Final Project Report

Document information	
Project Title	QM-7 – Integrated Sequence Building/Optimisation of Queues
Project Number	05.06.07
Project Manager	DFS
Deliverable Name	Final Project Report
Deliverable ID	D40
Edition	01.00.00
Template Version	03.00.04
Task contributors	
DFS	

Abstract

This Final Report provides an overview on goals, activities and achievements of the SESAR project P05.06.07. Thematically, the project is located within End to End Traffic Synchronization with operational focus on Enhanced Arrival & Departure Management in TMA and En-Route. It has contributed to the enhancement of several different SESAR solutions related to Arrival Management. According validation activities like real time and fast time simulations as well as live trials have confirmed the proposed solutions.

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Rational for rejection
None.

Document History

Edition	Date	Status	Author	Justification
00.00.01	17/07/2015	Draft	[redacted]	First Draft
00.00.02	20/01/2016	Draft		Modifications based on new template
00.00.03	27/01/2016	Draft		Editorial corrections
00.00.04	25/02/2016	Draft		Including review comments

00.00.05	04/03/2016	Draft	[redacted]	New Template
00.00.06	16/03/2016	Draft		Including review comments
00.01.00	31/03/2016	Final		Final Version for Submission
01.00.00	20/05/2016	Final		Final after SJU Assessment

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This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
AF	ATM Function
AMAN	Arrival Manager (Equipment or S/W Package)
ATCO	Air Traffic Controller
ATM	Air Traffic Management
CDA	Continuous Descent Approach
CTA	Controlled Time of Arrival
E-AMAN	Extended AMAN
E-OCVM	European Operational Concept Validation Methodology
FABEC	Functional Airspace Block Europe Central
i4D	Initial 4D
IBP	Industry Based Platform
INTEROP	Interoperability Requirements
OI Step	Operational Improvement Step
OSED	Operational Services and Environment Description
PMS	Point Merge System
RTS	Real-Time Simulation
SPR	Safety and Performance Requirements
TMA	Terminal Manoeuvring Area
UAC	Upper Area Control
VALP	Validation Plan
VALR	Validation Report
XMAN	Extended/Cross-border AMAN (terminology used in context of FABEC)

1 Project Overview

The scope of project P05.06.07 was End to End Traffic Synchronization with operational focus on Enhanced Arrival & Departure Management in TMA and En-Route. P05.06.07 has contributed to the enhancement of several different SESAR solutions related to Arrival Management and how integrated sequence building and optimization of arrivals can improve the overall arrival management process, both in terms of aircraft & ATC operations from En-Route to TMA.

For this purpose, this project was aiming at:

- Definition of operational requirements for the various Arrival Management concept elements (with focus on AMAN) and
- 'Integrated' validation of resulting prototypes & concept elements.

1.1 Project progress and contribution to the Master Plan

The program was organised in three steps where project P05.06.07 addressed step 1 and 2. Each step was divided in three development and validation stages (V1-V3): Scoping phase, Feasibility Phase and Integration Phase.

Step 1 has already worked from existing research and development outside and inside the SESAR program, leading to a V2 starting point for Step 1 already. Step 2 was building on SESAR Step 1 and needed to run through full V1 as no preparatory work could be considered.

V2 and V3 validation was performed via Real Time Simulation (RTS) and Live trial, whereas in V1 expert workshops and early prototyping simulations have been in place to scope the concept.

The project was organized in validation packages, contributing to one or two OI Steps. Each package was contributing to at least one OI Step.

The first validation package was focussed on "AMAN + Point Merge", where benefits and ability to support CDA from high altitudes/levels in high-density traffic environment by using a Point-Merge System (PMS) in an extended TMA were evaluated. This exercise investigated the use of a PMS on a single merge point. Conditions to support integration of several arrival flows towards one TMA entry point were derived, including requirements on airspace design, entry conditions and joint use of AMAN.

The validation was performed through

- a preparation phase involving a series of prototyping sessions culminating in a real time simulation exercise and
- two series of live trials performed in the Paris ACC environment respectively in June and November/December 2012.

