Final Project Report

Document information	
Project Title	Airborne Full 4D Trajectory Management
Project Number	9.02
Project Manager	[redacted]
Deliverable Name	Final Project Report
Deliverable ID	D07
Edition	00.01.03
Template Version	03.00.04
Task contributors	
Airbus	

Abstract

The aim of SESAR project 09.02 was to analyse the Full 4D Trajectory Management concept of SESAR step 2, and evaluate its operational and technical impact on-board beyond initial 4D (step1). The project team synthesised its understanding of the concept based on Step 2 CONOPS, Step 2 DODs and later on Transition CONOPS, and studied the impact on aircraft systems and operations. Free routing OSED was also analysed in the frame of the project. Partners further studied various items according to their own simulation capabilities. Outcomes were consolidated throughout the whole project with several Airspace Users and ANSPs involved from the beginning of the project, by means of various supports, participation to trials and workshops. This cooperative work finally resulted in a detailed operational and technical description of FULL 4D Trajectory Management from an on-board point of view, recommendations for a future OSED, and a list of open items to be further studied.

Authoring & Approval

Prepared By - *Authors of the document.*		
Name & Company	Position & Title	Date
[redacted] Airbus	[redacted]	29/09/2016

Reviewed By - *Reviewers internal to the project.*		
Name & Company	Position & Title	Date
<>	<Position / Title>	<DD/MM/YYYY>

Reviewed By - *Other SESAR projects, Airspace Users, staff association, military, Industrial Support, other organisations.*		
Name & Company	Position & Title	Date
[redacted] Airbus >	[redacted]	<29/09/2016>

Approved for submission to the SJU By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
<Name / Company>	<Position / Title>	<DD/MM/YYYY>

Rejected By - *Representatives of the company involved in the project.*		
Name & Company	Position & Title	Date
<Name / Company>	<Position / Title>	<DD/MM/YYYY>

Rational for rejection
None.

Document History

Edition	Date	Status	Author	Justification
00.00.01	01/03/2016	Draft		New document
00.01.00	22/08/2016	Draft		Issue at end of the project
00.01.01	22/08/2016	Release		Partners comments
00.01.02	27/09/2016	Final		SJU comments

Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
ADS-C	Automatic Dependent Surveillance - Contract
ANSP	Air Navigation Services Provider
AOC	Airline Operation Communications
ATC	Air Traffic Control
ATM	Air Traffic Management
ATN	Aeronautical Telecommunication Network
AU	Airspace User
CONOPS	SESAR CONcept of OPerationS
CPDLC	Controller Pilot Data Link Communication
EN	Enabler
EPP	Extended Projected Profile
ETA	Estimated Time of Arrival
FMS	Flight Management System
FPR	Final Project Report
FRD	Functional Requirements Document
FRT	Fixed Radius Transition
HMI	Human Machine Interface
MFA	Multilateral Framework Agreement
OI	Operational Improvement
OSED	Operational Service and Environment Definition
PCP	Pilot Common Project
RNP	Required Navigation Performances
RTA	Requested/Required Time of Arrival
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking

WG	Working Group

1 Project Overview

The project team analysed the SESAR Full 4D Trajectory Management concept (step 2) as described in SESAR CONOPS and DODs, and evaluated its operational and technical impact on-board beyond Initial 4D Operations (step 1). Free routing OSED was also studied. The project gathered Airbus, Thales Avionics, Finmeccanica, and Honeywell. External partied including ANSPs and Airspace Users were also involved all along the project.

1.1 Project progress and contribution to the Master Plan

The initial intent of this project was to produce the High level Functional Requirements for on-board systems and crew procedures to address the Full 4D Trajectory Management concept (step 2).
The project team thus first synthesised its understanding of the concept described in Step 2 CONOPS, Step 2 DODs and later on Transition CONOPS, and studied the impact on aircraft systems and operations. Free routing OSED was also analysed as it was considered to be part of Full4D Operations.
The scope of the project evolved as it appeared that many clarifications of the concept were necessary, and ground and air stakeholders did not share the same understanding of the concept. The aim then became to build inputs for a potential OSED on Full 4D Operations from gate to gate, agreed between all stakeholders involved in the execution phase.

