operations, the controller would expect ACC to deliver the aircraft without conflict.



In the Solution run, it was the task of FIM to create sufficient time-based spacing at the achieve-by-point between two sequential aircraft. The achieve-by-point is located nearer to the threshold than the merge-point. The controllers had more of a monitoring task, and before the start of RTS1 they had not built up sufficient trust in IM. Since FIM established spacing later, i.e. much closer to the threshold, than the controller was used to, and merged without a buffer ('just enough'), the controller felt like having little control over the aircraft. In some cases, the controller cancelled IM and gave the aircraft in question speed instructions to provide sufficient spacing at the merge point.

A combination of multiple factors contributes to the discomfort of the controller (see Appendix A.2 'Deviation from the planned activities' of the DEMOR Part I for more information):

- The merge support is 'distance-based', meaning the ghost of an aircraft on a specific RNP transition is projected on the other RNP transition at an equal distance from the merge-point. It does not take into account factors as actual wind speed and wind direction, unlike FIM does. The possible difference in wind speed and direction on the transitions, and thus the difference in relative speed between the aircraft, is not reflected in the projection of the ghost.
- The merge support tool takes into account the exact trajectory of the RNP transition. In the simulation, some transitions had right-angled (90 degrees) turns. However, aircraft cannot fly an exact right-angled turn and turn at a specific bend radius. This means that the actually flown trajectory of aircraft flying those transitions is shorter. This effect is not reflected in the projection of the ghost.
- A third factor is the accuracy of E-AMAN in predicting the IAF arrival time of an aircraft. In RTS1 an accuracy of +/-30 seconds was used. With a speed of approximately 250 kts when entering

the TMA, the accuracy in distance is ± 4 NM. This can result in two aircraft entering the TMA at an equal distance from the merge point. However, a more accurate delivery of the aircraft is unrealistic at this stage.

- FIM of a specific aircraft aims to realize enough spacing with its paired aircraft at the 'achieve-by-point'. The fact that this point is located closer to the threshold than the merge-point is an explanation for why FIM, from the perspective of the controller, creates spacing relatively 'late' (close to the merge-point).
- The minimal radar separation at the merge-point is 3 NM. FIM is not tasked with creating sufficient spacing on the merge-point, e.g. the spacing is not 'guaranteed by design'. It turned out that in most cases, FIM did create sufficient spacing at the merge-point. However, the controller did not always trust FIM to do this. In those cases, the controller cancelled IM and gave speed instructions and/or vectors. This may have prevented losses of separation which FIM would have prevented as well (but later).

The following SESAR solutions are involved:

- E-AMAN (SESAR 1 Solution #5)
- Airborne Spacing Flight-deck Interval Management (SESAR 2020 W1 PJ.01-05)
- Enhanced Terminal Airspace Routing using RNP-based Operations (SESAR 1 Solution #62, #09, #51)

In addition, the merge tool and associated ghost blip plays a significant role. However, this is not a SESAR solution to be validated in ITARO. This issue was also identified in the initial workshop with Solution Members and documented in the DEMOP Part II Safety, identifier SI-01: Inconsistency between algorithms of Merging Tool (MT) and Flight-deck Interval Management (FIM).

After RTS1, it is unclear what exact role is played by the interoperability of the different tools due to the many contributing factors. Some of these are due to simulation design and some are due to functionalities and tools that are not part of the SESAR solutions to be validated in ITARO.

In RTS2, some changes are made to the design of the simulation (route, algorithms) and the functionality of the merge tool. This aims to reduce the contribution of the factors that are not related to the interoperability of the SESAR solutions. In RTS2, this issue can be further investigated.

In RTS1, no other issues were identified in which the interoperability of the different tools is a factor.

A.3.2 Analysis for RTS2

Objective	OBJ-37-W3-DEMOP-SAF1-0003: The interoperability of the different tools in the integrated tool shall not introduce safety issues
Success criterion	CRT-37-W3-DEMOP-SAF1-0003: Ensure that the functionalities of all solutions complement one another without negative interference.
Analysis result	One interoperability issue has been identified. The FIM system's task is to create spacing between aircraft on fixed routes, but its efficiency depends on the accuracy of the EAT provided by E-AMAN. During the simulation, the actual flight sequence was sometimes different from the planned sequence, resulting in illogical pairings and an unpredictable operation. This highlights the need for reliable EAT on the TMA boundary for the FIM system to work properly. However, the likelihood of the E-AMAN



	system providing unreliable EAT in real-life operations is small and the consequences are likely to be low as the ACC controller and flight crew may detect and resolve any issues before the aircraft arrives in the TMA. However, controllers are not informed if the pairing is illogical, resulting in the safety objective not being fully met. The overall score for this system is "Partially OK." In future simulations or demonstrations, it is recommended to add a safety net to the system that warns controllers of any interoperability issues between the FIM and E-AMAN systems and algorithms.
Results	Partially OK Additional testing in simulations is required to provide further evidence on this safety objective.
Reference	RTS2 Post-run Questions 19-31, particularly Question 19 (<i>"In the last run, how do you rate the overall level of safety"</i>) and Question 31 (<i>"I have some safety concerns in addition to the ones mentioned above"</i>) Remarks end-of-run debrief-sessions Remarks end-of-experiment debrief session

Table 17: Extended results after RTS2 for OBJ-37-W3-DEMOP-SAF1-0003: The interoperability of the different tools in the integrated tool shall not introduce safety issues

Detailed analysis:

Location of achieve-by-point

Between RTS1 and RTS2, some changes have been implemented that are aimed to improve the operation, but that are not related to one of the SESAR solutions of Table 2. One aspect that changed between RTS1 and RTS2 is the location of the achieve-by-point, i.e. the point at which the IM spacing has to be realised. In RTS1, the achieve-by point was located at the planned termination point of the IM operation, i.e. on the FAP; in RTS2, the achieve-by-point was located at the merge point. This adjustment aimed to guarantee that in a nominal operation, spacing is sufficient between two consecutive aircraft on different RNP lags. However, this led to new potential safety issues. One is described in section A.5.2 and has a relation with the controllability from a controller perspective. The second issue is described below.

The FIM-system makes use of two different algorithms: one is used for the section from the entry-point of the TMA up until the merge point, and the other is used from the merge point up until the FAF. The transition from the first algorithm to the second one, in combination with other factors like the difference between supply and capacity and the difference in speed of paired aircraft, results in a gap between the actual distance between two consecutive (paired) aircraft and the distance according to interval management. The FIM-algorithm is programmed to close the gap, to benefit the actual capacity. However, because of this, in some cases the speeds of aircraft were not realistic, for example up to 200 knots at 6 NM before landing. In another case, an aircraft illogically increased its speed relatively close to the FAF. One may argue that this issue is due to a connection between the E-AMAN, ORD and FIM because the spacing target is based on inputs from the E-AMAN and ORD. However, it is more about how the FIM-system handles the transition between two algorithms and how it handles gaps between paired aircraft. Therefore, this issue is classified as an IM-specific issue. It is described here because it was brought up by the controllers in the simulation multiple times. In all cases, there

was enough time and lateral spacing between aircraft to resolve a loss of separation if that had happened.

Interoperability between FIM and E-AMAN

Based on the answers to question 19 of the questionnaire (“In the last run, how do you rate the overall level of safety?”) and on the remarks given in the debrief of each run, it can be indicated that the participating controllers rate the level of safety of the Reference runs higher than the level of safety of most of the Solution runs, depending on the percentage of aircraft equipped with FIM. It is noted that the runs in which the aircraft were 100% equipped with FIM scored lower on that question, while also scoring lower on the controllability of the operation (question 21), in comparison with runs where a lower percentage or none were equipped with FIM. The remarks given in the explanation box of question 21 and question 31 (“I have some safety concerns in addition to the ones mentioned above.”), and the remarks given during the debrief sessions provide a possible explanation for this. The explanation hints at an interoperability issue between two solutions: FIM and E-AMAN.