Second validation package was the first integrated validation exercise of P05.06.07. According validation exercise EXE-05.06.07-VP-485 was addressing an Arrival Management system supporting CTA operations on an extended operational horizon and drawing from experience gathered during previous work on elements of the system. Both projects investigated extended Arrival Management and CTA techniques respectively in conjunction with one another whilst focusing on the relevant individual concept elements. In the according validation exercise, the concept area was treated as a seamless integration and a wide range of associated aspects were investigated. The exercise was defined as Real-Time simulation based on Stockholm-Arlanda, it included the use of an AMAN prototype as system under test and applied the integrated concepts in a medium/medium density/complexity scenario.

Third validation package was focussed on the final validation of SESAR Solution #05 "Extended AMAN" (E-AMAN) including the long range horizon option. According validation exercise was

executed in the context of Release 4 within the overall Step 1 V3 of the SESAR Programme and was part of a larger set of FABEC live trials. This validation exercise was based on the concept set out in a related SESAR project (P05.06.04). The validation was performed through a live trial in the Reims ACC environment. The focus was to validate the ability to apply the AMAN in En-Route sectors notably those located beyond borders. DSNA XMAN @ UAC Reims IBP was used in the live trial aiming to improve London Heathrow arrival management. This was enabled by providing information between London TMA and Reims UAC communicated via SWIM (yellow service) for the pre-sequencing of the arrival stream.

Solution package two and three together contributed to SESAR solution #05, also called E-AMAN which equals to the terminology (basic) XMAN within the FABEC programme.

Fourth validation package: This validation package consisting of three validation activities was intended as a first step into setting the scope of an advanced cross-border AMAN concept in the context of multiple independent TMAs (relevant for SESAR 2020 PJ01-01). Prototyping sessions provided a basic working method. An AMAN collaboration tool was envisaged as one further solution element. This can be characterized as an En-Route tool supporting cross-border arrival management, taking input from one or more (extended) AMAN. Based on these AMAN information, the tool provides/distributes traffic synchronization-related advisories to ATCOs in an ACC/UAC. (1)

The scope of validation package activities was limited to the case of a single UAC. Building on Step 1, the package investigated the impact of arrival management constraints from multiple TMAs in a single UAC through a Real-Time Simulation (EXE-05.06.07-VP-696) and a Fast-Time Simulation (EXE-05.06.07-VP-444).

Code	Name	Project contribution	Maturity at project start	Maturity at project end
TS-0102	Basic Arrival Management Supporting TMA Improvements (incl. CDA, P-RNAV)	Project P05.06.07 performed preparatory RTS validation and two sets of live trials documented in according VALR. The project has produced OSED and SPR as key deliverables. Responding to local needs, EXE-05.06.07-VP-427 has successfully demonstrated the possible implementation of Point Merge procedures in an extended horizon of TMA operations in Paris ACC (Quick Win). TS-0102 was part of the Deployment Baseline.	V3	V3 (ready for deployment)
TS-0103	Controlled Time of Arrival (CTA) in medium density/complexity environment	P05.06.07 addressed this OI Step with one integrated validation where a pre-industrial prototype was used (EXE-05.06.07-VP-485). In addition to mandatory VALR & VALP, the project has produced a technical note to related SESAR projects. The validation was executed as Real Time Simulation on the NORACON IBP located in Malmö using an AMAN prototype as system under test. The exercise was in collaboration with P05.06.01. Project P05.06.07 addressed the AMAN-related aspects of CTA including i4D functionality. Results for TS-0103 have been considered in P05.06.01.	V2	V2 (V3 will be reached outside this project)
TS-0305-A	Arrival Management	Project P05.06.07 contributed with two validation exercises: EXE-05.06.07-VP-485 (via RTS mentioned before, see above!) and EXE-05.06.07-VP-695, each documented with VALP &	V2	V3

1 Within FABEC, this is analogue to elements of the 'Advanced XMAN' concept. It corresponds to the case of multiple TMAs/AMANs feeding an XMAN En-route Tool.

