Final Project Report

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Abstract

This project is responsible for pre-operational validation across several concept functions/elements of En Route operating context. It validated En-Route concept elements in an integrated way to demonstrate the consistency and the compatibility of single concept elements, gathered at project level. It mainly focused on en-route ground-ground and air-ground interoperability and integrated validations for free routing. The project performed iterative validations (i.e. RTS and live trials) on these aforementioned elements.

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Intellectual Property Rights (foreground)

This deliverable consists of SJU foreground.

Acronyms

Acronym	Definition
(I-)4D	(Initial-) 4 Dimensions
A-AMAN	Advanced-Arrival Manager
ACR	Aircraft
ANSP	Air Navigation Service Provider
ATC	Air Traffic Control
ATM	Air Traffic Management
ATSU	Air Traffic Service Unit
CDM	Collaborative Decision Making
CTA	Controlled Time of Arrival
ED	EUROCAE Document
EUROCAE	European Organisation for Civil Aviation Equipment
FPR	Final Project Report
FT	Flight Trial
IOP	Interoperability
MM	Medium/Medium
OI	Operational Improvement
RTS	Real Time Simulation
SESAR	Single European Sky ATM Research
SJU	SESAR Joint Undertaking
TS	Technical Specification
VALP	Validation Plan
VALR	Validation Report
WG	Working Group

1 Project Overview

The objective of this project was to perform a pre-operational validation across several concept functions/elements of En Route operating context. It validated En-Route concept elements in an integrated way to demonstrate the consistency and the compatibility of single concept elements, gathered at project level.

1.1 Project progress and contribution to the Master Plan

P04.03 worked very closely with the project dealing with TMA Integrated and Pre-Operational Validation & Cross Validation because of the strong dependencies between En-route and TMA operations. Together they performed validation across both En Route and TMA operational environment.

It prepared mainly Validation plans and reports of planned and executed validations. It supported the overall consolidation of the En-route concept of operation with the integration of all developed validation documents.

Due to the transversal nature of this project, apart from the quick wins activities at the beginning of the project, the executed validation exercises has contributed mainly to the following operational areas

- the ATC-ATC, ATC-NM and ATC-Aircraft interoperability

- the initial 4D and its integration with TMA operations (e.g. A-AMAN)

- the Direct routing and Free routing operations,

- the Ground Based Separation Provision in En Route, especially focusing on relevant integration Direct routing and Free routing operations

Following table highlight main OIs addressed by 04.03 validation campaign. Note that the OIs refer to those current in Dataset 15, the actual OIs evaluated within the exercises were sometimes older versions so the maturity is not a one-to-one mapping.

Code	Name	Project contribution	Maturity at project start	Maturity at project end
AUO-0204-A No longer in Dataset 14 – only refers to the C version for Step 3	Initial Agreed Reference/Mission Trajectory through Collaborative Flight Planning	The RTS exercises demonstrated that the sharing of the iRBT and the inclusion of ATC constraints was beneficial to obtaining an agreed trajectory to be used early in the planning process.	N/A	N/A
AUO-0205-A	Management and sharing of the Initial Reference Business Trajectory (iRBT/iRMT) from publication through to termination	The RTS and flight trial exercises assessed the consistency check made by the ground of the down linked airborne trajectory with respect to the ground trajectory, the synchronization of the ground trajectory with the airborne trajectory and the sharing of the	V2	V3

		trajectory between ground partners. It demonstrated immediate safety and situational awareness benefits for controllers.		
AUO-0302-A Version C in Dataset 14: Provision of clearances using Datalink: performance based implementation	Datalink exchange between Flight Crew and Controller for time based implementation related to airborne part of operation	The RTS and flight trial exercise showed that the exchange of time constraints can be managed efficiently between ground and air.	V2	V2
AUO-0303-A	Ground-Ground aspects related to iRBT/iRMT revision (executed at ground or flight crew initiative)	The RTS exercises demonstrate that the exchange of downstream constraints to the controlling unit by the use of the Flight Object enhance the ATCOs awareness and allow preplanning of the proposed trajectory	V2	V3
CM-0201-A	Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue through improved trajectory data sharing (Partial coverage)	The RTS exercises did not look at potential facilitation of conflict resolution however showed that the use of the Flight Object to support coordination and transfer shows significant benefits over OLDI due to a continuous update of information and increased flexibility in exchange of data.	V2	V3
IS-0302	Use of Aircraft Derived Data (ADD) to enhance ATM ground system performance	The RTS and flight trial exercises showed that the use of the Extended Projected Profile provided via the ADS-C datalink increased safety and ensured air and ground had the same view of the trajectory. It showed that certain elements of the EPP can be used to enhance the accuracy of the ground trajectory and therefore increase the performance of the ground tools. The exercise only used partial elements of ADS-C. Because only validated partial compliance with this OI the project achieve V2 maturity (or partially V3)	V3	V2