A first Full 4D workshop was held in December 2014 with several Airspace Users and ANSPs. Open items were identified, prioritised and discussed. Each partner then defined its own objectives, taking into account both the priorities and the partner's own simulation capabilities.

A second Full 4D Workshop was held in April 2016 to present and consolidate the outcomes of workshops and trials on simulator platforms, with last inputs from Airspace Users and ANSPs.

Final consolidation resulted in a detailed operational and technical description of FULL 4D Trajectory Management from an on-board point of view, recommendations for a future OSED, and a list of open items to be further studied. All intermediate and final outcomes are gathered in deliverable D02 "Analysis of Full 4D Trajectory Management".

The final major concept document "Transition ConOps SESAR 2020 - Consolidated deliverable with contribution from Operational Federating Project", Edition 00.01.00, 23/06/2016 and the final outcomes of the project 9.2 are fully aligned.

Due to its particular scope, the project did not contribute to a SESAR solution in particular. It rather concerned SESAR solutions in a transverse approach, by addressing 4D Trajectory Management from gate to gate re-using multiple Initial 4D A/C enablers.

Aircraft (A/C) enablers code	Name	Project contribution	Maturity at project start	Maturity at project end
A/C 04a	Flight management and guidance for Advanced RNP	Proposal of uses cases from gate to gate for FULL 4D Operations	TRL6	TRL6
A/C 31b	Data link exchange of clearances or instructions for full 4D operations	Proposal of uses cases from gate to gate for FULL 4D Operations	TRL6	TRL6

A/C 31a	Data link communication exchange for ATN baseline 2 (FANS 3/C)"	Proposal of uses cases from gate to gate for FULL 4D Operations	TRL6	TRL6
A/C 34	On-board Management of clearances or instructions revising trajectory	Proposal of uses cases from gate to gate for FULL 4D Operations	TRL6	TRL6
A/C 37a	Downlink of trajectory data according to contract terms	Proposal of uses cases from gate to gate for FULL 4D Operations	TRL6	TRL6
A/C 11	Flight management and guidance for improved single time constraint achievement (CTA/CTO)"	Proposal of uses cases from gate to gate for FULL 4D Operations	TRL6	TRL6
A/C 42b	On-board management of target times	On-board solution for the Regional aircraft for Target Times on-board monitoring, and enhanced on-board time predictions	No A/C enabler studied	TRL1

Similarly, the Operational Improvements covered by the project were multiple :

. AU0 0305 Improve the on-board flight management based on planning information

. AUO 0308 B Datalink Services used for Provision of Ground-related Clearances and Information for Step 2

. AUO 0309 Revision of Reference Business/Mission Trajectory (RBT) using datalink (aircraft on airport surface)

. CM 0105 B Enhanced ATC processes by the use of new CPDLC messages and related procedures in Trajectory based operations

. CM 0403 B Early Conflict resolution through CTO allocation in step 2

. CM 0607 S2 Separation Management in En Route using RBTs with 2D RNP Specifications

. AOM 0500 Direct Routing for flights both in cruise and vertically evolving for cross ACC borders and in high & very high complexity environments.

. AOM-0501 Free Routing for Flights both in cruise and vertically evolving within low to medium complexity environments

. A0M-0502 Free Routing for Flights both in cruise and vertically evolving within high & very high-complexity environments

1.2 Project achievements

The project team initially gathered operational and technical assumptions on FULL 4D operations and free routing, and provided a preliminary Concept and on board-impact analysis to external parties, including volunteering Airspace Users and ANSPs.

A wide operational clarification appeared to be necessary. A high amount of open points have been discussed systematically with air and ground stakeholders: A follow-up table was shared and fed all

along the project with intermediate and final results from various partners' trials and workshops, enabling a progressive consolidation of outcomes all along of the project. Human Performances (HP) related aspects have also been traced in this follow-up table and in a specific HP log.

Two major FULL 4D dedicated workshops took place with volunteering Airspace Users and ANSPs. Intermediate non-official deliverables, briefings, and questionnaires submitted before and during the workshops enabled to streamline the discussions.