	Extended to En Route Airspace - single TMA	VALR. The project produced an OSED update, contributed to SPR/INTEROP of P05.06.04 and provided an according SPR/INTEROP update as well. The first exercise (EXE-485) established a link between TS-0305-A and TS-0103 in order to refine the solution for extended AMAN that is supporting i4D/CTA operations. The aim of the second exercise (EXE-695) was to evaluate the use of an Extended AMAN Horizon for cross-border arrival management through Live Trials in Reims UAC for London Heathrow arrivals. The exercise used a prototype interconnected with London LHR and Reims UAC. The platform for Reims UAC was based on relevant parts of the AMAN platform used in EXE-485, which included both TopSky-ATC and AMAN. TS-0305-A was considered as completed.		
TS-0305-B	Arrival Management Extended to En Route Airspace - overlapping AMAN operations	Project P05.06.07 contributed with three validation exercises: EXE-5.6.7-VP-826 (expert assessment on iterative real time prototyping to mature the concept and prepare following exercises), EXE-5.6.7-VP-444 (FTS) and EXE-5.6.7-VP-696 (RTS). For V1 an initial OSED was produced. For V2 phase, the OSED was refined. V2 exercises were documented by VALP and VALR. Focus was on the validation sessions in EXE-696. In general, the problem statement was investigated in order to understand the implications of several overlapping AMAN horizons caused by an E-AMAN deployment across Europe. In addition, a basic working method was proposed. Beyond this, further solution elements have been identified in workshops and described in the OSED. The solution is not regarded as complete as it was only indicating first solution elements that require further iterations.	V1	V2

1.2 Project achievements

The project addressed the following solutions, with a different level of contribution:

- SESAR Solution Pack “Arrival Management (AMAN) and Point Merge”
- SESAR solution #06 (Controlled Time of Arrival (CTA) in Medium density / medium complexity environment) contribution
- SESAR solution #05 (Extended Arrival Management (AMAN) horizon) major contribution (ATM Function 01, AF#01)
- Preparation of potential input to SESAR 2020 Solution 01 in Project 01.

SESAR Solution Pack "Arrival Management (AMAN) and Point Merge"

Implementation of Extended AMAN operations coupled with Point Merge procedures successfully demonstrated benefits in terms of

- Increased safety resulting from a more structured airspace, with positive impacts on controller and pilot situational awareness;
- Reduced controller workload, due to the reduction in frequency usage, that could allow to increase capacity
- An improvement in trajectory prediction and a reduction in the number of open loops (due to radar vectoring) which have a positive impact on predictability;
- Increased number of CDOs leading to an equal or reduced fuel burn profile.

Further to the positive outcome of EXE427, Point Merge was put in operations in the TP terminal sector of Athis Mons ACC, feeding the northern runway of Paris Charles de-Gaulle's airport (LFPG) through a North West Entry point.

SESAR solution #06 (Controlled Time of Arrival (CTA) in Medium density / medium complexity environment) contribution

Regarding the interaction between extended AMAN and operational procedures using the i4D/CTA concept, project P05.06.07 demonstrated via its validation package 2 that E-AMAN captured the operational needs to support this kind of operations.

Within the validation of exercise 485, a first E-AMAN prototype (Thales) was used which was refined in activities of a related SESAR project later (P05.06.01).

SESAR solution #05 (Extended Arrival Management (AMAN) horizon) major contribution (ATM Function 01, AF#01)

Validation results in P05.06.07 confirmed E-AMAN development and preceding validation activities in related SESAR projects (P05.06.04, P05.03).

For exercise EXE-05.06.07-VP-695 in SESAR Release 4 and as part of the FABEC 'Heathrow XMAN trials'2, the project has refined the concept and introduced a new prototype (based on the same E-AMAN prototype as in EXE-485) in Reims UAC featured with the ability for gathering London arrivals data and with an improved radar trajectory prediction model.