FIM is tasked to create sufficient spacing between two aircraft on fixed routes, and it generally succeeds. However, the efficiency with which it does that depends heavily on the reliability or the accuracy of the EAT of aircraft on the TMA-entry point, provided by the E-AMAN [see Part I, Appendix B.4]. The simulation was configured to deliver flights on the TMA boundary with a ± 30 seconds EAT adherence. Each traffic scenario had an associated randomly derived distribution. The traffic for run #6 and #7bis had a limited number of flights (up to 6) with larger deviations (within ± 90 seconds) as part of the configuration: these were scripted as non-nominal traffic delivery events and were communicated with the controllers during the simulation. In addition, there were also some flights in run with an even larger deviation, up to minutes, which were not planned events and were not known by the controllers during the simulation. This was during run #2, #6, #7bis and #10. The actual order in which the flights entered the TMA was therefore different from the planned sequence of flights provided by the E-AMAN. Since FIM assigns a target aircraft based on the planned sequence provided by the E-AMAN, an inconsistency occurred in the pairing of aircraft with respect to IM, resulting in illogical pairing (i.e. a follower aircraft flying in front of its leader), disturbance of the sequence and an unpredictable operation. Due to this issue, the simulation runs of #2, #6 were stopped prematurely. This was because the controllers were unable to resolve the situation, given the limitations of the simulation (no ACC controller, pseudo-pilots) and the limited time the aircraft fly in the TMA (meaning limited time and space to create sufficient spacing).

While the root of this issue, an unplanned anomaly, can be classified as a ‘simulation issue’, it shows the dependency between E-AMAN and FIM. The EAT on the TMA boundary must be reliable for IM operation to work properly and predictably. However, it is likely that if an aircraft has a large deviation between the EAT and Actual time of arrival on the TMA boundary, that the ACC controller has already identified and solved the issue (the sequence) before the corresponding aircraft arrive in the TMA and are transferred to the approach controller. Therefore, the probability of this issue occurring in operational practice is likely to be small.

The nominal operation requires the use of fixed RNP routes. Therefore, the preferable solution when this issue occurs is reassigning the target aircraft for those affected in the sequence (those with a wrong target aircraft), or ‘disconnect’ IM and start giving speed instructions to those aircraft. This requires effort from the controllers and flight crews. In the simulation, the approach controller had little time to fix the situation without letting go of the nominal operation (without using vectors instead of only speed instructions). The approach controllers did not receive a warning of the late arrival of an aircraft in the TMA. They were therefore not aware that the pairing of aircraft was not consistent with the sequence they were flying in the TMA. The combination of tools does not provide an indication of

an incorrect pairing of aircraft. The earlier the controller identified or was notified about the issue, the more time they had to fix the issue. Altogether, this led to the situation in which the controllers were unable to safely direct all aircraft in the sequence to the FAF. The simulation was aborted earlier than planned.

A.3.3 Conclusions on OBJ-37-W3-DEMOP-SAF1-0003

Two issues, identified during RTS1 and RTS2, are assessed:

1. A potential safety issue was identified during RTS1 in which multiple SESAR solutions were involved. It was found that the spacing target of the FIM-system's achieve-by-point location resulted in the spacing at the merge point not being "guaranteed by design." This has a link with FIM and E-AMAN, but it was concluded that multiple factors contributed to the issue, not just the interoperability of the combination of tools. Changes were made in RTS2 to reduce the influence of external factors and an achieve-by-point at the merge point was implemented, which aimed to guarantee sufficient spacing in nominal operations. However, this resulted in new potential safety issues, such as high speeds and illogical speed changes. It turns out that this was due to an FIM-specific issue in the FIM-algorithms and not a result of interoperability issue(s) between different solutions.
2. FIM's task is to create sufficient spacing between aircraft on fixed routes, but its efficiency depends on the accuracy of the EAT provided by E-AMAN. During the simulation, the actual order in which the aircraft entered the TMA was sometimes different from the planned sequence, resulting in illogical pairings and an unpredictable operation. This shows the dependency between E-AMAN and FIM and highlights the need for reliable EAT on the TMA boundary for IM operation to work properly. From a safety perspective, it is problematic that the combination of tools did not warn the approach controller that follower aircraft were flying in front of their leader. The system E-AMAN may in operational practice provide unreliable EAT on the TMA boundary, but the likelihood of this happening is small. In addition the severity of the consequences is likely to be low as the ACC controller and flight crew may detect and resolve any issues before aircraft enter the TMA. However, controllers are not informed if the pairing is illogical, resulting in the safety objective not being fully met. The overall score for this system is "Partially OK."

Recommendations for future research are:

- For future simulations or demonstrations, implement a safety mechanism to alert controllers in case of any compatibility issues between the FIM system/algorithm and the E-AMAN system/algorithm, such as illogical aircraft pairings.
- Consider expanding the coverage of the FIM system to include the ACC airspace, in addition to the TMA airspace. This could provide more time and space for the system to maintain appropriate spacing between aircraft and to create gaps in case an aircraft needs to re-sequenced.
- Enhance the realism of future simulations or demonstrations by incorporating more realistic speed profiles of aircraft. Refining the FIM algorithms and ensuring seamless transitions between them may be necessary to achieve this.


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A.4 Analysis of OBJ-37-W3-DEMOP-SAF1-0004

A.4.1 Analysis for RTS1

Objective	OBJ-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)																																																																							
Success criterion	CRT-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)																																																																							
Analysis result	This objective aims to show that the use of the integrated tool and the Airborne Spacing Flight Deck Interval Management (FIM) does not lead to an increased number of separation losses (LOS) in the solution scenario (SOL) as compared with the reference scenario (REF). The more detailed analysis below this table presents each case of LOS in the runs of RTS1 and analyses the severity of the LOS (MRS and ROT; there were no WTS LOS). The LOS due to ROT are also Runway Incursions, since the follower aircraft is landing before the leader aircraft has vacated the runway. The results can be summarised by comparison of the numbers of LOSs in the REF runs with the numbers of LOSs in the corresponding SOL runs. Here, A indicates the most serious LOSs (remaining separation is less than 50% of the minimum required separation), B indicates moderate LOS (between 50% and 66%), C indicates minor LOS (between 66% and 99%) and D indicates LOSs that are negligible (99% of the minimum required separation): <table> <tr> <th>Run</th><th>A</th><th>B</th><th>C</th><th>D</th><th>Comparison (MRS)</th></tr> <tr> <td>#2 (REF)</td><td>0</td><td>0</td><td>1</td><td>0</td><td rowspan="2">#1 (SOL) has one additional LOS due to MRS of category A/B (50%). However, this may be due to unrealistic speeds being flown by the pilots in this first run. Both runs have one category C LOS (95%) right before leader is landing</td></tr> <tr> <td>#1 (SOL)</td><td>1</td><td>0</td><td>1</td><td>0</td></tr> <tr> <td>#4 (REF)</td><td>0</td><td>2</td><td>2</td><td>0</td><td rowspan="2">#4 (REF) has multiple category B (62% and 65%) and C LOS (97% and 86%) while #3 (SOL) has none. #4 was the one with strong headwind on final and many plots on top of ghosts</td></tr> <tr> <td>#3 (SOL)</td><td>0</td><td>0</td><td>0</td><td>0</td></tr> <tr> <td>#8 (REF)</td><td>0</td><td>0</td><td>2</td><td>7</td><td rowspan="2">Ignoring the 7 LOS of category D, #8 (REF) has two category C LOS (93% and 87%) compared to #5 (SOL) having one (93%)</td></tr> <tr> <td>#5 (SOL)</td><td>0</td><td>0</td><td>1</td><td>0</td></tr> <tr> <td>#7 (REF)</td><td>0</td><td>0</td><td>2</td><td>1</td><td rowspan="2">Ignoring the LOS of category D, #7 (REF) has two category C LOS (93% and 90%), while #6 (SOL) has one (75%)</td></tr> <tr> <td>#6 (SOL)</td><td>0</td><td>0</td><td>1</td><td>1</td></tr> <tr> <td>#10 (REF)</td><td>1</td><td>0</td><td>9</td><td>10</td><td rowspan="2">Ignoring the 10 LOS of category D, #10 has 9 category C LOS (mostly 90-93%, one 75%, one 85%), and one category A LOS (43%), while #9 (SOL) has one category C LOS (84%)</td></tr> <tr> <td>#9 (SOL)</td><td>0</td><td>0</td><td>1</td><td>0</td></tr> <tr> <td>#11 (SOL*)</td><td>0</td><td>0</td><td>0</td><td>0</td><td>-</td></tr> </table>					Run	A	B	C	D	Comparison (MRS)	#2 (REF)	0	0	1	0	#1 (SOL) has one additional LOS due to MRS of category A/B (50%). However, this may be due to unrealistic speeds being flown by the pilots in this first run. Both runs have one category C LOS (95%) right before leader is landing	#1 (SOL)	1	0	1	0	#4 (REF)	0	2	2	0	#4 (REF) has multiple category B (62% and 65%) and C LOS (97% and 86%) while #3 (SOL) has none. #4 was the one with strong headwind on final and many plots on top of ghosts	#3 (SOL)	0	0	0	0	#8 (REF)	0	0	2	7	Ignoring the 7 LOS of category D, #8 (REF) has two category C LOS (93% and 87%) compared to #5 (SOL) having one (93%)	#5 (SOL)	0	0	1	0	#7 (REF)	0	0	2	1	Ignoring the LOS of category D, #7 (REF) has two category C LOS (93% and 90%), while #6 (SOL) has one (75%)	#6 (SOL)	0	0	1	1	#10 (REF)	1	0	9	10	Ignoring the 10 LOS of category D, #10 has 9 category C LOS (mostly 90-93%, one 75%, one 85%), and one category A LOS (43%), while #9 (SOL) has one category C LOS (84%)	#9 (SOL)	0	0	1	0	#11 (SOL*)	0	0	0	0	-
Run	A	B	C	D	Comparison (MRS)																																																																			
#2 (REF)	0	0	1	0	#1 (SOL) has one additional LOS due to MRS of category A/B (50%). However, this may be due to unrealistic speeds being flown by the pilots in this first run. Both runs have one category C LOS (95%) right before leader is landing																																																																			
#1 (SOL)	1	0	1	0																																																																				
#4 (REF)	0	2	2	0	#4 (REF) has multiple category B (62% and 65%) and C LOS (97% and 86%) while #3 (SOL) has none. #4 was the one with strong headwind on final and many plots on top of ghosts																																																																			
#3 (SOL)	0	0	0	0																																																																				
#8 (REF)	0	0	2	7	Ignoring the 7 LOS of category D, #8 (REF) has two category C LOS (93% and 87%) compared to #5 (SOL) having one (93%)																																																																			
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#6 (SOL)	0	0	1	1																																																																				
#10 (REF)	1	0	9	10	Ignoring the 10 LOS of category D, #10 has 9 category C LOS (mostly 90-93%, one 75%, one 85%), and one category A LOS (43%), while #9 (SOL) has one category C LOS (84%)																																																																			
#9 (SOL)	0	0	1	0																																																																				
#11 (SOL*)	0	0	0	0	-																																																																			