Simulator sessions on a mainline cockpit simulator equipped with Initial 4D prototypes, and operational aspect dynamic presentations of use cases, both facilitated a shared understanding on how the Full 4D operations should work.

A solution for Target Times on-board monitoring was assessed on a regional Aircraft platform.

Free Route operations were assessed on a business jet platform. Possible naming conventions for LAT/LON waypoints in the frame of Free Routing operations have also been proposed.

A statistical study and analysis of the improvement of the computed predictions with Initial 4D FMS weather model and its associated weather forecast update in the FMS in mainline showed a constant FMS flight plan predictability, enhanced with a regular longitudinal spacing for waypoints in cruise and with weather data updates.

The final consolidation of all project outcomes resulted in a shared understanding of the FULL 4D Trajectory management concept, together with a description of how the concept should work between air and ground in execution phase.

The project team also provided potential inputs for a future OSED on Full 4D Trajectory Management: A nominal use gate to gate scenario, inputs for use cases, and recommendations for Air, Air/Ground, and Ground.

Finally, the project team identified open items which should be further studied in SESAR 2020.

1.3 Project Deliverables

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

Reference	Title	Description
D01	High Level Functional Requirements for Full 4D Trajectory Management - Issue 1	The first deliverable gathered all outcomes of the project on FULL 4D Trajectory Management concept after the analysis of SESAR step 2 CONOPS and DODS was done, and further to the first FULL 4D workshop with Airspace Users and ANSPs.
D02	Analysis of Full 4D Operations Concept.	The final deliverable gathers all intermediate and final outcomes of the project on FULL 4D Operations. Most of it has been consolidated thanks to a second FULL 4D workshop with Airspace Users and ANSPs. It includes detailed operational and technical description of FULL 4D Trajectory Management from an on-board point of view, recommendations for a future OSED, and a list of open items to be further studied.
D03	Improved Trajectory Performance Analysis	This Evaluation Report gives, from an airborne point of view, description and analysis of the statistical study of the improvement of the computed predictions with I4D FMS weather model and the weather forecast update in FMS on order to quantify the predictability of the EPP frame all along the flight plan.

D04	Mainline Aircraft Evaluations Plan and Report	This deliverable synthesizes results of studies and evaluations on A320 simulator conducted by Airbus to further define Full 4D operations and Free routing. It explains how the analysis was performed, describes all intermediate results, and provides conclusions and recommendations before a final Full 4D workshop with Airspace Users and ANSPs.
D05	Regional Aircraft Evaluations Plan and Report	This deliverable synthesizes results of activities performed by Finmeccanica : The objective was to evaluate, from a pilot perspective, new Full4D on-board solutions for the Regional Aircraft. The exercise consisted of flight simulation tests performed on a Regional Aircraft real-time simulator. It was focused on two topics of SESAR Step2: - new weather model and weather data uplink capabilities to improve on-board time predictions (V2 evaluation). - new Target Time on-board monitoring HMI (V1 evaluation).
D06	Business jet Evaluations plan and Report	This deliverable consists in Honeywell business jet oriented contributions, namely: - analysis of Free Route Airspace impacts to the business jet pilot, - fuel benefit study on statistically significant weather samples of the advanced vertical profile optimization with use of weather grid data on business jets.

1.4 Contribution to Standardisation

For Full 4D special attention has been taken to the Initial 4D Baseline definition and evolution. Therefore, several standards have been identified and taken into account by the project team:

- A702A-4 published in 2014: extension of AOC Met data exchange to FMS defined.
- ATN Baseline 2: With WG 78 participation and activities, the first release of all the documents that composed the baseline has been published in April 2014. Following the progress performed in 2015 including revisions and corrections to the standard regarding i4D requirements and definitions, the revision 1 has been published beginning of 2016. This baseline defines :

  Clearances (CPDLC) and Predictions (ADS-C) for 4D Trajectory operations

  Clearances / Predictions support Free Route (unpublished latitude/longitude) waypoints

  No ATC wind via CPDLC foreseen for the moment

- For the SC 227, the main points related to 4D Trajectory Operations of the DO283B (published in December 2015) concern:

  The required increased repeatability of 4D trajectory during RNP operations with increased capabilities (AT and AT or above speed constraint types, Offset, fly-by and FRT transitions, RF legs, scalable RNP,….)