Benefits demonstrated in the XMAN Heathrow live trials were:

- Fuel savings for airline customers
- An environmentally-friendly procedure: less time spent in the holding stacks over London, CO2 savings and a reduction in noise for local communities living under the stacks
- No need of additional equipment for airlines
- Acceptable workload increase for ATCOs and flight crews

The cross-border arrival management is part of SESAR solution #05 (E-AMAN) corresponding to Pilot Common Projects (PCP) ATM Function 01 (AF#1).

2 The XMAN concept ("Cross-Border Arrival Management") developed together by the FABEC and the UK-Ireland FAB introduces the ability for controllers to manage delays in the tactical phase of flight well before the top of descent.

Preparation of potential input to SESAR 2020 Solution 01 in Project 01

Validation package 4 paved the way towards Solution 01 in Project 01 of SESAR 2020. Beneath a first set of documentation, iterative prototyping sessions investigated the problem statement for multiple AMAN environment and developed a first solution attempt. V2 will be the starting point in SESAR 2020 for the relevant OI Step TS-0305-B.

1.3 Project Deliverables

The following table presents the relevant deliverables that have been produced by the project.

Reference	Title	Description
D02	Step 1 AMAN + Point Merge in E-TMA - SPR	This document sets out the Safety and Performance Requirements related to "AMAN + Point Merge" produced by Project P05.06.07 in STEP1. The concept extends the usage of Point Merge to the E-TMA airspace, based on the concept previously developed by EUROCONTROL for the TMA. This SPR describes the safety and performance aspects of the operating method associated with a Point Merge centric route structure, with the support of an AMAN, for En-route ACCs and TMAs with Very High Capacity needs.
D14	Step 1 AMAN + Point Merge in E-TMA OSED	This document sets out the Operational Service and Environment Definition related to "AMAN + Point Merge" produced by Project P05.06.07 in STEP1. This concept is extending the concept previously developed for the TMA by EUROCONTROL to the E-TMA airspace, coupled with the use of a basic AMAN tool. This issue of the document describes the operating method associated with a Point Merge centric route structure, with the support of an AMAN, for En-route ACCs and TMAs with Very High Capacity needs.
D45	Step 1 AMAN + Point Merge Validation Report	This document is the Validation Report for the solution "AMAN + Point Merge" validated by Project P05.06.07 in STEP1 through two series of live trials performed in the Paris ACC environment (exercise EXE-05.06.07-VP-427).
D17	EXE-05.06.07-VP-485 Validation Report	This document presents the Validation Report for EXE-485 within P05.06.07. EXE-485 was a Real Time Simulation based validation aimed at a joint validation of operational improvements concerned with Extended Arrival Management and Controlled Time of Arrival in close interaction with one another. The validation was executed using an Industrial Based Platform simulating the ground system environment and airborne traffic of Stockholm Arlanda Airport.
D15	Update of 5.6.4 OSED – Step 1	This document is the final OSED for OI Step TS-0305-A proposed by P05.06.07 for Step 1 of the SESAR Program (Solution #05 – Extended AMAN). It builds on the foundations of the 05.06.04 D35 Consolidated OSED v03.00.00 that includes a mature vision of the