Run	A	B	C	D	Comparison (ROT)
#2 (REF)	0	0	0	0	#1 (SOL) has one LOS of category A (42%) due to ROT and one of category C (89%) while #2 (REF) has none
#1 (SOL)	1	0	1	0	
#4 (REF)	0	0	2	0	#4 (REF) has two category C LOS (86%, 83%) due to ROT while #3 (SOL) has none
#3 (SOL)	0	0	0	0	
#8 (REF)	0	0	0	0	#5 (SOL) has one category C LOS (93%) due to ROT while #8 (REF) has none
#5 (SOL)	0	0	1	0	
#7 (REF)	0	0	0	0	Neither run had a LOS due to ROT
#6 (SOL)	0	0	0	0	
#10 (REF)	0	1	0	0	#10 (REF) has one category B (55%) LOS due to ROT while #9 (SOL) has none
#9 (SOL)	0	0	0	0	
#11 (SOL*)	0	0	0	0	-

Based on this data, overall, the SOL runs did not seem to have more cases of LOS due to MRS than the REF runs, and even have much fewer. For LOS due to ROT, the REF runs and SOL runs have similar numbers on average. No LOS due to WTS was identified.

In the questionnaire, the controllers were asked whether they thought that the combination of tools will improve (i.e. decrease or not increase) the number of losses of separation. Overall, the controllers noted more concerns with WTS, rather than MRS or ROT, which is notable since no WTS losses were identified in the data.

Concluding, overall, the data showed that for both MRS and ROT, the SOL runs did not seem to have more cases of LOS than the REF runs, and even showed much fewer. In the questionnaires and the debriefing the controllers did have a few concerns with WTS separation losses, however. Therefore it is advised to study this matter more closely during RTS2.

Results	OK (Full), but to be confirmed during RTS2
Reference	RTS1 Post-run Question 23 (<i>"I think that the combination of tools will improve (i.e. decrease or not increase) the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)"</i>) Data analysis on KPI-02, KPI-03

Table 18: Extended results after RTS1 for OBJ-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)

Detailed analysis:

In the questionnaire, the controllers were asked whether they thought that the combination of tools will improve (i.e. decrease or not increase) the number of losses of separation. Overall, in their ratings, the controllers were slightly more positive about this aspect in the REF runs, compared to the SOL runs. In their explanations, the controllers noted that some of these beliefs were due to unrealistic aircraft speeds being flown, or due to less than optimally separated aircraft entering the TMA. In a REF run, one controller also noted, however, that he sometimes lacked the time to check separation between aircraft close to each other on final track. This concern was confirmed by the data, in which almost all losses of separation appeared to have occurred right before landing. Overall, the controllers noted more concerns with WTS, rather than MRS or ROT, which is notable since no WTS LOSs were identified in the data.

The table below provides a detailed analysis of all LOSs measured in the data of RTS1. In the last column, the severity of the LOS is categorised using the following definitions:

- A: The LOS is smaller than 50% of the separation norm
- B: The LOS is between 50% and 66% of the separation norm
- C: The LOS is between 66% and 99% of the separation norm
- D: There is a brief LOS but it is barely visible (99% of the separation norm)

Run	Nr of LOS WTS	Nr of LOS ROT	Nr of LOS MRS	Callsigns [leader- follower]	Observations	Severity
#1 (SOL)	0	2	2	BAW440- KLM1634	MRS and ROT. Follower (F) is at 7000 ft altitude for too long, then expedites descent, thus reducing separation with Leader (L) quickly. When L lands, F is only 400 ft 1.3 NM behind L (note that MRS=2.5NM). When F lands, L still has 35 s ROT remaining (out of 60.41 sec). Therefore, this is a very serious Runway Incursion. This LOS may be due to 'unrealistic speeds' being flown in this very first run. After this run the pilots try to adapt their speeds to make them more realistic	MRS: A/B (50%) ROT: A (42%)
				N904DF- VLG73SB	MRS and ROT. When L lands, separation with F is 800 ft, 2.4 NM, so just below MRS (=2.5NM). When F lands, leader has few seconds ROT remaining	MRS: C (95%) ROT: C (89%)
#2 (REF)	0	0	1	KLM1308- AXG11	MRS. When L lands, separation with F is 900 ft, 2.9 NM (MRS=3.0), so just below MRS and not further reducing.	MRS: C (97%)
#4 (REF)	0	2	4	KLM1634- BAW440	MRS. When L lands, separation with F is 900 ft, 2.9 NM, so just below MRS and not further reducing.	MRS: C (97%)
				KLM87H- EVA075	MRS and ROT. About 8 minutes before L landing, F is descending faster and flying faster than L. Between 8 minutes and 5 minutes	MRS: B (62%)

					before L landing, their horizontal separation quickly reduces from 7 NM to 3 NM and their vertical separation reaches near zero. After 5 minutes before landing, the horizontal separation remains fixed at 2.7 NM (MRS = 3.0NM) and the vertical separation is gradually increased to 900 ft. With 100 seconds to go, the separation reduces again and is 600 ft and 1.9 NM when L lands (MRS=3.0NM). When F lands, leader has few seconds ROT remaining	ROT: C (86%)
				ELY339-KLM896	MRS. In the last 100 seconds before L lands, the separation is decreasing from 1000 ft to 850 ft, and from 3 to 2.6 NM.	MRS: C (86%)
				EJU57FT-TRA88N	MRS and ROT. In the last 100 seconds before L lands, the separation is decreasing from 1000 ft to 600 ft, and from 3 to 1.95 NM (MRS=3.0NM). When F lands, leader has few (at most 10) seconds ROT remaining	MRS: B (65%) ROT: C (83%)
				DLH9JF-FIN2XL	MRS. In the last 3 minutes before L lands, F is at 3500 ft altitude, and stays that way. In the last few seconds before L lands, the horizontal separation is just below 3 NM, but F is still at 3500 ft when it passes the threshold. This is not a LOS. Further analysis revealed that pilot had forgotten to arm ILS approach	No LOS
#5 (SOL)	0	1	1	ELY339-UAE149	MRS and ROT. In the last 100 seconds before L lands, the separation is decreasing from 1000 ft to 700 ft, and from 2.5 to 2 NM (MRS=2.5). When F lands, leader has few seconds ROT remaining	MRS: C (81%) ROT: C (93%)
#6 (SOL)	0	0	2	BAW432-KLM1566	MRS and go-around. From IAF to about 80 sec before L lands, the separation is just above 2.5 NM. At 80 sec, it dips below 2.5 NM (MRS=2.5 NM) but there is still 1200 ft vertical. Vertical separation quickly reduces to 750 ft while horizontal reduces to 1.9NM, F initiates a go-around. Further analysis revealed: F was kept at FL100 and at too high speed for too long. At EFMIG, it was 1 NM ahead of the TBS indicator. At 3 NM before the threshold, at 1000 ft, flight crew initiated go-around. At 3 NM the large vertical deviation was just fully corrected. F was 2 NM behind L, still 0.5-1 NM ahead of the TBS indicator.	MRS: C (75%)
				BEE6CP-KLM56C	MRS. In the last 80 seconds before L lands, the vertical separation is decreasing from 1000 ft to 800 ft, but is horizontally still above 2.5 NM	MRS: D (99%)