IS-0303-A	Downlink of on-board 4D trajectory data to enhance ATM ground system performance: initial and time based implementation	The RTS and flight trial exercises showed that the downlink of flight management system information regarding the expected time over future waypoints can be used within ground tools to generate time constraints that are within the aircraft ability to achieve in an optimised and economical manner.	V3	V3
IS-0901-A	Swim for Step 1	The RTS exercises demonstrated that ground-ground coordination and transfer functions between en-route systems based on the Flight Object are possible and effective.	V2	V2
TS-0103	Controlled Time of Arrival (CTA) in medium density/complexity environment	The RTS and flight trial exercises demonstrated that the air and ground can make use of the ability of the flight management system to manage an aircraft to a single time constraint under nominal conditions. It also highlighted limitations to this functionality and additional requirements needed to allow optimisation of its use.	V3	V3
CM-0202	Automated Assistance to ATC Planning for Preventing Conflicts in En Route Airspace	The RTS exercise demonstrated that the systems assisted the controller in conflict identification and planning tasks by providing automated early detection of potential conflicts; facilitating identification of flexible routing/conflict free trajectories; identifying aircraft constraining the resolution of a conflict or occupying a flight level requested by another aircraft	V2	V3
CM-0203	Automated Flight Conformance Monitoring	The RTS exercises demonstrated that the systems provided to the controller with warnings if aircraft deviate from a clearance or plan, and reminders of instructions to be issued with positive impact on safety.	V3	V3
CM-0204	Automated Support for Near Term	The RTS exercises demonstrated that system	V3	V3

	Conflict Detection & Resolution and Trajectory Conformance Monitoring	provided assistance to the Tactical Controller to manage traffic in his/her sector of responsibility and provides resolution advisory information based upon predicted short term conflict information within the tactical ATC environment with positive impact on safety		
CM-0205	Advanced Conflict Detection and Resolution in En-Route	The RTS exercises demonstrated that the system provided real-time assistance to the En-route controllers (both Planning and Tactical) in conflict detection and resolution. It will be replaced later on by 2 new OIs (one for TCT, and one for MTCD).	V3	V3
CM-0207A	Advanced Automated Ground Based Flight Conformance Monitoring in En-Route	The RTS exercises demonstrated that the system provided the En-Route controller with warnings if aircraft deviate from the calculated ground system trajectory or the ATCOs tactical clearances. It is representing the main positive result of the exercise performing the validation.	V3	V3
AOM-0500	Direct Routing for flights both in cruise and vertically evolving for cross ACC borders and in high & very high complexity environments	The RTS exercises demonstrated that direct routing operations provides additional flight planning route options on a larger scale across FIRs such that overall planned leg distances are reduced in comparison with the fixed route network and are fully optimised due to AFUA specifically within high & very high-density workload environments and / or involving cross ACC/FIR boundaries.	V2	V3
AOM-0501	Free Routing for Flights both in cruise and vertically evolving within low to medium complexity environments	The RTS exercises demonstrated that airspace user are able to plan and re-plan a route according to the user-defined segments within significant blocks of Free Route Airspace.	V2	V3

Main SESAR Solutions which have been matured with P04.03 validation contributions are:

1. SESAR Solution #32 (Free Route through the use of Direct Routing)

2. SESAR Solution #33 (Free Route through Free Routing)

3. SESAR Solution #27 (Enhanced Tactical Conflict Detection & Resolution (CD&R) services and Conformance Monitoring Tool for En-Route Controllers)

4. SESAR Solution #28 (Automated Assistance to Controller Seamless Coordination, Transfer and Dialogue through improved trajectory data sharing)

5. SESAR Solution #06 (CTA in MM environment)

1.2 Project achievements

Project Achievements are linked to the 04.03 validation campaign which can be broken down in the following threads:

- Quick wins validations such as Complexity management (1 exercise), CDM and Sector Team Operations (2 exercises) validations have been performed to boost the program start up.
- I-4D Validation, for ATC-ACR interoperability for CTA in MM environment, has been executed using a stepwise approach (6 exercises) with incremental scope and relevant developments.
- IOP Validation, for ATC-ATC Interoperability also supporting I-4D operations and for ATC-NM Interoperability, has been similarly executed using a stepwise approach (6 exercises) with incremental developments, maturity and scope.
- Free Route validation, addressing both Direct Routing and Free Routing operations.