		Extended Arrival Management (E-AMAN) concept. The concept extends the Arrival Manager horizon out to 200nm. Optional long-range arrival management will reach out up to 400-550nm.
D16	Update of 5.6.4 SPR-INTEROP - Step 1	This document presents Safety, Performance and Interoperability Requirements for SESAR Solution #05 (E-AMAN) on operational level that have been developed in P05.06.04 (QM-4 – Tactical TMA and En-route Queue Management) and P05.06.07 (QM-7 – Integrated Sequence Building/Optimisation of Queues) within SESAR Step 1. Since E-AMAN and CTA are closely related, relevant CTA requirements are provided in addition not belonging to the solution as such. The document addressed Operational Improvement TS-0305-A at the E-OCVM V3 phase. It is based on safety assessment conducted by the project and reported in D34-001 Safety Assessment Report. It further draws from outcomes of a series of validation exercises executed in projects P05.06.04 and P05.06.07.
D49	EXE-05.06.07-VP-695 (Extended AMAN) Validation Report	This document is the Validation Report for the exercise EXE VP-695 performed by P05.06.07 within the overall Step 1 V3 of SESAR Programme. Through a live trial, the exercise EXE-05.06.07-VP-695 was addressing the OI TS-0305-A (Arrival Management Extended to En Route Airspace-single TMA). The validation exercise is mainly focusing on the evaluation of the use of the Extended AMAN horizon for cross border arrival management between ANSPs. The live trial took place in Reims UAC for London Heathrow arrivals where NATS was providing Reims with information communicated via SWIM for the pre-sequencing of the arrival stream.
D53	Update of 5.6.4 SPR-INTEROP - Step 1 - Edition 2	This document presents Safety, Performance and Interoperability Requirements for an Extended AMAN concept identical to SESAR Solution #05 (E-AMAN) but including the aspects of a Long Range AMAN in addition.
D30	Preliminary Validation Report - Step 2	This document is the Validation Report for the exercises EXE-05.6.07 VP-696 and EXE-05.06.07 VP-444 performed by the P05.06.07 project within the overall Step 2 V2 of SESAR Programme. Through a series of Real Time Simulations and a Fast Time Simulation (FTS) respectively, EXE VP-696 and EXE VP-444 were addressing the OI TS-0305-B (Arrival Management Extended to En-Route Airspace – overlapping AMAN horizons). Both exercises focused on the key SESAR objective of extending arrival management into the En-Route phase of flight. Both exercises investigated the impact of arrival management constraints from multiple TMAs feeding an XMAN in a single UAC.
D26	Preliminary Operational Concept	En-Route sectors will be expected to contribute to the

	REVIEW and preliminary OSED part 1 - Step 2	arrival sequencing towards multiple (independent) TMAs simultaneously with potentially conflicting sequencing constraints. The described operational solution represented by OI Step TS-0305-B (Arrival Management Extended to En-Route Airspace - overlapping AMAN operations) will integrate information from arrival management systems operating out to extended range with local traffic/sector information and balance the needs of each.

1.4 Contribution to Standardisation

The project contributed to SESAR solution #05 which is part of the implementing regulation PCP of the European Commission and is being implemented by the SESAR Deployment Manager.

EUROCAE Standard is in development covering the extended horizon AMAN coordination service to facilitate the interoperability between various ANSPs taking into account the documents produced for E-AMAN. EUROCAE Standard is foreseen to be ready by 2018. [25]

However, no specific standardisation or regulation activities were performed within this project.

1.5 Project Conclusion and Recommendations

The project was able to contribute to the validation of Extended Arrival Management in a near-term as well as in time-based environment in the future. It was demonstrated in cooperation with other projects that Arrival Management supported by the AMAN tool could be further improved by extending the eligibility horizon.

Extended AMAN supports the planning and optimisation process in a tactical environment. For the controller this means there is less need for path stretching, possibly more accurate metering and a higher potential for delay absorption with more effect on linear rather than lateral profiles. For the KPAs, this implies an improvement in the areas Predictability, Efficiency (Environmental Sustainability/Flight Efficiency) and Capacity.

Nevertheless, other limitations invoked by this solution have been revealed. For the controller work, this means that additional sectors/actors are affected (En Route planners and tactical) and increased workload for the Sequence Manager (more coordination, larger sequence). The Ground system is challenged by Sequence instability (ground TP) that is impacted by increased sensitivity to perturbations (e.g. pop up flights from departures within the horizon). All this might constrain KPA Flexibility mainly but also others as well.

The overall conclusion is that the sum of benefits outbalances the negative effects and limitations for a single E-AMAN implementation. However, this depends on the implementation. For a multiple AMAN environment with overlapping horizons, benefits could be degraded. This was investigated and covered as well (TS-0305-B) but a general solution needs to be further developed in following SESAR 2020 programme.