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					(MRS=2.5NM). In the last 10 seconds it just dips below 2.5 NM.	
				EJU9043-KLM32Z	MRS. Near the IAF, KLM32Z and EJU9043 entered the system same time same place, which resulted in a LOS. Controller gave KLM32Z a holding lap, followed by a direct to final to solve a conflict with the next aircraft TAP678. Separation was restored after 25 seconds. This was a simulation issue: the previous controller would not have handed over two aircraft like this.	MRS: Very serious, but due to simulation issue, therefore declared no LOS
						
#7 (REF)	0	0	3	KLM26K-VLG6292	MRS. In the last 30 seconds before L lands, the separation dips to just below 1000 ft and just below 3 NM. Barely visible.	MRS: D (99%)
				TRA66H-KLM1870	MRS. 200 seconds before L lands, L levels off at 3000 ft while F is still descending. Their vertical separation decreases to 100 ft and their horizontal separation briefly dips to 2.8 NM before it is restored again due to L descending further and F levelling off at 3000 ft for a short while	MRS: C (93%)
				VLG6292-KLM1766	MRS. In the last 60 seconds before L lands, the separation decreases from 1000 ft to 850 ft and from 3 NM to 2.7 NM (MRS=3.0 NM).	MRS: C (90%)
#8 (REF)	0	0	9	CFE67W-KLM1688	MRS. In the last 25 seconds before L lands, the separation decreases from 1000 ft to 900 ft and from 3 NM to 2.8 NM.	MRS: C (93%)
				EJU53JD-AXG11	MRS. 250 seconds before L lands, the vertical separation decreases below 1000 ft while the horizontal separation briefly dips below 3NM	MRS: D (99%)
				EJU2727-KLM58A	MRS. In the last 60 seconds before L lands, the separation dips to just below 1000 ft and just below 3 NM. Barely visible.	MRS: D (99%)
				EZY75EU-KLM1308	MRS. Twice. 300 seconds before L lands, the vertical separation decreases below 1000 ft while the horizontal separation briefly dips from 3NM to 2.6 NM until it is restored again.	MRS: C (87%)



					At 50 seconds before landing, the separation dips to just below 1000 ft and just below 3 NM, barely visible.	MRS: D (99%)
				IBS37CG-KLM37D	MRS. 230 seconds before L lands, the vertical separation decreases below 1000 ft while the horizontal separation briefly dips below 3NM	MRS: D (99%)
				KLM1634-BAW440	MRS. 250 seconds before L lands, the vertical separation decreases below 1000 ft while the horizontal separation briefly dips below 3NM (barely visible)	MRS: D (99%)
				VLG73SB-KLM1020	MRS. 250 seconds before L lands, the vertical separation decreases below 1000 ft while the horizontal separation briefly dips below 3NM (barely visible)	MRS: D (99%)
				ELY339-KLM882	MRS. In the last 10 seconds before L lands, the separation dips to just below 1000 ft and just below 3 NM. Barely visible.	MRS: D (99%)
#9 (SOL)	0	0	1	BAW432-KLM1018	MRS. At 50 seconds before L lands, F is instructed a go-around due to too high speeds (pilot error). The vertical separation decreases to 800 ft and 2.1 NM (MRS = 2.5 NM) at one point before it is restored	MRS: C (84%)
#10 (REF)	0	1	20	AMC478-KLM1918	MRS. Twice. At 300 sec and at 200 sec before L lands, the vertical separation is 700 ft and the horizontal separation briefly dips below 3 NM, barely visible	MRS: D (99%) MRS: D (99%)
				BTI6D9-K1132	MRS and ROT. During the last 260 seconds before L lands, the vertical separation varies between 800 ft and 400 ft, while the horizontal separation gradually decreases from 3 NM to about 1.3 NM due to F flying faster. When F lands, L has still 20 seconds of ROT remaining. Therefore, this is a very serious Runway Incursion.	MRS: A (43%) ROT: B (55%)
				KLM46C-KLM84L	MRS. In the last 40 seconds before L lands, the separation dips to 900 ft and 2.8 NM.	MRS: C (93%)
				KLM1092-KLM1604	MRS. During the last 60 sec before L lands, separation decreases from 1000 ft to 850 ft and from 3 NM to 2.7 NM	MRS: C (90%)
				KLM1382-FOO6824	MRS. During the last 80 sec before L lands, separation decreases from 1000 ft to 900 ft and from 3 NM to 2.8 NM	MRS: C (93%)
				KLM1592-KLM46C	MRS. Between 350 and 220 sec before L lands, the vertical separation is about 700 ft while the horizontal separation dips below 3 NM a few times, barely visible	MRS: D (99%)

				KLM1810-KLM52X	MRS. In the last 20 seconds before L lands, the separation dips to just below 1000 ft and just below 3 NM. Barely visible.	MRS: D (99%)
				AFR89JT-KLM1200	MRS. During the last 100 sec before L lands, separation decreases from 1000 ft to 900 ft and from 3 NM to 2.8 NM	MRS: C (93%)
				AFR1640-CFE23X	MRS. Twice. At about 250 sec before L lands, the separation dips just below 1000 ft and 3NM, barely visible and only for 2 seconds. During the last 80 sec before L lands, separation decreases from 1000 ft to 900 ft and from 3 NM to 2.8 NM	MRS: D (99%) MRS: C (93%)
				EIN610-KLM938	MRS. During the last 100 sec before L lands, separation gradually decreases from 1000 ft to 700 ft and from 3 NM to 2.2 NM	MRS: C (75%)
				KLM26V-GHCSA	MRS. Twice. About 250 sec before L lands, the separation dips just below 1000 ft and 3 NM, barely visible and only for 2 seconds. In the last 20 seconds before L lands, the separation dips to just below 1000 ft and 2.75 NM.	MRS: D (99%) MRS: C (92%)
				KLM51Q-RAM850W	MRS. In the last 30 seconds before L lands, the separation dips to just below 1000 ft and just below 3 NM. Barely visible.	MRS: D (99%)
				KLM964-KLM1080	MRS. In the last 30 seconds before L lands, the separation dips to 900 ft and 2.8 NM.	MRS: C (93%)
				KLM1234-LCO1505	MRS. In the last 20 seconds before L lands, the separation dips to 900 ft and just below 3 NM, barely visible.	MRS: D (99%)
				TAP658-KLM1054	MRS. In the last 30 seconds before L lands, the separation dips to just below 1000 ft and just below 3 NM. Barely visible.	MRS: D (99%)
				CGJCY-KLM76K	MRS. When L is at about 3500 ft, F is slowly closing in. When vertical separation is about 300 ft, horizontal separation briefly dips below 3 NM. Barely visible	MRS: D (99%)
				BAW438-KLM1022	MRS. During the last 80 sec before L lands, separation decreases from 1000 ft to 800 ft and from 3 NM to 2.6 NM	MRS: C (85%)
#3 (SOL)	0	0	0		No LOS cases identified	
#11 (SOL*)	0	0	0		No LOS cases identified	

Table 19: Details feeding into Table 18

An additional safety issue that was tested by means of the questionnaires was SI-02: Cascading effects in longitudinal separation due to use of various tools in combination. Due to the use of various solutions and tools in combination, which give speed instructions to aircraft without the intervention

of the controller, the controller may find it difficult to predict how the separation between an aircraft pair further away from the threshold, translates to a separation nearer the threshold. For example, the RECAT-EU-PWS may indicate a minimum separation of 2.5NM for an aircraft pair near the FIR. Would there still be sufficient separation at the threshold for this pair?