Main achievement of these aforementioned validations is the performance assessment of the concept under validation and the stimulus for technical development of relevant enabler.

As an example of quick wins, CDM & Sector Team Operation validation activities conducted under this project, aimed at running two validation exercises that took place between June 2011 and December 2011. These validation exercises consisted in Shadow Mode Trials and Live Trials performed in the Brest ATSU environment to assess the Enhancement of cooperation between Executive and Planner Controllers, Monitoring of the air traffic situation and Detection and resolution of conflicts. The concept applicability in other than the French environments has been demonstrated.

With IOP Validations, in the framework of 04.03 project, both ATCOs and the validation teams recognized the potential of the IOP enabler for future enhancements. However, the maturity of the system delivered by industry was not up to the expected level and did not provide sufficient stability to perform the operational validations as initially expected. The validations achieved V2 maturity level, equivalent for the technical verification to achieve TRL 5. Considering the expertise developed in the IOP validation campaign, the team contributed to the development of the Trajectory Management Framework Interoperability document.

With I-4D Validations, in the framework of 04.03 project, the partners collected valuable feedback on ADS-C, the Extended Projected Profile (EPP) and its synchronisation, the use of time constraints in En-route airspace, CTA provision horizon, CTA cancellation or re-issue, the impact on Pre-Sequencing, the management of Consecutive flights on the AMAN horizon limit and the impact on LoAs and tactical instructions.

The integration of the IOP with I-4D concepts posed questions regarding the impact of extending the AMAN horizon and the complexity to use the EPP and the RTA data in an AMAN algorithm. The lessons learnt on the i4D modifications for the AMAN can be a valuable input for future developments.

With Free Route Validation, in the framework of 04.03 project, the partners performed several validation exercises to assess free routing and direct routing operations. They collected evidence of the concept maturity addressing part of the Free Route concept, supported by Conflict Detection and Resolution services (i.e. Conflict Detection and monitoring aids to ATCOs), IOP services and the “Extended ATC Planning” (EAP) function for decomplexification measures; specific validation

activities investigated as well on minimum Flight Level and associated acceptable complexity level within the core area. Considering the expertise developed in the Free Route validation campaign, a specific contribution (i.e. performance requirements) for the consolidation of the operational deliverable Free Route SPR has been developed.

Refer to relevant validation reports for more details on validation descriptions, conclusions and recommendations as indicated in the project deliverable section.

1.3 Project Deliverables

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

Reference	Title	Description
D103, D77 and D127	IOP Validation (Validation Report for EXE-04.03-VP-022, VP-711 and VP-841)	These deliverable contained the analysis of the results of the validation exercises related to IOP. In addition it highlighted the required changes for the TMF/IOP Technical Note and INTEROP documents
D111, D62, D64	i4D Validation Report Step A,B and C (EXE-04.03-VP323, VP-029, VP-330, VP-324 and VP-463)	This deliverable contained the analysis of the results of the validation exercises related to i4D. In addition it highlighted the required changes for relevant OSED, SPR, INTEROP.
D114	IOP and i4D integration Validation Report (EXE-04.03-VP-030)	This deliverable contained the analysis of the results of the validation exercise related to the required evolution of IOP to support i4D exchanges in a cross border environment. In addition it highlighted the required changes for the TMF/IOP Technical Note and INTEROP documents.
D116	CM Validation Report	This deliverable contained the analysis of the results of the validation exercises related to Complexity Management quick win. In addition it highlighted the required changes for relevant OSED, SPR, INTEROP.
D123	CMD & Sector Team Ops - Validation Report	This deliverable contained the analysis of the results of the validation exercises related to CDM & Sector Team Operations quick win. In addition it highlighted the required changes for relevant OSED, SPR, INTEROP.

1.4 Contribution to Standardisation

No direct contribution to standardisation from the project. However, the outcomes of produced VALPs and VALRs are made available for supporting standardisation activities. For example to EUROCAE WG59, working on the ED133 Flight Object, which may consider the results in their ED133 update process.