Key questions for further development and deployment have been answered. By demonstrating the benefits also in live trials there is a high confidence that concepts around Extended AMAN are deployable and at the same time beneficial in a real operational environment for permanent use.

The project delivered the matured SESAR Solution #05 which is in the PCP scope for deployment.

Additional conceptual elements like i4D/CTA or technical enabler like SWIM referring to the Arrival Management Information Service should be subject to further investigations before deployment could be considered. Here results of other SESAR projects (e.g. P05.06.01 or WP8) are required.

2 References

[1] SESAR Programme Management Plan, Edition 03.00.01

[2] European ATM Master Plan

[3] Multilateral Framework Agreement ("MFA") signed between the SJU, EUROCONTROL and its 15 selected members on August 11, 2009, amended on 14 June 2010, 19 October 2010 and 2 July 2012

[4] Integrated Roadmap Dataset 14

[5] P05.06.04 – Consolidated OSED, D35, Ed. 03.00.00, 19/12/2014

[6] P05.06.04 – Consolidated SPR-INTEROP, D34, Ed. 00.01.01, 12/05/2015

[7] P05.06.07 – Step 1 AMAN + Point Merge in E-TMA - SPR, D02, Ed. 00.01.01, 25/04/2013

[8] P05.06.07 – Step 1 AMAN+ Point Merge OSED, D04, Ed. 00.01.03, 01/06/2011

[9] P05.06.07 – Technical Note to 5.6.4 OSED part 1 - Step 1, D05, Ed. 00.01.00, 24/07/2014

[10] P05.06.07 – Technical Note to 5.6.4 OSED part 1 - Step 1, D06, Ed. 00.01.01, 25/04/2014

[11] P05.06.07 – Step 1 AMAN + Point Merge - Validation Plan, D09, Ed. 00.01.00, 02/03/2012

[12] P05.06.07 – Step 1 AMAN + Point Merge in E-TMA OSED, D14, Ed. 00.01.01, 25/04/2013

[13] P05.06.07 – Update of 5.6.4 OSED – Step 1, D15, Ed. 00.01.01, 30/09/2015

[14] P05.06.07 – Update of 5.6.4 SPR-INTEROP - Step 1, D16, Ed. 00.01.01, 30/09/2015

[15] P05.06.07 – EXE-05.06.07-VP-485 Validation Report, D17, Ed. 00.02.00, 05/12/2014

[16] P05.06.07 – Operational Concept Document (initial) REVIEW and initial OSED - Step 2, D19, Ed. 00.01.00, 31/07/2015

[17] P05.06.07 – V2 Validation Plan - Step 2, D21, Ed. 00.01.00, 24/11/2015

[18] P05.06.07 – Preliminary Operational Concept REVIEW and preliminary OSED part 1 - Step 2, D26, Ed. 00.01.00, 31/03/2016

[19] P05.06.07 – Preliminary Validation Report - Step 2, D30, Ed. 00.01.00, 31/03/2016

[20] P05.06.07 – Step 1 AMAN + Point Merge Validation Report, D45, Ed. 00.01.00, 03/04/2013

[21] P05.06.07 – V3 Validation Plan - Step 1 - for EXE-485, D46, Ed. 00.02.00, 21/02/2014

[22] P05.06.07 – Validation Plan EXE-05.06.07-VP-695, D48, Ed. 00.02.00, 11/12/2013

[23] P05.06.07 – Validation Report EXE-05.06.07-VP-695, D49, Ed. 00.02.00, 25/06/2015

[24] P05.06.07 – Update of 5.6.4 SPR-INTEROP - Step 1 - Edition 2, D53, Ed. 00.01.00, 28/01/2016

[25] SESAR Solution Regulatory Overview - Extended Arrival management (AMAN) horizon Ed. 01.00.00, 20.11.2015

[26] SESAR Template Toolbox 03.00.00

[27] European Operational Concept Validation Methodology (E-OCVM - Version 3.0)

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