Two questions were asked to analyse this (both only applicable for Solution runs): Question 20: *'I found it difficult to predict if the separation between two aircraft near the achieve-by-point would still be a sufficient separation nearer the threshold'* and Question 21: *'I found it difficult to predict if a sufficient separation between two aircraft near the merge point would still be a sufficient separation nearer the threshold.'* See **Error! Reference source not found.** for insight into the difference between achieve-by point (the point at which FIM needs to have ensured separation between leader and follower) and merge point (the point where two routes merge); the achieve-by point is closer to the threshold than the merge point. The responses to Question 20 were rather similar to the responses to Question 21. The controllers responded unfavourably (4 to 6 points on a scale of 1 = Strongly disagree and 7 = Strongly agree, to the question whether they found it difficult to predict if the separation is sufficient) in runs #1 and #9, and responded favourably (2 points on a scale of 1 = Strongly disagree and 7 = Strongly agree) in runs #3, #5, #6, #11. The unfavourable responses in run #1 may be due to unrealistic speeds being flown by aircraft during this first run, which affected the opinion of the controllers throughout the questionnaire. It is unclear why the controllers responded unfavourably to run #9. There was only one loss of separation in this run. Therefore, no definite conclusions can be drawn on this for now, and it is recommended to further study this issue during RTS2.

A.4.2 Analysis for RTS2

Objective	OBJ-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)						
Success criterion	CRT-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)						
Analysis result	This objective aims to show that the use of the integrated tool and the Airborne Spacing Flight Deck Interval Management does not lead to an increased number of separation losses (LOS) in the solution scenario (SOL) as compared with the reference scenario (REF). The more detailed analysis below this table presents each case of LOS in the runs of RTS2 and analyses the severity of the LOS. The LOS due to ROT are also Runway Incursions since the follower aircraft is landing before the leader aircraft has vacated the runway. There were no WTS LOSs. The results for MRS and ROT are summarised below. Here, A indicates the most serious LOSs (remaining separation is less than 50% of the minimum required separation), B indicates moderate LOS (between 50% and 66%), C indicates minor LOS (between 66% and 99%) and D indicates LOSs that are negligible (99% of the minimum required separation): <table><tr><td>Run</td><td>A</td><td>B</td><td>C</td><td>D</td><td>Summary (MRS)</td></tr></table>	Run	A	B	C	D	Summary (MRS)
Run	A	B	C	D	Summary (MRS)		



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#8 (REF)	0	0	1	0	1 LOS 2.4 NM 700 ft at MRS=3.0 NM (80%) between an inbound and an outbound flight
#9 (SOL)	0	0	1	0	1 LOS 2.6 NM 750 ft at MRS=3.0NM (87%) between two merging flights
#1 (REF)	0	0	1	0	1 LOS 1.8 NM 600 ft at MRS=2.5NM (72%) before landing
#3 (SOL)	0	0	2	0	1 LOS 2.2NM 700ft at MRS=2.5NM (88%) before landing, and 1 LOS 2.3NM 700ft at MRS=2.5NM (92%) before landing
#4 (SOL)	0	0	0	0	-
#4bis (SOL)	0	0	1	0	1 LOS 1.85NM 600ft at MRS=2.5NM (74%) before landing
#2 (SOL)	0	0	2	0	1 LOS 2.2 NM 700 ft at MRS=2.5 NM (88%) before landing 1 LOS 2.8 NM 0 ft at MRS=3.0NM (93%) after merging point, and 2.9 NM 600 ft a little later
#2bis (SOL)	0	0	0	0	-
#5 (SOL)	0	0	2	1	1 LOS 2.98 NM 700 ft at MRS=3.0NM (99%) 1 LOS 2.7 NM 550 ft at MRS=3.0NM (90%), before final approach segment of F 1 LOS 2.3NM 700ft at MRS=2.5NM (92%) before landing
#7bis (SOL)	0	0	1	0	1 LOS 2.4NM 200ft at MRS=3.0NM (80%) between an inbound and an outbound flight
#10 (SOL*)	0	0	0	0	-

Run	A	B	C	D	Summary (ROT)
#8 (REF)	0	0	0	0	-
#9 (SOL)	0	0	0	0	-
#1 (REF)	0	0	2	0	Two category C LOS (84% and 96%) due to ROT
#3 (SOL)	0	0	1	0	One category C LOS (97%) due to ROT
#4 (SOL)	0	0	0	0	-
#4bis (SOL)	0	0	1	0	One category C LOS (86%) due to ROT
#2 (SOL)	0	0	1	0	One category C LOS (85%) due to ROT
#2bis (SOL)	0	0	0	0	-
#5 (SOL)	0	0	1	0	One category C LOS (90%) due to ROT
#7bis (SOL)	0	0	0	0	-
#10 (SOL*)	0	0	0	0	-





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	From this data, it cannot be concluded that the SOL runs had more cases of LOS than the REF runs. The questionnaires did not reveal major concerns regarding this objective either. The controllers provided a neutral to positive scoring, except in two runs which had to deal with several simulation issues. Therefore, overall, from RTS2 it cannot be concluded that the use of the integrated tool and the Airborne Spacing Flight-deck Interval Management leads to an increased number of separation losses in the solution scenario as compared with the reference scenario. However, there are some safety concerns that may be due to a lower controllability (OBJ-37-W3-DEMOP-SAF1-0005) which may have an impact on risk of LOS.
Results	OK (Full)
Reference	RTS2 Post-run Question 25 (<i>"I think that the combination of tools will reduce the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)."</i>) RTS2 Post-run Question 26 (<i>"Did you observe any Losses of Separation (LOS) in the last run? If yes how many of each type, in which segment did they occur, were the LOSs of any concern to you for safety, did you have enough time to monitor them as they unfolded?"</i>) RTS2 Post-run Question 29 (<i>"At some moment during the approach of an aircraft, I was tempted to intervene by giving additional vectoring or altitude instructions to the aircraft".</i>) Data analysis on KPI-02, KPI-03

Table 20: Extended results after RTS2 for OBJ-37-W3-DEMOP-SAF1-0004: There shall not be a negative impact on the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts)

Detailed analysis:

In question 26 the controllers were asked whether they observed any Losses of Separation (LOS). The controllers appeared to have detected LOSs in runs #1 (REF), #2 (SOL) and #2bis (SOL). These LOSs and their types (according to the controllers and/or the corresponding data) are described and analysed in Table 21, which feeds into Table 22:

Run	Sector	WTS	ROT	MRS	Explanation
#1 (REF)	ARR2	0	1	1	The controller for ARR2 reported one LOS on final when the aircraft was under control of TWR controller; he did not indicate the type of LOS. He did note that the LOS was not a safety concern; the TWR controller would have handled it. An analysis of the data revealed that this concerned a LOS of type MRS and ROT between EJU7934 and SAS1555. This is further detailed in Table 22.
#2 (SOL)	ARR2	0	0	1	The controller for ARR2 reported one LOS of type MRS in the area from 6NM to touchdown. He indicated that the LOS would likely have led to a go-around; it happened just when a lot of technical problems occurred in the simulation.

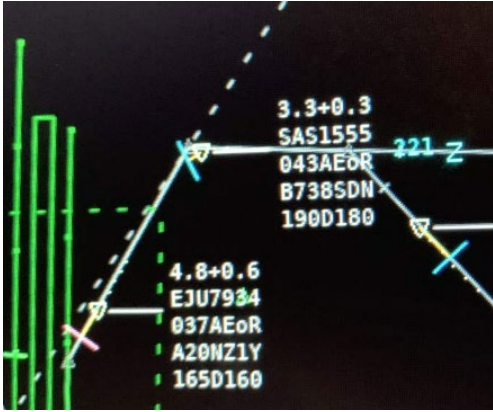


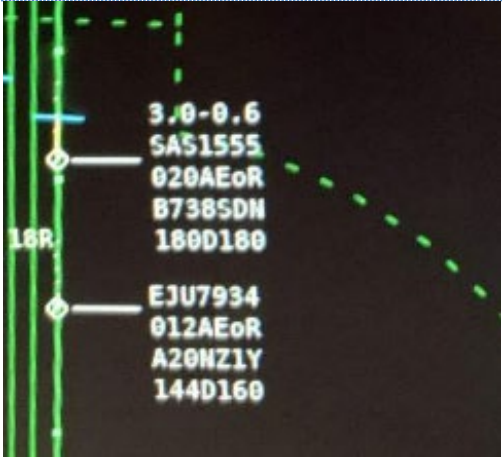
					An analysis of the data revealed that this concerned a LOS of type MRS between IBK54CA and KLM896. This is further detailed in Table 22.
#2bis (SOL)	APP1	0	1	1	This LOS was reported by the Feeder in charge of APP1. He did not give many details but the data showed that this concerned a LOS of type MRS between VLG73SB and UAL71 near the top of descent of VLG73SB; aircraft UAL71 was an outbound flight. The minimum distance was as close as 1.95 NM, 300 ft (65%), where MRS = 3.0NM. After the run it was revealed that the controller had been bored and, as an experiment had tried to prevent the aircraft from having to level off. This did not work out well. Since this was not a LOS due to the traffic situation but rather an experiment by a controller (which he would not have tried out in a real environment), it is not considered a real LOS in Table 22.
#2bis (SOL)	ARR2	0	0	1	The controller for ARR2 reported a LOS of type MRS before the merging point of the routes on approach towards runway 18C, adding that this was a safety concern, but because of unclarities in the situation he had let the situation play out longer than he would have done in reality. Normally, he would have given vectors earlier. An analysis of the data revealed that this concerned a LOS of type MRS between KLM882 and ABW451, which was due to a simulation issue and therefore not considered a real LOS. This is further detailed in Table 22.