Main contributions to standardisation are on the two topics:

Interoperability Ground-Ground

The Flight Object is defined by document ED133 issued by the EUROCAE standardisation Working Group 59. P04.03 contributed to the creation of the Technical Specifications providing operational expertise and advice. These specifications provided the implementation scheme for the exercises to fulfil ED133, where necessary using temporary solutions in order to clarify requirements and ensure progress under SESAR; P04.03 assisted in the update of the final TS following the exercises. This final TS is provided to E-WG59 by SJU Analysis Team with the contribution of P04.03 partners.

Interoperability Air-Ground

The exchange of information between air and ground was defined by the initial release of the document ED228 issued in March 2014 by the EUROCAE standardisation Working Group 78 in cooperation with RTCA Special Committee 214 representation America. The version used during the trials was a draft of the document that was under construction and was known as Version H. P04.03 contributed to the relevant Technical Specifications providing operational expertise and advice. These specifications provided the implementation scheme for the exercises to fulfil ED228 (draft Version H), where necessary using temporary solutions in order to clarify requirements and ensure progress under SESAR; P04.03 assisted in the update of the final TS following the exercises. This final TS is provided to WG78 by SESAR and members of the P04.03 partners (outside of SESAR) participate to WG78 and ensure the exercise findings are carried forward.

1.5 Project Conclusion and Recommendations

Project Overall Conclusion:

The project provided evidence of maturity mainly in the following SESAR Solution:

SESAR Solution	Conclusions
#32 (Free Route through the use of Direct Routing)	Direct routings shall be designed so as to induce a manageable level of airspace complexity for controllers (e.g. avoid Direct Routing too close to sector boundaries, creating potential conflict geometries difficult to manage…). In doing so, a Direct Routing environment could then be controlled as an “enriched" fixed route network environment in which ATC support tools (e.g. MTCD, TCT ...) are more than welcome to overcome the increasing number of conflict points to monitor. The concept of long-range segments respecting airspace design constraint would not degrade the safety level neither the overall En-route airspace capacity. It is the opinion of the validation team that the IOP technology has the potential to bring new possibilities for inter-center coordination and negotiation enabling future ATC functions, facilitating inter-ATSU electronic exchanges in a way close to the intra-ATSU exchanges.
#33 (Free Route through Free Routing)	Free Routing in Low to Medium complexity environment increases the Controller's workload, which nevertheless remains acceptable. In case of traffic variability, if high peaks of traffic load and/or complexity would happen, the workload could however be unmanageable. Therefore to keep the workload at a manageable level and preserve safety, a decreased En-route airspace capacity compared to ARN with an equivalent level of Safety and Human Performance as in ATS Route Network will be required. In term of working methods, almost all of the controller's tasks were impacted, from route identification to conflict

	detection and resolution. There is thus a strong need to build a new working method for controllers. MTCD was judged mandatory in FRA whatever the level of traffic density or complexity was. Moreover, the strategic separation of the traffic requires to be reconsidered, as current ATFCM measures could not be sufficient to avoid "bottlenecks". It is the opinion of the validation team that the IOP technology has the potential to bring new possibilities for inter-center coordination and negotiation enabling future ATC functions, facilitating inter-ATSU electronic exchanges in a way close to the intra-ATSU exchanges.
#27 (Enhanced Tactical Conflict Detection & Resolution (CD&R) services and Conformance Monitoring Tool for En-Route Controllers)	TCT and MONA concepts have been considered as acceptable for an operational use. All ATCOs considered MONA shall be mandatory in FRA, as they need to be assured that the aircraft follows its planned trajectory without any deviation as flight routes vary much in FRA from one flight to another. The controllers could not remember precisely the routes of all the flights they integrated. TCT is really helpful in various airspace conditions (validation in large vertical layers, from FL100 to UNL) and supports efficiently ATCOs in their trajectories separation tasks.
#28 (Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue through improved trajectory data sharing)	At concept level proved as concept but more work is needed to mature technical aspects. Further development is likely required to enhance some aspects of the operation in the tested environment (e.g. improved system support etc.) and on the concept validation as reported.
#06 (CTA in MM environment)	Technically, the validation campaign was successful and provided valuable results. Aircraft met all time constraints (e.g. RTA achieved within the set 10 seconds tolerance in flight trial). New data link techniques worked all as expected. Airborne data availability on the ground is essential. New challenges: the provision of the RTA from TMA to en-route needs to be discussed (AMA message horizon); assessment of the accuracy of the airborne trajectory prediction versus the ground based trajectory prediction requires more time and more samples.