  The ETA required performance (1% of remaining time or 10 sec)

  The Required Time of Arrival (RTA) function which includes Achievable ETAs, Alerting, performance requirement on RTA accuracy with 10 sec (in descent)/30 sec (in cruise) 95% of flight time with defined meteorological assumptions.

Concerning the other Full 4D topics such as Free Route, target times, there is no specific standard evolutions linked to those items.

1.5 Project Conclusion and Recommendations

The scope of the project evolved as it appeared to be necessary to clarify the concept and to get all stakeholders to share the same view on how Full 4D Operations should work. Also, free routing needed to be integrated in the 4D Trajectory management concept.

As the project gathered only airborne partners, a continuous exchange process with all external partied concerned by the Full4D Operations had to be put in place : Outcomes were consolidated throughout the whole project with several Airspace Users and ANSPs involved from the beginning of the project, by means of various supports, participation to trials and workshops.

This cooperative work finally resulted in a refinement and a shared understanding of the FULL 4D Trajectory management concept, together with a description of how the concept should work between air and ground in execution phase.

Because of the continuous exchange process applied during the project, the final major concept document "Transition ConOps SESAR 2020 - Consolidated deliverable with contribution from Operational Federating Project", Edition 00.01.00, 23/06/2016 and the final outcomes of the project 9.2 are fully aligned.

The continuous and simultaneous involvement of Ground and Air stakeholders proved very efficient, and could be of great use in SESAR 2020 for similar transverse concepts.

The outcomes of the project, gathered in deliverable D02 "Analysis of Full 4D Trajectory Management", could be further consolidated in SESAR 2020 with a continuous transverse approach from gate to gate, both operationally and technically :

. The list of new open items identified by the project team could be further studied in SESAR 2020. It gathers topics such as the need for closed loop clearances in order to ensure a continuous reliable 4D Trajectory Sharing between all stakeholders.

. The nominal gate to gate scenario could be extended with ground aspects.

. Operational aspect dynamic presentations of use cases facilitated a shared understanding on how the Full 4D operations should work. They could also be re-used for detailed use cases. In each use case, the question of "Best Equipped Best Served" should be addressed.

. Recommendations for Air, Air/Ground, and Ground could be addressed in SESAR 2020 relevant operational and technical documents (OSEDs, INTEROP …).

. Appropriate air-ground exchanges need to be defined in details, using ATN B2 standards on datalink. Preliminary Air/Ground exchange diagrams from pre-flight phase to landing phases provided in the project could be re-used and refined for that purpose.

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 15 of the Master Plan, aligned with the released Edition 2015 of the Master Plan, 08 February 2016

[5] P9.02, High Level FRD for Full 4D Trajectory Management, D01, Edition 00.01.02, 30/04/2015

[6] P9.02, High Level Functional Requirements for Full 4D Trajectory Management, D02, Edition 00.01.00, 28/07/2016

[7] P9.02, Improved Trajectory Performance Evaluations Analysis, D03, Edition 00.01.00, 21/06/2016

[8] P9.02, Mainline Aircraft Evaluations Plan and Report, D04, Edition 00.01.00, 27/06/2016

[9] P9.02, Regional Aircraft Evaluations Plan and Report, D05, Edition 00.01.00, 17/06/2016

[10] P9.02, Business jet Evaluations plan and Report, D06, Edition 00.01.01, 24/06/2016

[11] B4.2, Transition ConOps SESAR 2020 - Consolidated deliverable with contribution from Operational Federating Project, Edition 00.01.00, 23/06/2016

[12] P4.2, WP 4 Detailed Operational Description Step 2, Edition 00.02.01, 03/07/2014

[13] P5.2, DOD Step 2 Iteration 3,M319, Edition 00.01.01, 09/06/2015

[14] P6.2, Airport Detailed Operational Description - STEP 2 Edition 00.01.00, 16/01/2015

[15] P7.2, Network Operations Step 2 V1 Detailed Operational Description, D31, Edition 00.02.00, 07/03/2014

[16] P11.01.01, Detailed Operational Description - Step 2 and 3, Edition 01.00.00, 10/10/2013

-END OF DOCUMENT-