Table 21: Details feeding into Table 22

Conclusion so far: The four situations of LOSs reported by the controllers in the questionnaires were also identified in the data, and are further detailed in the following table. Therefore, Table 21 above does not provide additional situations of LOS and we can focus on the next one, Table 22.

Run	Nr of LOS WTS	Nr of LOS ROT	Nr of LOS MRS	Callsigns [leader-follower]	Observations	Severity
#8 (REF)	0	0	1	KLM26V-TFL365	MRS. A LOS occurred between an inbound and an outbound flight when the inbound flight was at an altitude of about 10 000 ft under the control of APP1. The separation reduced to 2.4 NM and 700 ft at some point.	MRS: C (80%)
#9 (SOL)	0	0	1	KLM1566-BEE6CP	MRS. Leader (L) and follower (F) were merging from two different routes on approach for runway 18R and when L passed the merging point they had a vertical separation of about 800 ft and a horizontal separation of about 2.8 NM (at MRS = 3.0 NM). For the next 165 seconds, the horizontal separation kept varying between about 2.6 NM and 2.9 NM, and at one point it was 2.6 NM and 750 ft (at MRS = 3.0 NM). Just before the point when L passed the FAF, the separation increased to more than 3.0 NM and was no longer a LOS.	MRS: C (87%)

						
#1 (REF)	0	2	1	EJU7934- SAS1555	MRS and ROT. L and F were merging from two different routes on approach for runway 18C and when L passed the merging point they had a vertical separation of about 600 ft and a horizontal separation of about 3.1 NM (at MRS = 3.0 NM), i.e. not yet a LOS. However, from that point onwards, the vertical separation varied between 300 ft and 950 ft, while the horizontal separation gradually reduced to 1.8 NM at the moment when L landed (at MRS = 2.5 NM). At that moment, the vertical separation was 600 ft. When F landed, L still had 9 seconds of runway occupancy time remaining. Notice that the controller made a note of this LOS in the questionnaire, and indicated that it was not a major safety concern; the TWR controller would have handled it, see also Table 21. 	MRS: C (72%) ROT: C (84%)

						
				RYR7NP-AMX025	ROT. When F landed, L still had 2 to 3 seconds of runway occupancy time remaining.	ROT: C (96%)
#3 (SOL)	0	1	2	SAS1555-DLH4TV	MRS. L and F were merging from two different routes on approach for runway 18C and when L passed the FAF they had a vertical separation of about 600 ft and a horizontal separation of about 2.6 NM (at MRS = 3.0 NM). From that point onwards, the vertical separation was mostly about 800 ft, while the horizontal separation reduced further but more or less stabilized to between 2.2 NM and 2.45 NM (at MRS = 2.5 NM).	MRS: C (87%)
				TFL708-QTR8201	ROT. When F landed, L still had 2 to 3 seconds of runway occupancy time remaining.	ROT: C (97%)
				TRA88N-DLH9JF	MRS. L and F were both on approach for runway 18C, with their separation gradually reducing. About 60 seconds before the landing of L, the separation was 3.0 NM 1000 ft, i.e., not yet a LOS. The separation reduced further, and at about 20 seconds before L landing it was 2.3NM 700ft at MRS=2.5NM. It did not reduce further.	MRS: C (92%)
#4 (SOL)	0	0	0	-	-	-
#4bis (SOL)	0	1	1	KLM1942-ELY339	MRS and ROT. L and F were merging from different routes on approach for runway 18C, with their separation gradually reducing. About 124 seconds before the landing of L (with L and F having both passed the FAF), the separation was 3.0 NM 1000 ft (at MRS = 2.5 NM), i.e. not yet a LOS. However, the separation reduced further, and at about 35 seconds before landing it was 1.85 NM 600ft at MRS=2.5NM. It did not reduce further from then on. When F landed, L still had 8 seconds of runway occupancy time to go.	MRS: C (74%) ROT: C (86%)

#2 (SOL)	0	1	2	IBK54CA-KLM896	MRS and ROT. L and F were on approach for runway 18C, with their horizontal separation gradually reducing. About 89 seconds before landing of L (with L and F having both passed the FAF), the separation was 3.0 NM 1000 ft (at MRS = 2.5 NM), i.e. not yet a LOS. The separation reduced further. At 53 seconds before the landing of L it was below 2.5 NM, and when L landed it was 2.2 NM 700 ft at MRS=2.5NM. When F landed, L still had 9 seconds of runway occupancy time to go. It is noted that the controller made a note of this LOS in the questionnaire, and indicated that the LOS would likely have led to a go-around; it happened just when a lot of technical problems occurred in the simulation, see Table 21.	MRS: C (88%) ROT: C (85%)
				KLM1634-KLM44G	MRS. L and F were merging from different routes on approach for runway 18R. Just after the merging point, the horizontal separation briefly dropped to 2.8 NM (MRS = 3.0NM), with the vertical separation hovering around 0 ft. It increased to 3.1 NM 500 ft, but a little later, it briefly dipped to 2.9 NM 600 ft. After that, when MRS = 2.5 NM, the separation was between 2.7 NM and 3.4 NM, i.e. no longer a LOS.	MRS: C (93%)
#2bis (SOL)	0	0	1	VLG73SB-UAL71	MRS. A LOS occurred between an inbound and an outbound flight when the inbound flight was at an altitude of about 10 000 ft under the control of APP1. The separation reduced to 1.95 NM and 300 ft at some point (65%); this would have been a LOS of type B. However, after the run, it was revealed that the controller had been bored and, as an experiment had tried to prevent the aircraft from having to level off, which led to the LOS, Table 21. Since this was not a LOS due to the traffic situation but rather an experiment by a controller (which he would not have tried out in a real environment), the LOS is not considered further in the analysis.	No LOS
				KLM882-ABW451	L and F were merging from two different routes on approach for runway 18C. About 52 seconds before the merging point, the separation was less than 3.0 NM 600 ft and reduced further. Around the merging point it was 2.4 NM 300 ft (MRS = 3.0 NM). After that, the horizontal separation increased rapidly.	No LOS

					Investigation of the data reveals that this situation was due to a simulation issue: The order in which the aircraft entered the system was such that the Leader flew behind the Follower. Therefore, this is considered not a real LOS.	
#5 (SOL)	0	1	3	EJU49HM-AFR73WG	MRS. 26 seconds before L turned in for final approach, the separation with its follower reduced to at or just below 3.0 NM where the vertical separation was 700 ft. This is considered a LOS of category D at most.	MRS: D (99%)
				AFR73WG-KLM84F	L had made a go-around (scripted by the RTS2 organisation), and was re-introduced into sequence for approach towards runway 18R. The sequencing was tight, but there was no LOS. However, upon turning in for final approach, due to a simulation issue, L did not intercept the localizer. The controller gave it a heading towards the right. Due to the extra distance travelled, the separation with the follower reduced to 2.3 NM 0 ft. Subsequently, however, it was decided to remove the aircraft from the simulation. Since this situation was due to a simulation issue, it is considered not a real LOS.	No LOS
				TRA96U-BAW430	MRS. L had made a go-around (scripted by the RTS2 organisation), and was re-introduced into sequence for approach towards runway 18R. The horizontal separation with its new F was just above 3 NM for a while. However, 28 seconds before L passed the FAF, the separation was down to 2.7 NM 800 ft, and reduced further to 2.7 NM 550 ft when L passed the FAF. At that point, F had not turned in for final approach yet, so MRS = 3.0 NM.	MRS: C (90%)
				VLG2XN-DAL74	MRS and ROT. A few seconds before F passed the FAF (hence in the area where MRS = 2.5 NM), the separation was 3.0 NM 1000 ft, i.e. not yet a LOS. However, from that point onwards both the horizontal and the vertical separation decreased gradually, and were 2.3 NM 700 ft at the moment when L landed (where MRS = 2.5NM). When F landed, L still had 6 seconds of its 62.8 seconds runway occupation time remaining.	MRS: C (92%) ROT: C (90%)
#7bis (SOL)	0	0	1	KLM12P-CFE93PN	MRS. A LOS occurred between an inbound and an outbound flight when the inbound flight was at an altitude of about 10 000 ft under control of APP1. The separation reduced to 2.4 NM and 200 ft at some point (MRS = 3.0NM).	MRS: C (80%)