Project Main Recommendations for future activities (e.g. SESAR 2020):

SESAR Solution	Recommendation
#32 (Free Route through the use of Direct Routing)	Before operational deployment, attention shall be paid to the definition of the direct segments to avoid creating situations difficult to manage for the controllers. If the introduction of IOP environment is envisaged, ATCOs roles, responsibilities and task sharing should be clearly defined and adequate training should be provided before introducing . Also during the definition phase of the direct segments, Fast Time Simulations on large geographical perimeters should be performed in

	order to evaluate the impact of Direct Routings on Environment/Fuel efficiency.
#33 (Free Route through Free Routing)	The performed validations shown the limits of traffic management in FRA in case of high traffic variability or high complexity environments. Further R&D work is there required. Moreover, the role of the NM in term of regulation definition and impact and/or benefits to smooth the traffic complexity and load in Free Routing Airspace is still to be analysed. It is also important to clearly define roles, responsibilities and task sharing and to provide adequate training before introducing IOP environment. Fast Time Simulations on large geographical perimeters, rather than Real Time Simulations on small geographical perimeters should be performed to evaluate the impact of FRA on Predictability and Environment/Fuel efficiency.
#27 (Enhanced Tactical Conflict Detection & Resolution (CD&R) services and Conformance Monitoring Tool for En-Route Controllers)	Relevant Algorithms shall be improved to take into account open clearances to avoid false positive detection.
#28 (Automated Assistance to Controller for Seamless Coordination, Transfer and Dialogue through improved trajectory data sharing)	The concept has been proven however it is recommended to further mature the technical aspects and work must continue as a priority to consolidate the Operational and Technical requirements.
#06 (CTA in MM environment)	It is recommended that development of ADS-C is continued in order to bring benefits to the ATM participants and validations are continued to optimise the use of CTA where applicable.

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] European ATM Master Plan Integrated Roadmap Dataset 15

[5] Project04.03, IOP, OSED & Requirements , D07, 21/06/2011

[6] Project04.03, IOP Validation Plan, D100, 15/05/2012

[7] Project04.03, EXE-04.03-VP-022 Validation Report , D103, 28/02/2014

[8] Project04.03, i4D Validation Plan, D104 15/09/2011

[9] Project04.03, i4D Validation Report, D111, 01/03/2012

[10] Project04.03, EXE-04.03-VP-030 Validation Plan, D112, 29/11/2013

[11] Project04.03, EXE-04.03-VP-030 Validation Report, D114, 28/10/2016

[12] Project04.03, CM Validation Report, D116, 10/07/2012

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[14] Project04.03, i4D OSED & Requirements, D12, 31/05/2011

[15] Project04.03, CMD & Sector Team Ops - Validation Report, D123, 09/03/2012

[16] Project04.03, Validation Exercise Plan EXE-04.03-VP-841, D126, 29/04/2016

[17] Project04.03, Validation report EXE-04.03-VP-841, D127, 28/10/2016

[18] Project04.03, i4D Integration Plan, D13, 15/09/2011

[19] Project04.03, i4D Validation Exercise Plan, D14, 27/09/2011

[20] Project04.03, CM OSED & Requirements, D22, 15/10/2011

[21] Project04.03, CM Integration Plan, D23, 24/02/2012

[22] Project04.03, CDM & Sector Team Ops OSED & Requirements, D27, 29/06/2011

[23] Project04.03, CM Validation Plan, D53, 24/02/2012

[24] Project04.03, i4D Validation Plan - Step B, D61, 31/08/2012

[25] Project04.03, i4D Validation Report - Step B, D62, 24/05/2013

[26] Project04.03, i4D Validation Plan - Step C, D63, 26/07/2013

[27] Project04.03, i4D Validation Report - Step C - VP-463, D64, 28/02/2014

[28] Project04.03, Validation Exercise Plan EXE-04.03-VP-711, D76, 03/09/2014

[29] Project04.03, Validation report EXE-04.03-VP-711 (Consolidated deliverable 05.03 - T119), D77, 03/12/2015

[30] Project04.03, Validation Exercise Plan EXE-04.03-VP-797, D80, 12/08/2015

[31] Project04.03, Validation Exercise Plan EXE-04.03-VP-798 , D82, 01/10/2015

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