#10 (SOL*)	0	0	0	-	-	-
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Table 22: Details feeding into Table 20

From this, the following observations can be made:

- The numbers of LOSs in #8 (REF) and #9 (SOL) were the same.
- The average number of LOSs in #3 (SOL with 20% IM), #4 and #4bis (SOL with 80% IM) and #2bis (SOL with 100% IM) was similar to that in #1 (REF).
- In #2 (SOL with 100% IM) there were more LOSs than in #1 (REF), but this may partially have been due to some issues in the simulation.
- In #5 (SOL with 100% IM and scripted go-arounds) there were more LOSs than in #1 (REF), but most were due to the tight re-sequencing after the scripted go-arounds.
- #7bis (SOL with scripted EAT in-adherence) had a similar number of LOSs as run #1 (REF), despite the EAT in-adherence issues.
- Run #1 (REF) had more LOSs due to ROT than any of the comparable SOL runs.

Therefore, it cannot be concluded that the SOL runs had more cases of LOS than the REF runs. The fact that both the scripted go-arounds (in run #5) led to a LOS after resequencing is a concern for safety, but it is unclear if this is due to the combination of tools rather than to the very high traffic density (see also the detailed analysis in Section A.2.2 for the reasoning on this).

In the questionnaire (Question 25), the controllers were asked whether they thought that the combination of tools will improve the number of losses of separation (wake turbulence separation, minimum radar separation infringements and tactical conflicts). For almost all runs, the controllers either gave a neutral response (“4”, i.e. in the middle between 1 = Strongly disagree and 7 = Strongly agree), or a slightly positive response (mostly “5”, a few “6” on a scale of 1 = Strongly disagree and 7 = Strongly agree). The exceptions were runs #2 and #2bis. In #2, one controller gave the score “2”, with the comment “not agreed in this run, with so many simulation issues”, and the other controllers gave “3” and “6”, without comments. In #2bis, the scores were “2” (with comment “due to an earlier issue”, “4” (with the comment that the planning was too tight; the controller would have preferred a lower traffic density and larger margins) and “6” (with the comment that the tools provided insight into separations). Note that runs #2 and #2bis had to deal with some simulation issues.

Part of the expectations may also be due to the perceived controllability for the controllers (see also Section A.5). In the solution runs, the controllers reported to have the perception to be less in control of the aircraft. They had a more monitoring role, and when something happened that could lead to a LOS, they were already too late. They also said that the situation in this simulation environment was relatively ‘clean’: all pseudo-pilots understood and followed the instructions. In the real world, there are airlines who are notorious for never listening, always flying too fast or too slow, etc. The controllers had some concerns with having to deal with those airlines when using IM and giving some of the spacing task to them. However, this conclusion may be more due to the use of IM, than due to the use of the combination of tools.

In the questionnaire (question 29), the controllers were also asked whether, at some moment during the approach of an aircraft, they were tempted to intervene by giving additional vectoring or altitude instructions to the aircraft. Such situations could point to attempts to avoid an expected LOS.

In the comparison of #8 (REF with strong wind) and #9 (SOL with strong wind), the approach controllers were equally positive in both runs. However, the arrival controllers were more negative about the solution run, because of a conflict they had to solve in combination with the strong wind.

In the comparison of the responses to question 29 for the runs with calm wind, the controllers were positive in #3, #4, and #4bis (SOL), compared to #1 (REF), but negative in #2 (SOL) and neutral in #2bis (SOL), compared to #1 (REF). In the non-nominal solution runs, they were positive about #5 (SOL with scripted go-arounds), but negative about #7bis and neutral in #10, compared to #1. The runs about which they were negative, i.e. #2, #2bis and #7bis, were also runs in which there were simulation issues, leading to aircraft not behaving well, which required the controllers to intervene. Therefore, overall, it cannot be definitely concluded that the solution runs required the controller to intervene more often than the reference runs.

A.4.3 Conclusions on OBJ-37-W3-DEMOP-SAF1-0004

During RTS1, the data showed that for both MRS and ROT, the SOL runs did not seem to have more cases of LOS than the REF runs, and even showed much fewer. The controllers did raise some concerns regarding WTS losses during the questionnaires and debriefings. It was recommended to further study this concern during RTS2.

During RTS2, the number of LOSs during SOL runs was similar to the number of LOSs in REF runs under comparable circumstances. In the run with scripted go-arounds, there were additional LOSs caused by having to re-sequence the aircraft that made the go-arounds in a situation of very high traffic density. The controllers did have a few concerns regarding LOSs, but these seemed to be mainly due to perceived controllability and the use of IM, rather than due to the combination of tools. Therefore, the results of RTS2 appeared to confirm the RTS1 conclusion.

Recommendations for future research are:

- To include a runway controller in the simulations, who controls the traffic on the final approach segment, and who can coordinate with the arrival (ARR) controller regarding situations that may lead up to losses of separation due to WTS, MRS, and ROT. This would provide a more realistic picture regarding the safety objectives studied.
- The previous recommendation would also create the opportunity to study a safety objective that was omitted from the analysis in this report: OBJ-37-W3-DEMOP-SAF1-0002 (The variability in Clearance to Land margin decreases for ROT constrained pairs).
- The objectives studied looked at safety risk up to the level of potential for loss of separation, limited by the nature of real time simulations. In order to assess the risk of a mid-air collision and the risk of wake turbulence related accidents, as is required in SESAR safety reference material (SRM), in a follow on project it is recommended to use Dynamic Risk Modelling to assess the safety benefits of the combination of tools more accurately (Guidance K of the SRM).



A.5 Analysis of OBJ-37-W3-DEMOP-SAF1-0005

A.5.1 Analysis for RTS1

Objective	OBJ-37-W3-DEMOP-SAF1-0005: The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool
Success criterion	CRT-37-W3-DEMOP-SAF1-0005: The tool gives the controller the means to intervene. The use of the tool does not lead to a perceived loss of controllability of the operation by the controller in relation to the conventional operation.
Analysis result	As concluded in the detailed analysis below this table, in the beginning, the controllers did feel less in control during the solution runs, compared to the reference runs. However, this was mainly due to the use of a single tool rather than the combination of tools. Moreover, post-experiment they indicated to be more positive regarding the solution runs. It is concluded that perceived controllability of the operation by controller did not degrade due to the use of the integrated tool.
Results	OK (Full), but to be confirmed during RTS2
Reference	RTS1 Post-run Question 24 (<i>"The combination of tools aims to decrease the number of controller interventions by giving a spacing task to the aircraft. This makes me feel less in control of the operation"</i>) Additional input from Post-experiment questions on perceived workload, situation awareness and potential for human error.

Table 23: Extended results after RTS1 for OBJ-37-W3-DEMOP-SAF1-0005: The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool

Detailed analysis:

The Human Machine Interface of the integrated tool for the controller is designed to limit the number of unnecessary interventions. However, it is still the role of the controller to intervene when needed. The integrated tool gives the controller the means to intervene.

Especially during the earlier SOL runs, the controllers indicated to feel less in control of the traffic. In the REF runs they gave vectors and speed instructions, which gave them a sense of control, while in the solution runs, they had a more monitoring role, and had to trust FIM to prevent losses of separation. This was especially an aspect at merge points. In addition, the controllers indicated to be less positive about their situational awareness and potential for human error.

The controllers did note that in the solution runs, insufficient spacing was usually solved by FIM, but at a later stage than what the controllers were used to (see also the detailed analysis of OBJ-37-W3-DEMOP-SAF1-0003). In the reference runs the controllers (specifically FDR) gave vectors to create more spacing earlier on the route, thus separating the aircraft at an earlier point on the route, and aiming to avoid having to instruct a GA later.

It is observed that the controllers liked the Merge tool, and that their lack of trust and their lower perception of controllability in the first performed runs was mainly directed to the use of IM, rather than to the combination of tools specifically. Moreover, the situation improved while more simulation

experience was obtained. In the post-experiment questionnaire, the controllers' perception of situational awareness for the solution run was equal or even slightly better than for the reference run.

Post-experiment, when asked how much confidence they had in the combination of tools, two controllers gave 7 out of 9 points, and one gave 6 out of 9.

It is concluded after RTS1 that perceived controllability of the operation by controller did not degrade due to the use of the integrated tool. However, this needs to be confirmed during RTS2.

A.5.2 Analysis for RTS2

Objective	OBJ-37-W3-DEMOP-SAF1-0005: The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool
Success criterion	CRT-37-W3-DEMOP-SAF1-0005: The tool gives the controller the means to intervene. The use of the tool does not lead to a perceived loss of controllability of the operation by the controller in relation to the conventional operation.
Analysis result	The execution of a second series of runs helped the controllers to become more familiar with and obtain more experience with the integrated tool, resulting in increased trust. However, some simulation issues arose during the runs, leading to concerns about the perceived controllability in real-world operations. In real operational context, controllers must handle various disturbances such as rain clouds, go-arounds, unexpected aircraft behaviour, and aircraft flying too fast or too slow. Some of such types of situations were also encountered during some of the RTS2 runs (grossly unexpected aircraft/pilot behaviour, difference between actual and planned arrival sequence), leading to a rapid loss of control and the need to halt the simulation. The main issue is the integration between AMAN and FIM; the concerns warrant further attention in future testing and simulations. Therefore, at this moment we cannot conclude that objective OBJ-37-W3-DEMOP-SAF1-0005 is fully met.
Results	Partial OK (POK)
Reference	RTS2 Post-run Question 21 (<i>"In the last run, regarding separation assurance, did you feel in control of the operation?"</i>) RTS2 Post-run Questions 22 (<i>"I found it difficult to predict if a sufficient separation between two aircraft near the merge point would still be a sufficient separation nearer the threshold"</i>) and 23 (<i>"I found it difficult to predict if a sufficient separation between two aircraft near the achieve-by-point would still be a sufficient separation nearer the threshold"</i>). RTS2 End of Day questionnaire. Additional input from Post-experiment questions on perceived workload, situation awareness and potential for human error.

Table 24: Extended results after RTS2 for OBJ-37-W3-DEMOP-SAF1-0005: The perceived controllability of the operation by controller shall not degrade due to the use of the integrated tool

Detailed analysis:

In the questionnaire, the controllers were asked in question 21 if they felt in control of the operation with regards to separation assurance.

The results for run #9 (SOL) appeared to be equal to those for run #8 (REF): On a scale from 1 = No to 7 = Yes, the average answer was 6.5 for both runs.

When compared to run #1 (REF), all solution runs were generally rated more positively regarding controllability, with the exception of runs #2, #2bis, and #7bis where there were some simulation issues, such as leader aircraft entering the TMA behind their follower and increasing speed, or aircraft that did not descend as instructed. In those runs, two of the three controllers were equally positive as in the reference run, while one controller was negative. This one controller indeed reported to be negative due to the simulation issues encountered during that run.

This reaction to runs with simulation issues was also apparent in the end-of-day questionnaire and the post-experiment questionnaire, where controllers specifically referred to these issues. They indicated that more training and testing beyond this simulation environment will be necessary. In a simulation environment, the situation has the appearance to be less complex than real operation, and the pseudo-pilots behave and listen to instructions well. In real operation there are some concerns regarding airlines who are notorious for not listening to instructions and for deviating from route or for flying too fast or too slow on final. These disturbances, in addition to e.g. weather-related disturbances such as rain clouds, or a few go-arounds, could easily lead to a situation running out of control. The simulation issues that arose due to disruptive aircraft behaviour emphasized the potential for this to happen.¹: if there are a few aircraft that behave irregularly, the controller needs to intervene by getting aircraft off IM and giving vectoring and/or speed instructions instead. If this occurs late in the approach, there is limited time to resolve the situation.

The controllers indicated that this is particularly due to the use of IM compared to traditional speed instructions given by the controllers. In operation without IM, the controller is in control of the speeds that are flown, but also has a higher workload regarding speed instructions and R/T. In IM operation, they have a more monitoring role and need to wait and see. The controller does not know what speeds the FIM-system might be providing, especially related to horizontal speed, and is therefore not really in control. In the case of a disturbance and the need of a controller to act with speed instructions and/or vectors, the IM -operation requires more time before the flight crew processes the instructions and the aircraft acts accordingly, compared to the traditional operation. This negatively impacts the perceived controllability of the controller.

It was observed that one of the factors causing controllers discomfort was the lack of margin in spacing in the FIM system, which creates a spacing between aircraft coming from two different RNP legs that is barely above the minimum when they pass the merge point. The controllers monitored those situations closely but did not interfere in order to give IM a chance. When asked about this during the debrief of a run, one controller indicated that a human controller would not have allowed such 'marginal' spacings and would have made earlier arrangements by intermediate speed instructions. This is due to the 'harmonica effect,' in which the leading aircraft is closer to the FAF and is expected

¹ In particular, Run #2 was stopped after 45 minutes after a pseudo pilot had made an erroneous input, which had a big knock-on effect on the traffic stream behind this aircraft. Run #2bis was stopped after 47 minutes due to an aircraft that had an incorrect IM target which went unnoticed by the controllers. This resulted in the need to shift in the arrival planning in order to create room for aircraft to be re-sequenced. Continuing the simulation would obtain a similar result as was simulated in run #5 and thus the run was stopped.

to reduce its speed towards the final approach speed, which results in the spacing between the two aircraft reducing towards the end of the approach. Another issue is that aircraft flying towards the merge point are on the same altitude, and if the lateral spacing is not sufficient, it could pose a serious risk. In the questionnaire (questions 22 and 23) the controllers were also asked whether they found it difficult to predict if a sufficient separation between two aircraft near the merge point (or the achieve by point) would still be a sufficient separation nearer the threshold. This ability to predict the development of the separation could also be regarded a measure for their controllability. From the answers, it appears that the solution runs received better scores than the reference runs, except for run #4bis, where one controller gave a negative scoring, though the other two were positive. Unfortunately, the controllers did not comment on their scoring.

Concluding, even though the scoring from the controllers on specific questions in the questionnaire were not particularly negative regarding the solution scenarios when compared to the reference scenarios, the general perception of the controllers regarding controllability is somewhat less favourable, in particular in case of disturbances in nominal behaviour. A main contributing cause for such disturbances in the operation with the new combination of tools is the interoperability issues between E-AMAN and FIM (see A.3 Analysis of OBJ-37-W3-DEMOP-SAF1-0003); the concerns warrant further attention in future testing and simulations.

A.5.3 Conclusions on OBJ-37-W3-DEMOP-SAF1-0005

At the beginning of RTS1, the controllers felt less in control during the solution runs, compared to the reference runs. However, this was mainly due to the use of a single tool rather than the combination of tools. Moreover, post-experiment they indicated to be more positive regarding the solution runs.

The execution of a second sequence of real time simulations helped the controllers to become more familiar with and obtain more experience with the integrated tool and build more trust with it. Unfortunately, some of the runs experienced some simulation issues which led to concerns regarding perceived controllability in a real operation (beyond a simulation environment). In real-operation scenarios, controllers have to deal with disturbances like rain clouds, go-arounds, aircraft not behaving as expected (like performance issues), aircraft flying too fast or too slow. This is similar to what they experienced during some of the RTS2 runs in which the situation ran out of control quickly and the simulation had to be stopped. The main issue is the integration between AMAN and FIM; the concerns warrant further attention in future testing and simulations. Therefore, at this moment we cannot conclude that objective OBJ-37-W3-DEMOP-SAF1-0005 is fully met.

Recommendations for future research are:

- Assess the similarity of simulation issues encountered during RTS2 to real-world operational scenarios. In future testing and simulations, include these types of events in scenarios to gauge the operational efficiency and durability of the tools used.
- Evaluate the ability of controllers to handle non-typical operational disruptions that occur frequently in real-world practice. Incorporate these events into scenarios for future testing and simulations to assess the efficiency and stability of the tools and overall operation during such situations.